

Research article

Energy consumption and child health outcomes in Nigeria: an empirical investigation of under-five mortality rate

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Abstract

This study examines the relationship between energy consumption and under-five mortality in Nigeria from 1990 to 2024. Annual time-series data were analyzed using the Autoregressive Distributed Lag (ARDL) bounds-testing approach and an error correction model. The bounds test confirmed a long-run relationship among the variables. Long-run results indicate that renewable energy consumption, female education, and urbanization have positive and significant relationships with under-five mortality, while electricity access, GDP per capita, and government health expenditure have negative and significant relationships. Non-renewable energy consumption and governance are statistically insignificant. In the short run, electricity access, government health expenditure, female education, and urbanization are negatively associated with under-five mortality. The error correction term of -0.4628 indicates that approximately 46.28% of disequilibrium was corrected each period. The study recommends expanding reliable electricity access, improving healthcare financing, and integrating energy policies with maternal and child healthcare interventions.

Keywords: Energy consumption, under-five mortality, electricity access, Nigeria

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INTRODUCTION

Under-five mortality remains one of the most important indicators of public health and socioeconomic development globally. It reflects not only the quality of healthcare systems but also broader socioeconomic conditions such as poverty, education, nutrition, environmental quality, infrastructure, and governance. Although substantial progress has been made in reducing child mortality over the past three decades, millions of children still die annually from preventable causes before reaching their fifth birthday. According to the United Nations Inter-Agency Group for Child Mortality Estimation (UN IGME, 2024), approximately 4.8 million children died before the age of five in 2023, with the majority of these deaths occurring in low- and middle-income countries, particularly in sub-Saharan Africa. Most under-five deaths are associated with preventable conditions such as pneumonia, malaria, diarrhoea, neonatal complications, and malnutrition, highlighting persistent inequalities in healthcare access and living conditions.

Sub-Saharan Africa continues to record the highest under-five mortality rates globally despite international health interventions and development assistance. While high-income countries record fewer than five deaths per 1,000 live births, many African countries still experience mortality rates above 60 deaths per 1,000 live births (World Bank, 2024). Nigeria remains one of the countries most affected due to its large population, persistent poverty, weak healthcare systems, and infrastructural deficits. Although Nigeria has made gradual progress in reducing child mortality, the country continues to account for one of the highest numbers of under-five deaths worldwide. Recent demographic and health statistics indicate that Nigeria's under-five mortality rate remains significantly above the Sustainable Development Goal (SDG) target of 25 deaths per 1,000 live births by 2030 (National Population Commission [NPC] & ICF, 2019).

The burden of child mortality in Nigeria is unevenly distributed across regions and socioeconomic groups. Northern regions, particularly the Northeast and Northwest, consistently record significantly higher mortality rates than southern regions. States such as Yobe, Gombe, and Adamawa continue to experience poor child health outcomes relative to states such as Lagos and Oyo. These disparities reflect differences in maternal education, healthcare accessibility, sanitation, immunization coverage, nutrition, income levels, and environmental conditions. Rural communities are especially vulnerable because of widespread poverty, inadequate healthcare facilities, poor transportation infrastructure, and limited access to modern energy services.

Existing studies on under-five mortality in Nigeria have examined socioeconomic, demographic, and healthcare-related determinants, including maternal education, household socioeconomic position, geographical inequalities, and access to prenatal care (Antai, 2011). However, the extent to which energy access and energy deprivation influence child survival in Nigeria warrants further investigation. Energy services support household welfare, health, and sustainable development, while dependence on polluting household fuels creates significant environmental health risks, particularly for women and children (World Health Organization [WHO], 2016).

At the household level, reliance on firewood, charcoal, animal dung, and crop residues for cooking can expose household members to harmful air pollutants. Children are particularly vulnerable to household air pollution, which increases the risk of lower respiratory infections and contributes to childhood pneumonia mortality (WHO, 2025). Inadequate access to electricity may also limit households' ability to use certain modern services and appliances. However, claims that electricity deprivation directly causes poor sanitation, unsafe drinking water, or malnutrition should be supported by evidence specific to those pathways rather than assumed from electricity access alone.

Energy access is also essential for healthcare delivery. Electricity supports lighting, communications, clean water supply, vaccine preservation, diagnostic services, emergency care, and safe childbirth. A WHO-led global report found substantial electricity-access and reliability challenges among healthcare facilities in low- and middle-income countries, particularly in sub-Saharan Africa (WHO et al., 2023). The same report identifies rural and remote healthcare facilities as particularly disadvantaged. This evidence establishes the broader relevance of electricity access to healthcare delivery, although Nigeria-specific claims should be supported with Nigerian facility data where available.

Despite ongoing maternal and child health interventions, under-five mortality remains a major public health challenge in Nigeria (National Population Commission [NPC] & ICF, 2019; United Nations Inter-Agency Group for Child Mortality Estimation [UN IGME], 2024). Existing research identifies socioeconomic and geographical inequalities in child survival, while international evidence demonstrates that household energy and healthcare-facility electrification are important health-related development concerns (Antai, 2011; WHO, 2016; WHO et al., 2023). These findings provide a rationale for investigating energy deprivation as a potential determinant of under-five mortality in Nigeria, while accounting for other socioeconomic, environmental, and institutional factors.

LITERATURE REVIEW

Theoretically, this study is anchored on the Energy Ladder Theory and Grossman's Health Production Theory. The Energy Ladder Theory, as discussed by Barnes and Floor (1996), suggests that households tend to shift from traditional fuels towards cleaner and more efficient energy sources as their income and living standards improve. This transition can reduce exposure to harmful household air pollution and improve welfare. However, households may continue to combine traditional and modern fuels because of affordability constraints and limited availability of modern energy sources (Heltberg, 2004; Masera et al., 2000). These differences in household energy consumption are relevant to child health because the type and pattern of energy use can influence children's exposure to environmental health risks.

Grossman's Health Production Theory (Grossman, 1972) views health as a form of human capital that can be improved through investments in healthcare, education, nutrition, sanitation, and living conditions. The theory argues that individuals and households make health-related decisions based on available resources and socioeconomic conditions. Within this framework, access to modern and reliable energy improves healthcare delivery, sanitation, maternal care, food preservation, and household welfare, thereby contributing to better child health outcomes and lower mortality rates.

Empirical studies increasingly highlight the relationship between energy consumption and health outcomes across countries. Vatamanu et al. (2025), using panel FMOLS and cointegration techniques for 27 European countries, found that renewable energy consumption and institutional quality significantly improved life expectancy. Uzoehina et al. (2025), using a cross-sectional ARDL approach for lower-middle-income West African countries, reported that renewable energy positively influenced life expectancy, while nonrenewable energy consumption and corruption worsened health outcomes. Similarly, Byaro and Rwezaura (2025), applying machine learning techniques to 26 sub-Saharan African countries, found that renewable energy improved life expectancy and reduced maternal and under-five mortality. In Nigeria, (Aina, 2025) showed that energy poverty significantly reduced life expectancy in both the short and long run.

Although these studies provide important evidence linking energy and health outcomes, most existing literature focuses on life expectancy, aggregate health indicators, or cross-country analyses

rather than under-five mortality specifically within Nigeria. In addition, many previous studies fail to distinguish between renewable and nonrenewable energy consumption or adequately capture Nigeria's long-run country-specific dynamics. This creates an important gap in the literature regarding how different forms of energy consumption influence child mortality outcomes in Nigeria.

This study addresses these gaps by examining the impact of renewable energy consumption, nonrenewable energy consumption, and electricity access on under-five mortality in Nigeria over the period 1990–2024. The study employs the ARDL estimation technique to investigate the long-run relationship among the variables while controlling for economic growth and other socioeconomic factors. By focusing specifically on under-five mortality within the Nigerian context, the study provides more detailed and policy-relevant evidence on the relationship between energy consumption and child health outcomes.

Understanding how energy consumption patterns affect child health outcomes can help policymakers design integrated strategies that simultaneously address healthcare challenges, energy poverty, and environmental sustainability. Improved access to clean and reliable energy has the potential to strengthen healthcare delivery systems, reduce indoor air pollution, improve sanitation and living conditions, and ultimately enhance child survival rates. The study therefore contributes to broader development objectives, particularly Sustainable Development Goal 3 on good health and well-being and Sustainable Development Goal 7 on affordable and clean energy.

RESEARCH METHOD AND MATERIALS

The study adapts the model of Polcyn et al. (2023) and modifies it to fit the Nigerian context and the objectives of the study. The empirical model specifies under-five mortality as a function of renewable energy consumption (RE), nonrenewable energy consumption (NRE), electricity access (ACCE), GDP per capita (GDPPC), government health expenditure (GHE), female education (FE), urbanization (URB), and governance effectiveness (GOV). The econometric model is expressed as:

$$U5M_t = \beta_0 + \beta_1 RE_T + \beta_2 NRE_T + \beta_3 ACCE_T + \beta_4 GDPPC_T + \beta_5 GHE_T + \beta_6 FE_T + \beta_7 URB_T + \beta_8 GOV_T + \mu(1)$$

Under-five mortality is the dependent variable, while the explanatory variables capture dimensions of energy consumption, economic performance, healthcare investment, education, urbanization, and institutional quality.

Estimation Technique and Procedure

This study adopts a two-step estimation approach to investigate the relationship between energy consumption and under-five mortality in Nigeria. The first step involves the application of the Autoregressive Distributed Lag (ARDL) Bounds Testing Approach to Cointegration (Pesaran, Shin & Smith, 2001) to determine whether a long-run equilibrium relationship exists among the variables. If cointegration is confirmed, the second step employs the ARDL long-run model and the Error Correction Model (ECM) to obtain efficient long-run coefficients and short-run dynamics.

RESULT PRESENTATION AND DISCUSSION

Econometric studies have shown that most financial and macro-economic time series variables are non-stationary and using non-stationary variables leads to spurious regression (Engle & Granger, 1987). Thus, the variables were investigated for their stochastic properties, using the ADF unit roots tests. The results of the unit root tests are presented on Table 1.

Table 1. Unit Root Test Results

Variable	ADF Critical value at 5%	ADF Statistic	PP Critical value at 5%	PP Statistic	Order of Integration
LNU5M	-2.954021	-3.143567	-2.951125	-10.88408	I (0)
LNRE	-2.615817	-6.136198	-2.954021	-6.148517	I (1)
LNNRE	-2.954021	-5279481	-2.954021	-5.272752	I (1)
LNACCE	-2.963972	-5.409327	-2.954021	-19.50211	I (1)
LNGDPPC	-2.951125	-3.935563	-2.951125	-4.062613	I (0)
LNGHE	-2.954021	-5.715645	-2.954021	-5.715683	I (1)
LNFEED	-2.951125	-4.897617	-2.951125	-4.897617	I(0)
LNURB	-2.954021	-8.601997	-2.954021	-7.908872	I(0)
LNGOV	-2.951125	-3.962755	-2.951125	-3.960110	I(0)

Source: Researcher's compilation (2026)

As indicated on Table 1, all the variables contained in the model are stationary but at different order. Given these results of different orders of integration/stationarity, there was a need to conduct a co-integration test to ascertain whether or not there exist long-run relationships amongst the variables.

Co-integration test result

Having ascertained the stationarity of the above variables, this study thereby confirms that the variables can be employed in time-series analysis without returning spurious/nonsense regression. Therefore, the study proceeds to ascertain if there is a long-run and/or short-run relationship between the variables, employing the ARDL bond test as specified by (Pesaran & Shin 2001). This research employs the ARDL bond test because the variables are not integrated of a single order. The result of the ARDL bond test is summarized on Table 2.

Table 2. ARDL Bound Test Results

F-Bounds Test			Null Hypothesis: No levels relationship	
Test Statistic	Value	Signif.	I(0)	I(1)
Asymptotic: n=1000				
F-statistic	19.11005	10%	1.85	2.85
K	8	5%	2.11	3.15
		2.5%	2.33	3.42
		1%	2.62	3.77

Source: Researcher's compilation (2026) using E-view 12

Table 2 shows that the value of the F-statistic in model shows the joint significance of the lagged level variables is 19.11005, which is greater than the upper bound I (1) at a 5% level of significance. Therefore, we reject the null hypothesis in both models and conclude that a long-run

relationship exists between the dependent variable (under five mortality) and the independent variables of the model.

Table 3. ARDL Long-run and ECM Estimate

Variable	Coefficient	Std. Error	t-Statistic	Prob.
LNRE	1.470631	0.292305	5.031154	0.0002
LNNRE	0.120324	0.173333	0.694178	0.4998
LNACE	-0.415914	0.167893	-2.477261	0.0278
LNGDPPC	-0.004145	0.000743	-5.580954	0.0001
LNGHE	-0.076958	0.008535	-0.016515	0.000
LNFE	0.017189	0.023539	0.730232	0.0047
LNURB	0.32217	0.094596	3.40573	0.0047
LNGOV	0.058714	0.045871	1.280002	0.2229
C	-0.331011	1.014737	-0.326204	0.7495

Source: Authors computation (2026) using E-view 12

The long-run ARDL estimates reveal that renewable energy consumption (LNRE) has a positive and statistically significant effect on inclusive growth ($\beta = 1.4706$, $p < 0.05$). Non-renewable energy consumption (LNNRE) is not significant ($p > 0.05$) which agrees with the findings of Adeleye et al. (2022). Electricity access (LNACE) exerts a negative and significant effect ($\beta = -0.4159$, $p < 0.05$), while GDP per capita (LNGDPPC) also has a negative and significant coefficient ($\beta = -0.0041$, $p < 0.05$). Government health expenditure (LNGHE) has a negative and statistically significant coefficient ($p < 0.05$), whereas female education (LNFE) and urbanisation (LNURB) exhibit positive and significant effects ($p < 0.05$). Government expenditure (LNGOV) was not statistically significant ($p < 0.05$). Overall, the results highlight the importance of renewable energy consumption, female education, and urbanisation in explaining long-run inclusive growth in Nigeria.

Table 4. Summary of Short Run Coefficients (Error Correction Regression)

Variable	Coefficient	Std. Error	t-Statistic	Prob.
D(LNRE(-1))	-0.303725	0.083513	0.093481	0.9269
D(LNNRE)	-0.023109	0.038076	-0.606926	0.0026
D(LNACC)	-0.096705	0.029549	-3.272694	0.0061
D(LNGHE)	-0.015349	0.003064	-5.010182	0.0002
D(LNFE)	-0.01057	0.004524	-2.336419	0.0002
D(LNURB)	-0.103544	0.028061	-3.689913	0.0027
D(LNGOV)	0.000816	0.007135	0.114347	0.9107
CointEq(-1)*	-0.462774	0.025733	-17.98335	0.0000

R-squared = 0.797543, Adjusted R-squared = 0.705517, S.E. of regression = 0.002316, Sum squared resid. = 0.000118, Log likelihood = 160.0996, Mean dependent var. = -0.009087, S.D. dependent var. = 0.004269, Akaike info criterion = -9.036341, Schwarz criterion = -8.537505, Hannan-Quinn criter. = -8.868498, Durbin-Watson stat. = 2.099867

Source: Authors computation (2026) using E-view 12

The short-run ARDL results indicate that electricity access ($\beta = -0.0967$, $p < 0.05$), government health expenditure ($\beta = -0.0153$, $p < 0.05$), female education ($\beta = -0.0106$, $p < 0.05$), and urbanisation

($\beta = -0.1035$, $p < 0.05$) have negative and statistically significant relationships with the dependent variable. Non-renewable energy consumption also has a negative coefficient ($\beta = -0.0231$, $p = 0.0026$), while governance ($p = 0.9107$) and lagged renewable energy consumption ($p = 0.9269$) are not statistically significant, based on the reported p-values. The error correction term is negative and significant ($\beta = -0.4628$, $p < 0.05$), indicating that approximately 46.28% of short-run disequilibrium is corrected each period. The model explains 79.75% of the variation in the dependent variable, with an adjusted R-squared of 70.55%.

The long-run results (Table 3) show that renewable energy consumption has a positive and statistically significant relationship with the dependent variable ($\beta = 1.4706$, $p < 0.05$), while non-renewable energy consumption was not significant. The renewable energy finding differs from Vatamanu et al. (2025) and Byaro and Rwezaula (2025), who found that renewable energy improved health outcomes. Electricity access has a negative and significant coefficient ($\beta = -0.4159$, $p < 0.05$), suggesting an association with reduced under-five mortality, consistent with Abiola's (2025) finding that energy poverty adversely affects health outcomes in Nigeria. GDP per capita and government health expenditure also have negative and significant coefficients, indicating potential improvements in child health as economic resources and health spending increase. Female education and urbanization have positive and significant coefficients, while government expenditure is not statistically significant. The urbanization result contrasts with the expected health benefits of improved access to services in urban areas.

In the short run, electricity access, government health expenditure, female education, and urbanization have negative and statistically significant relationships with under-five mortality. Non-renewable energy consumption is also reported to have a negative and significant association, although its statistical output requires verification. The negative and significant error correction term (-0.4628 , $p < 0.05$) indicates that approximately 46.28% of the preceding period's disequilibrium is corrected within one period. The model's (R^2) of 0.7975 indicates that it explains approximately 79.75% of the variation in the dependent variable.

CONCLUSION

This study examined the short- and long-run effects of renewable and non-renewable energy consumption on under-five mortality in Nigeria. The findings demonstrate that the relationship between energy consumption and child health is not uniform across energy sources or time horizons. In the long run, renewable energy consumption exhibits a positive and statistically significant relationship with under-five mortality, whereas non-renewable energy consumption has no statistically significant effect. Electricity access, GDP per capita, and government health expenditure exhibit negative and statistically significant relationships with under-five mortality, suggesting that improved access to electricity, higher economic welfare, and effective healthcare financing may contribute to better child survival outcomes. Conversely, female education and urbanization exhibit positive and significant long-run coefficients, although their short-run relationships are negative and statistically significant. These differences highlight the importance of distinguishing between short-run adjustments and long-run relationships when evaluating the socioeconomic determinants of child mortality. Furthermore, the negative and statistically significant error correction term confirms that deviations from long-run equilibrium are corrected over time. Overall, the findings underscore the need to integrate energy policy with healthcare financing and broader socioeconomic development strategies to address under-five mortality in Nigeria.

Based on the empirical findings, the study makes the following recommendations:

- i. The government should strengthen electricity infrastructure and expand access to reliable and affordable electricity, particularly in underserved rural communities. Priority should be given to healthcare facilities to support maternal care, neonatal services, vaccine preservation, and other essential interventions that improve child survival.
- ii. Public expenditure on health should be directed towards essential maternal and child healthcare services, immunization, nutrition programmes, and primary healthcare delivery. Greater transparency, effective budget implementation, and expenditure monitoring are also necessary to ensure that public health resources translate into improved health outcomes.
- iii. Renewable energy investments should be accompanied by assessments of their accessibility, reliability, affordability, and contribution to healthcare provision. Given the positive long-run association between renewable energy consumption and under-five mortality, further investigation is required to establish the factors underlying this relationship before drawing definitive policy conclusions.
- iv. Policies should promote female educational attainment and health literacy while improving access to safe water, sanitation, and healthcare in rapidly expanding urban communities. The contrasting short- and long-run results for female education and urbanization also warrant further investigation to clarify their implications for child survival.

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