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Population growth, Industrial employment and Clean Energy use in Nigeria

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Abstract

This study investigates the impact of population growth and industrial employment on renewable energy use in Nigeria. Using annual time-series data and employing the Fully Modified Ordinary Least Squares (FMOLS) estimation technique with robustness checks from Ordinary Least Squares (OLS), the analysis examines the long-run relationships among the variables. The results reveal that population growth has a positive and statistically significant effect on renewable energy consumption, suggesting that rising demographic pressures may stimulate demand for cleaner energy sources. In contrast, industrial employment and economic growth exert negative effects on renewable energy use, indicating that Nigeria's structural transformation and growth process remain largely dependent on conventional fossil fuel energy. The findings highlight the need for integrated energy and industrial policies that align economic expansion with renewable energy development to support Nigeria's transition toward sustainable and low-carbon growth.

Keywords: *Rising population, industry workforce, alternative energy, growth*

Introduction

In the presence of a rising population and industrial expansion, the transition toward renewable energy has become central to achieving sustainable development. Global energy demand has continued to increase due to demographic pressures and structural economic transformation, with industry accounting for a significant share of total final energy consumption [10]. In line with this, rapid population growth has increased pressure on energy demand, infrastructure, and environmental sustainability in Nigeria. The country has experienced sustained demographic expansion and rapid urbanization, both of which significantly increase household and commercial energy consumption. Empirical studies have shown that population growth and changing demographic structures are positively associated with rising aggregate energy demand, particularly in developing economies where energy infrastructure expansion lags behind population increases [9; 11]. Inadequate electricity supply often compels households and small businesses in Nigeria to rely on fossil-fuel-based generators and traditional biomass. This constrains the transition toward clean and modern energy sources.

Industrial employment also plays a critical role in shaping clean energy use in Nigeria. The industrial sector, particularly manufacturing, is energy-intensive and remains largely dependent on fossil fuels, contributing to carbon emissions and energy inefficiencies [20]. As industrial employment expands, overall energy demand increases, potentially slowing clean energy adoption if growth is powered primarily by conventional energy sources. However, industrialization can simultaneously create opportunities for energy efficiency improvements, technological innovation, and renewable energy investments when supported by effective regulatory frameworks and institutional quality. The interaction between population growth, labor absorption into industry, and energy policy therefore, becomes central to understanding Nigeria's clean energy transition, especially within the broader goals of sustainable development.

Nigeria's rapid population growth and rising industrial employment present a significant problem for the adoption of clean energy, as existing energy infrastructure and clean generation capacity struggle to keep pace with demand. With a population exceeding 218 million and growing at around 2.38% annually, Nigeria's energy needs have expanded faster than investments in reliable and clean electricity systems [14]. Despite being Africa's largest economy, only about 60% of the population has access to electricity, leaving roughly 40% of Nigerians without basic power services, particularly in rural areas [19]. This shortfall has driven households and industries to depend on expensive and polluting fossil fuel sources such as diesel generators, undermining efforts to reduce emissions and transition to sustainable energy sources. Simultaneously, the industrial sector's energy consumption continues to rise as employment grows, increasing pressure on an already stressed grid that often produces far less than the country's demand and limits the ability to meaningfully scale renewable energy uptake [19]. This gap between demographic and industrial energy demand and clean energy supply underlines the urgent need for strategic policies, investment, and technology deployment to enable a sustainable energy transition in Nigeria.

Despite a growing body of research on Nigeria's energy challenges, significant empirical gaps remain regarding how population growth and industrial employment influence clean energy adoption. Existing studies tend to examine broad links between renewable energy use and environmental outcomes [e.g. 8]. Another study assess the determinants of renewable energy consumption across African economies without focusing specifically on Nigeria's labour market dynamics [12]. While research shows that increased renewable energy uptake can reduce pollution and enhance energy efficiency, it does not routinely account for how population pressures or shifts in employment toward industry mediate these effects in Nigeria. Additionally, much of the literature focuses on household-level energy choices rather than the interaction between workforce structure, industrial demand, and clean energy transitions. This leaves a knowledge gap on whether and how demographic growth and industrial employment together spur or constrain the adoption of modern, low-carbon energy technologies in Nigeria.

Thus, the primary objectives of this study are to investigate the impact of population growth on clean energy consumption patterns in Nigeria; to examine the role of industrial employment as a determinant of renewable energy use within the broader economy; and to integrate these factors into a coherent framework that informs policy and planning. Hence, this study contributes to the literature in the following ways. First, it provides empirical evidence that links demographic and industrial dynamics with clean energy uptake. Second, it incorporates policy discourse by showing how labour market changes and demographic trends can either facilitate or hinder the transition to sustainable energy sources. Finally, the findings offer country-specific insights that can support Nigeria's energy policy, particularly in aligning industrial development with renewable energy goals and sustainable development strategies.

Brief literature underpinning

Empirical evidence on clean energy use in Nigeria has shown the growing importance of renewable energy adoption in mitigating environmental degradation. For instance, [8] employed an autoregressive distributed lag (ARDL) framework to examine the relationship between renewable energy consumption and environmental pollution in Nigeria. Their findings reveal that renewable energy adoption significantly reduces carbon emissions in both the short and long run, suggesting the environmental benefits of transitioning toward cleaner energy sources. This study reinforces the role of renewable energy in promoting sustainable development, although it does not explicitly incorporate demographic and labor market factors. At the household level, socio-demographic characteristics have been shown to significantly influence energy choices in Nigeria. [1] found that traditional biomass energy remains dominant relative to modern energy sources, with larger household sizes and rural residence negatively associated with modern energy adoption. Their results suggest that population growth and household composition can shape energy demand patterns and potentially slow the transition to clean energy. These findings imply that demographic pressures may constrain renewable energy uptake unless accompanied by targeted access and affordability policies.

Macroeconomic conditions also play a crucial role in determining renewable energy consumption. [4] investigated the effects of economic policy uncertainty, economic growth, foreign direct investment, and trade openness on renewable energy use in Nigeria. Using an ARDL approach, they reported that economic growth and foreign direct investment positively influence renewable energy consumption, whereas policy uncertainty dampens it. Their findings emphasize the importance of a stable policy environment and sustained economic expansion in promoting clean energy investment. Similarly, [16] demonstrated that financial development and gross domestic product are significant long-run drivers of renewable energy consumption in Nigeria, while dependence on fossil fuels exerts a negative effect. Their empirical analysis highlights the structural dimensions of energy transition, indicating that broader economic transformation, including industrial growth, can create conditions conducive to renewable energy expansion if supported by financial and institutional development.

Beyond Nigeria, regional evidence from Sub-Saharan Africa further shows the determinants of renewable energy adoption. [12], applying applied a system generalized method of moments (GMM) estimator across African countries and found that economic growth positively influences renewable energy consumption. This suggests that structural economic expansion, which often involves industrial employment growth, can enhance renewable energy uptake when supported by effective institutions and policy frameworks. Earlier empirical work by [9] showed that urbanization and working-age population dynamics significantly increase overall energy consumption in Nigeria. Although the study focused on aggregate energy demand rather than renewable energy specifically, its findings imply that demographic expansion and labor force growth intensify energy requirements. Without deliberate policy interventions to channel this rising demand toward clean sources, population growth and industrial employment expansion may reinforce reliance on conventional energy rather than accelerate the transition to sustainable alternatives.

Methodology

Framework and estimations

A suitable theoretical framework for examining the impact of population growth and industrial employment on clean energy use in Nigeria is anchored in the Environmental Kuznets Curve (EKC) hypothesis and the theory of structural transformation. The EKC posits that environmental degradation initially increases with economic growth and industrialization but eventually declines as income levels rise and economies adopt cleaner technologies and stronger environmental regulations [7]. In the case of Nigeria, rapid population growth and expanding industrial employment may initially intensify energy demand and fossil fuel dependence; however, sustained economic development, technological progress, and institutional improvements can facilitate a transition toward renewable and cleaner energy sources. Complementing this, structural transformation theory suggests that shifts from agrarian to industrial and modern sectors reshape energy demand patterns and technological adoption, potentially enabling cleaner production processes if supported by appropriate policy frameworks [13]. Together, these theories provide a foundation for analyzing how demographic pressures and industrial labor dynamics interact with economic development to influence clean energy adoption.

This study employs the Fully Modified Ordinary Least Squares (FMOLS) estimator to examine the long-run relationship between population growth, industrial employment, and clean energy use in Nigeria. FMOLS is particularly suitable for cointegrated time-series analysis because it corrects for endogeneity and serial correlation through semi-parametric adjustments, thus yielding consistent and asymptotically efficient long-run parameter estimates [17]. Given the potential simultaneity between renewable energy consumption, demographic dynamics, and industrial employment, FMOLS provides a reliable framework for estimating the structural relationships among the variables. To ensure the robustness and stability of the results, baseline estimates are further compared with those obtained from Ordinary Least Squares (OLS), which, although simpler, may suffer from bias in the presence of cointegration and endogenous regressors. Consistency in the magnitude and significance of coefficients across FMOLS and OLS strengthens confidence in the empirical findings.

Data and model

The study utilizes annual time-series data to examine the impact of population growth and industrial employment on clean energy use in Nigeria. The variables measurements include renewable energy consumption (% of total final energy consumption) as the dependent variable, employment in industry (% of total employment, modeled ILO estimate) as a key independent variable, population growth (annual %) to capture demographic pressures, and GDP growth (annual %) as a control for macroeconomic performance. Their data are sourced from international databases, including the International Labour Organization (ILO) and World Bank Development Indicators [19]. The empirical analysis employs a Fully Modified Ordinary Least Squares (FMOLS) model, which estimates long-run relationships among cointegrated variables to correct for endogeneity and serial correlation [18]. Robustness of the results is further confirmed using the Ordinary Least Squares (OLS) estimator, ensuring consistent and reliable estimates of the effects of population growth and industrial employment on renewable energy consumption [17]. Equations 1 & 2 modelled the empirical specifications, allowing for an integrated assessment of demographic, industrial, and economic determinants of clean energy use, while Figure 1 presents the average trends of the variables.

$$Renewable\_energy = f(Pop\_growth\ , indust\_empl, econs\_growth) \quad (1)$$
$$Renewable\_energy_t = a_1 + a_2 Pop\_growth_t + a_3 indust\_empl_t + a_4 econs\_growth_t + u_t \quad (2)$$

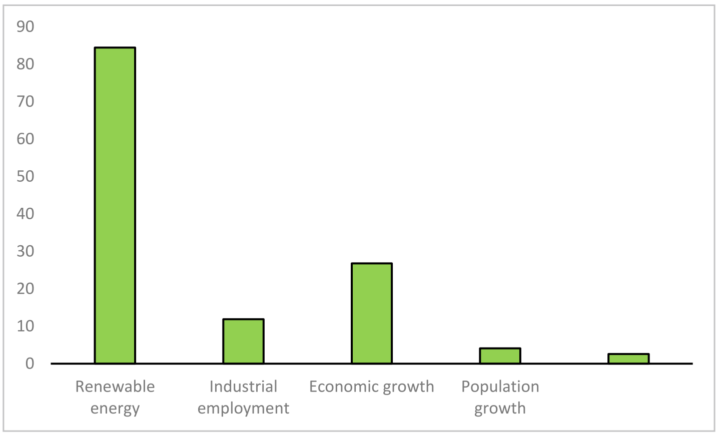


Figure 1: Average trends of variables

Results

The result discussion begins with correlation matrix in Table 1 which reveals that renewable energy consumption is positively associated with population growth (0.5734), suggesting that demographic expansion may coincide with higher renewable energy use.

However, it is negatively correlated with industrial employment (-0.6253), implying that industrial labor expansion may be linked to lower clean energy reliance. Economic growth shows a weak positive relationship with renewable energy (0.0715), while it is strongly positively correlated with population growth (0.6277) and negatively correlated with industrial employment (-0.2419). Overall, the correlations are moderate and below critical multicollinearity thresholds, indicating suitability for regression analysis.

Table 1: Correlations

	Renewable energy	Population growth	Industrial employment	Economic growth
Renewable energy	1			
Population growth	0.5734	1		
Industrial employment	-0.6253	-0.6113	1	
Economic growth	0.0715	0.6277	-0.2419	1

Furthermore, the unit root test was conducted to examine the stationarity properties of the variables prior to long-run estimation. Using conventional tests of Augmented Dickey–Fuller (ADF) procedures, the results indicate that renewable energy consumption, population growth, industrial employment, and economic growth are non-stationary at levels but become stationary after first differencing. This implies that all variables are integrated of order one, I(1), thus justifying the application of cointegration-based estimation techniques such as FMOLS for long-run analysis. The results of the unit root test are presented on in Table 2. Since all variables are integrated of order one, I(1), the [6] two-step cointegration technique is applied to test for a long-run equilibrium relationship among them. In the first stage, an Ordinary Least Squares (OLS) regression is estimated by specifying renewable energy as the dependent variable and the others as explanatory variables to capture the potential long-run association. The residuals derived from this regression are then tested for stationarity using a unit root test such as the Augmented Dickey–Fuller (ADF) test. If the residuals are stationary at level, I(0), this confirms cointegration among the variables, implying the existence of a stable long-run relationship [6]. The unit root test of residual is tested and stationary at level with t-statistics of -3.3434***, as such, we conclude that long-rum relationship exists among the variables enabling the estimation on long-run link among the variables using the FMOLS.

Table 2: Unit root tests

Variable	ADF-Level		ADF-1st Difference	
	Intercept	Intercept and trend	Intercept	Intercept and trend
Renewable energy	-1.4009 (0.5690)	-2.5821 (0.2903)	-5.7532*** (0.0000)	-5.66097*** (0.0004)
Population growth	-0.7708 (0.814)	-2.0243 (0.5670)	-1.74176 (0.4002)	-2.6560* (0.0907)
Industrial employment	-0.1313 (0.9374)	-1.6852 (0.7352)	-2.7941** (0.0703)	-3.4284** (0.0671)
Economic growth	-2.2035 (0.2088)	-2.1914 (0.4785)	-4.5758*** (0.0009)	-4.4920*** (0.0059)

*Note: Values in bracket (.) are p-values while *** and ** are significance at 1 & 5% respectively.*

The long-run empirical findings from this study (Table 3) indicate that population growth has a positive and statistically significant impact on renewable energy use in Nigeria. This result suggests that as the population increases, demand for cleaner energy sources also rises, possibly due to greater consumption needs and heightened environmental awareness.

Comparable empirical studies support this relationship; for example, [15] found that demographic expansion in Sub-Saharan African countries is associated with increased commitment of renewable electricity generation, as rising populations drive energy demand beyond traditional biomass and fossil fuels. Similarly, [2] showed that population growth significantly promotes renewable energy penetration in West African economies. This highlights the role of demographic pressures in encouraging investment and policy emphasis on cleaner energy alternatives.

In contrast, the relationship between industrial employment and renewable energy use in Nigeria was estimated to be negative and statistically significant, implying that expansion in industrial labor tends to coincide with lower reliance on clean energy consumption. This may reflect the continued dependence of Nigerian industries on conventional fossil fuels, such as diesel generators and grid electricity with high carbon intensity, rather than on renewable sources. These results align with empirical evidence from [3], who reported that industrialization in Nigeria has historically increased fossil fuel energy consumption due to the high energy intensity of manufacturing sectors and inadequate clean energy infrastructure. Additionally, economic growth was also observed to exert a negative effect on renewable energy use. While economic expansion generally enhances energy consumption, its association with renewable energy adoption appears limited in Nigeria, likely due to growth being driven by sectors reliant on traditional energy inputs. This finding resonates with the work of [5], who found that in developing economies with underdeveloped renewable sectors, GDP growth does not automatically translate into higher renewable energy use without supportive policies and investments. The empirical results obtained using both methods (FMOLS and OLS) are consistent in terms of coefficient signs and statistical significance. This consistency across estimation techniques confirms the robustness and reliability of the long-run relationship among the variables.

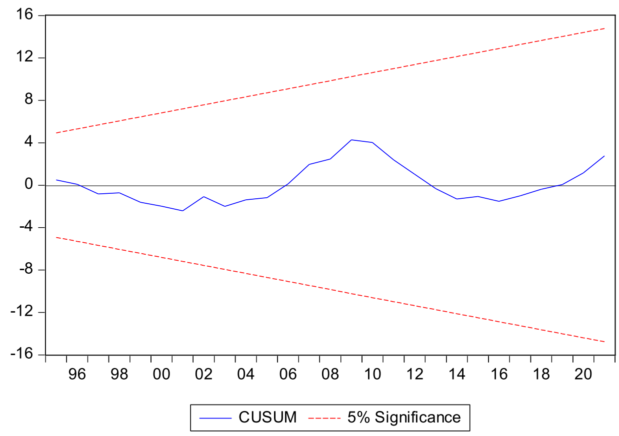
The findings that population growth positively influences renewable energy use, while industrial employment and economic growth exert negative effects, carry important policy implications for Nigeria's energy transition strategy. First, policymakers should leverage rising demographic demand as an opportunity to expand decentralized renewable energy systems, particularly solar mini-grids and off-grid solutions, so as to sustainably meet growing household energy needs. Second, the negative impact of industrial employment suggests the urgent need to green the industrial sector through targeted incentives such as renewable energy subsidies for manufacturers, tax credits for clean technology adoption, and stricter energy efficiency standards. Third, since economic growth alone does not automatically translate into higher renewable energy consumption, growth policies must be deliberately aligned with clean energy investment frameworks, including improved grid infrastructure, renewable financing mechanisms, and stable regulatory policies. Integrating industrial policy with renewable energy planning will be critical to ensuring that Nigeria's structural transformation does not reinforce fossil fuel dependence but instead accelerates a low-carbon development pathway.

Table 3: Effect of population growth and industrial employment on clean energy use

Dependent Variable: Renewable energy			Method (FMOLS)	
Variable	Coefficient	Std. Error	t-Statistic	Prob.
Population growth	5.477632	2.774925	1.973975	0.0591
Industrial employment	-0.884444	0.229393	-3.855581	0.0007
Economic growth	-0.242424	0.107405	-2.257096	0.0326
Constant	80.98491	8.841902	9.159218	0.0000
R-squared	0.735653			
Dependent Variable: Renewable energy			Method (OLS)	
Variable	Coefficient	Std. Error	t-Statistic	Prob.
Population growth	4.746638	2.120770	2.238167	0.0337
Industrial employment	-0.953737	0.174951	-5.451460	0.0000
Economic growth	-0.198709	0.080733	-2.461310	0.0205
Constant	83.56935	6.773222	12.33820	0.0000
R-squared	0.745831			
Serial correlation test	1.9935 [0.1418]			
Heteroskedasticity Test	0.7533 [0.5300]			
Normality test	1.4993 [0.4725]			

Note: Values in bracket [.] are p-values for diagnostic tests

The post-estimation diagnostic tests (in the lower part of Table 3) confirm the robustness and reliability of the models. The serial correlation test indicates the absence of autocorrelation in the residuals, while the heteroskedasticity test confirms homoskedastic error variance, suggesting that the estimates are efficient and unbiased. The normality test further shows that the residuals are normally distributed, supporting valid statistical inference. In addition, the stability tests based on CUSUM and CUSUM of Squares (Figure 2) reveal that the cumulative sum plots remain within the critical bounds, indicating that the estimated coefficients are stable over the sample period.



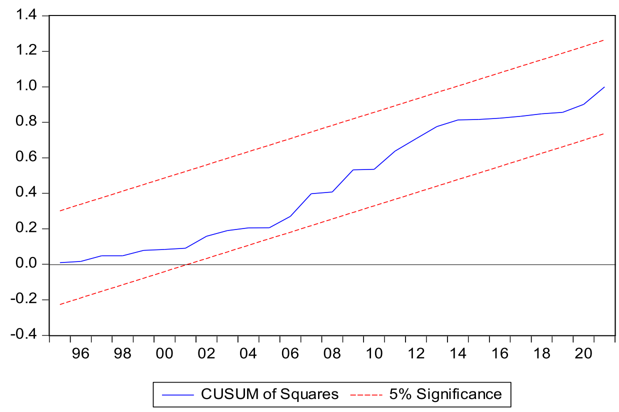


Figure 2: Stability test first and second conditions

Conclusion and policy implications

This study examined the impact of population growth, industrial employment, and economic growth on renewable energy use in Nigeria using cointegration-based estimation techniques. The findings reveal that population growth exerts a positive and significant influence on renewable energy consumption. This implies that rising demographic pressures may stimulate demand for alternative and cleaner energy sources. In contrast, industrial employment and economic growth were found to negatively affect renewable energy use, indicating that Nigeria's current industrial expansion and growth trajectory remain largely dependent on conventional fossil fuel energy sources. These results imply that while demographic expansion may encourage renewable energy adoption, structural economic transformation in Nigeria has not yet been sufficiently aligned with clean energy transition objectives.

From a policy perspective, the results emphasize the need to strategically integrate energy, industrial, and economic policies. Government efforts should focus on expanding renewable energy infrastructure to accommodate growing population demand sustainably. At the same time, industrial policies must incorporate clean energy incentives, such as tax credits, renewable energy mandates for manufacturing firms, and investments in green industrial technologies to reduce fossil fuel dependence. Furthermore, economic growth strategies should be deliberately linked to renewable energy financing, regulatory stability, and private sector participation to ensure that growth translates into sustainable energy development. Aligning demographic trends and industrial expansion with clean energy investment will be critical for achieving Nigeria's long-term climate and sustainable development goals.

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