Vol. 6 No. 2, Dec. 2026

FUAM
Journal of Pure and Applied Science

Available online at
www.fuamjpas.org.ng

An official Publication of
College of Science
Joseph Sarwuan Tarka University,
Makurdi.

FUAM Journal of Pure and Applied Science

© College of Science, Joseph Sarwuan Tarka University, Makurdi

https://fuamjpas.org.ng/

Vol.6 No. 2 Dec. 2026

Modeling the Impacts of Demographic Indicators on Human Development in Nigeria: A Fully Modified Ordinary Least Square (FMOLS) Regression Approach

E. I[*]. Aniah-Betiang, D. A. Kuhe, T. Uba and O. Peter

Department of Statistics, College of Physical Sciences, Joseph Sarwuan Tarka University, Makurdi, Benue State, Nigeria

[*]Correspondence E-mail: aniahbetiang01@gmail.com

Received: 19/02/2026 **Accepted**: 20/04/2026 **Published online**: 21/04/2026

Abstract

The aim of this study is to model the impact of demographic indicators on human development in Nigeria using Fully Modified Ordinary Least Square (FMOLS) regression. The study employed annual panel data covering 1994-2024 (30 years) in Nigeria. The annual data was sourced from National Bureau of Statistics (NBS) and National Population Commission (NPC). The panel unit root test (LLC) revealed that the variables were non-stationary at levels, $I(0)$ and stationary at first difference, $I(1)$. The Pesaran cross-sectional dependence (CD) test showed the presence of cross-sectional dependence among the variables indicating interdependence in the dataset. The Fisher statistics showed that there exists more than one cointegrating relationship among the variables in the study. AIC, BIC, HQC, and FPE all attain their minimum at Lag 3, confirming Lag 3 as the optimal lag length for the Panel VAR. The FMOLS showed that Life expectancy at birth (LLEB) exerts a positive and significant impact on human development ($\beta = 0.2146$, $p < 0.01$), indicating that improvements in life expectancy contribute positively to human well-being. Urbanization rate (LUR) showed negative and highly significant effects ($\beta = -0.4509$ and -0.3261, respectively; $p < 0.01$), suggesting that higher urbanization reduce the level of human development. Dependency ratio (LDR) also carried a negative and significant coefficient ($\beta = -0.0709$, $p < 0.05$). The explanatory variables jointly account for about 94% of the long-run variations in human development in Nigeria.

Keywords: Fully Modified Ordinary Least Square, Lag length, Co-integration, Human development, Demographic indicators

Introduction

The world is undergoing profound demographic changes marked by rapid population growth, declining fertility and mortality rates, and shifts in population age structure. It took over 50,000 years for the global population to reach 1 billion, but since the 1960s, the pace has quickened, with billions added every few decades. By 2037, global population is projected to surpass 9 billion, although the annual growth rate has steadily declined from above 2% in the 1960s to about 1% today and will likely fall further [1].

[2] examined the relationship between human development and economic growth employing time series econometric technique and a Solow Augmented model. In the study, the dependent variables were measured by GDP per growth while the independent variables include growth rate of labour, growth rate of capital, Structural Adjustment Programme (SAP) and the human capital output method Life literacy rate and adult literacy rate.

[3] analyzed the performance and the relationship between competitiveness, real gross domestic product (GDP) growth and human development in 20 countries of the Latin America and Caribbean region during the 2006-2015 period. At the individual country level, no statistically significant relationship between economic growth and human development was detected. Controlling for potential lagged effects of initial life expectancy using data from 1900, employing a nonlinear estimator and using information from microeconomic estimates on the effects of improving health and found no evidence for a positive effect of life expectancy on GDP per capita in this important historical episode.

[4] investigated the influence of life expectancy on economic growth in Nigeria. The study covers the period of 1980 to 2012. The study used descriptive statistics to analyses the trends of life expectancy in Nigeria. Vector autoregressive (VAR) was employed to examine the contributions of life expectancy on economic growth. The variables used were per capita income, gross capital formation, life expectancy at birth, primary school enrolment and carbon dioxide emissions. The variables were stationary at levels.

[5] studied the dynamics of population and economic growth in Nigeria using data from Statistical Bulletin from 1970 to 2014. With the help of ADF test the study found that the two series were only differenced stationary and Johansen co-integration test revealed that both variables

had long-run relationship. VECM revealed that economic growth adjusts to its long –run equilibrium.

[6] investigated the demographic dividend-growth nexus in the Nigerian economy from 1970 to 2017 using a multivariate VAR modeling technique. The study found that the innovation in gross enrollment made much contribution to the variation in economic growth relative to innovation in economic support ratio. This result, thus, lends credence to the theoretical view of the education-triggered dividend model which ascribes to education twofold roles of helping to lessen fertility and also enhancing productivity but invalidates the conventional dividend paradigm.

[7] investigated how human development responds to selected macroeconomic shocks in Nigeria. The study employed the Sen's capabilities approach as the analytical approach and posited that the level of education, health status, quality of investment, technology, and government fiscal and monetary policies are plausible determinants of human development. The study employed Structural Vector Autoregression (SVAR) to estimate the responses of selected shocks, which were inflation, interest rate, government capital expenditure, exchange rate, current account balance, and savings shocks.

[8] investigated demographic transition in Nigeria. Using time-series data covering a period of 40 years (1980 – 2019). The data were obtained from the World Bank repository. Unit root test was employed to test the stability of the data using Augmented Dickey Fuller (ADF) test. Granger causality test was used for the causality between variables of interest. The study examined the causality between birth rate, death rate, fertility rate and economic growth in Nigeria.

[9] examined the relationship between demographic indicators and economic growth in both Nigeria and South Africa covering the period 1999–2020. Ordinary Least Squares (OLS) estimation technique was employed. The results of the study show that secondary school enrollment and employment are positive and significant in driving the economic growth of both Nigeria and South Africa. However, inflation and mortality rate reduce economic growth in both countries. But in South Africa, life expectancy reveals a negative impact on economic growth.

Few studies [7]; [9] conducted in Nigeria looked at the impact of demographic indicators on economic growth and impact of human development on economic growth in Nigeria. But none of the literatures investigated the impact of demographic indicators on human development in Nigeria. Therefore, this current study fills the gap in the existing literatures by modeling the impact of demographic indicators on human development in Nigeria using Fully Modified Ordinary Least Square (FMOLS). The remaining parts of the paper are arranged as follows: FMOLS regression is specified in section 2, results and discussion are presented in section 3 and concluding remarks are in section 4.

Methods

The Cointegrating Regression Model

According to [10] consider the long-run equilibrium relationship as shown in Equation (1)

$Y_t = B_0 + \beta' X_t + u_t \quad t = 1, 2, \dots, T$ (1)

where, $Y_t =$ scalar dependent variable, $I(1)$, $X_t = k \times 1$ vector of regressors, $I(1)$, $\beta = k \times 1$ vector of long-run coefficients and $u_t =$ equilibrium error term. Assume Y_t and X_t are cointegrated, so that $u_t \sim I(0)$ and share a stable long-run relationship [11].

Stochastic Structure of the Regressors

Let the regressors follow a random walk process [10] as shown in Equation (2)

$X_t = X_{t-1} + e_t$ (2)

where, $e_t \sim I(0)$ and Equation (3) defines the innovation vector

$\eta_t = (\begin{smallmatrix} u_t \\ e_t \end{smallmatrix})$ (3)

The Long-Run Covariance Matrix

The long-run covariance matrix of η_t is shown in Equation (4)

$\Omega = \sum_{j=-\infty}^{\infty} E(\eta_t \eta'_{t-j}) = \begin{bmatrix} \Omega_{uu} & \Omega_{ue} \\ \Omega_{eu} & \Omega_{ee} \end{bmatrix}$ (4)

where, $\Omega_{ue} \neq 0$ implies endogeneity and serial correlation exist in u_t [12]. This violates the assumptions of the classical ordinary least square (OLS).

The Bias in the OLS Estimator

The OLS estimator [10] is shown in Equation (5)

$\hat{\beta}_{OLS} = (\sum_{t=1}^{T} X_t X_t')^{-1} \sum_{t=1}^{T} X_t Y_t$ (5)

Substituting for Y_t, we get Equation (6)

$\hat{\beta}_{OLS} - \beta = (\sum_{t=1}^{T} X_t X_t')^{-1} \sum_{t=1}^{T} X_t u_t$ (6)

Since X_t and u_t are correlated, the probability limit is biased as shown in Equation (7)

$plim(\hat{\beta}_{OLS}) \neq \beta$ (7)

Decomposition of the Error Term

The error term can be decomposed as shown in Equation (8)

$\mathrm{u}_t = \varphi' e_t + \xi_t$ (8)

where, $\psi = \Omega_{ee}^{-1} \Omega_{eu}$ and ξ_t is orthogonal to e_t. This decomposition isolates the endogenous component [10].

Fully Modified Transformation

To correct for endogeneity, substitute the decomposition in to the model (9)

$\mathrm{Y}_t = \beta' X_t + \varphi' e_t + \xi_t$ (9)

since, $e_t = \Delta X_t$, Equation (10) defined the transformed dependent variable.

$Y_t^* = Y_t - \varphi' \Delta X_t$ (10)

were, $\hat{\varphi} = \widehat{\Omega}_{ee}^{-1} \widehat{\Omega}_{eu}$. To correct for serial correlation, the one-sided long-run covariance matrix [10] is given by Equation (11)

$\Lambda = \sum_{j=-\infty}^{\infty} E(\eta_t \eta'_{t-j}$ (11)

The FMOLS corrects the intercept using Equation (12)

$\widehat{\Omega}_{uu}^* = \Omega_{uu} - \Omega_{ue} \Omega_{ee}^{-1} \Omega_{eu}$ (12)

This ensures asymptotically efficient inference [13].

Fully Modified Ordinary Least Square (FMOLS) Estimator

Using Equation (11), the FMOLS estimator is shown in Equation (13)

$$\hat{\beta}_{OLS} = \left(\sum_{t=1}^{T}(X_t - \bar{X})\,(X_t - \bar{X})'\right)^{-1} \sum_{t=1}^{T}(X_t - \bar{X})\ Y_t^*) \quad (13)$$

where $Y_t^* = Y_t - \Omega_{ee}^{-1}\Delta X_t$. Under standard regularity conditions, we have $\sqrt{T}(\hat{\beta}_{OLS} - \beta) \overset{d}{\rightarrow} N(0, \sum)$ indicating consistency, asymptotic normality and efficiency

Results and Discussion

The summary statistics reported in Table 1 revealed that Human Development Index (HDI) had a mean value of 347.01. Life Expectancy at Birth (LEB) averaged 54.49 years, which is relatively low compared to global standards, and ranges between 42.48 and 56.04 years. Urbanization Rate (UR) and Dependency Ratio (DR) have mean values of 101.29% and 103.55% respectively, with wide variations across the data, reflecting fluctuations in demographic pressures and urban growth. The standard deviation for HDI (110.58) showed notable variation, while LEB (30.91), UR (60.65) and DR (62.87), equally showed substantial variability. The skewness values revealed that all variables are positively skewed, with UR (7.36) and LEB (4.36) being highly skewed, implying the presence of extreme values in the distributions.

Table 1: Summary Statistics of Demographic Study Variables

	HDI	LEB	UR	DR
Mean	347.01	54.49	101.29	103.55
Std. Dev.	110.58	30.914	60.654	62.872
Skewness	0.3881	4.3594	7.3565	4.1057
Kurtosis	2.4632	37.889	80.956	26.462
Jarque-Bera	6.6786	9699.8	47202	4634.2
p-value	0.0355	0.0000	0.0000	0.0000

Kurtosis showed that the variables are leptokurtic, with LEB (37.89), UR (80.96), and DR (26.46) being particularly peaked and heavy-tailed. The Jarque-Bera normality test confirmed that all variables except HDI deviate significantly from normality, with p-values of 0.0000 for LEB, UR and DR. Although HDI has a p-value of 0.0355 which showed deviation from normality. The results suggested that the demographic indicators exhibit considerable variability, skewness, and leptokurtosis, with strong evidence against normality.

The time plots of the logarithmic series for HDI, life expectancy at birth, urbanization rate and dependency ratio reported in Figures 1-3 exhibit noticeable fluctuations and visible trending behavior over the study period. These patterns indicate that the variables do not maintain constant means or variances in their levels, indicating the presence of non-stationarity and potential long-run movements driven by demographic and development dynamics.

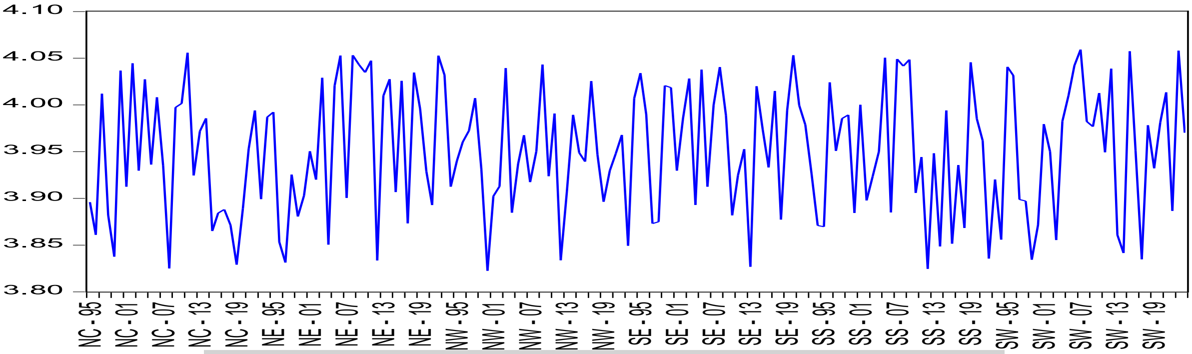

Figure 1: Time Plot of Life Expectancy at Birth in Nigeria (Level Series)

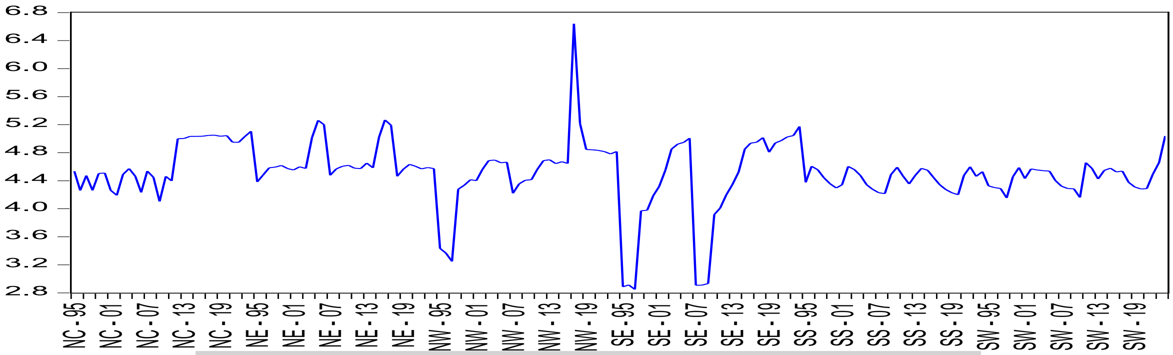

Figure 2: Time Plot of Log Urbanization Rate in Nigeria (Level Series)

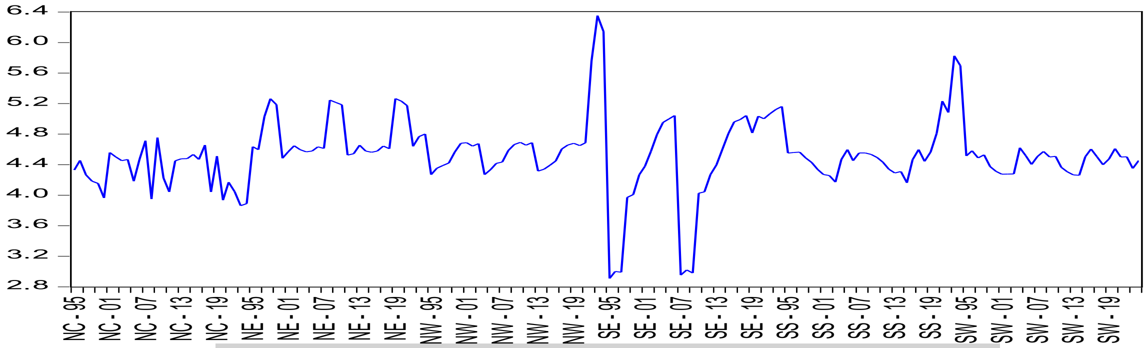

Figure 3: Time Plot of Log Dependency Ratio in Nigeria (Level Series)

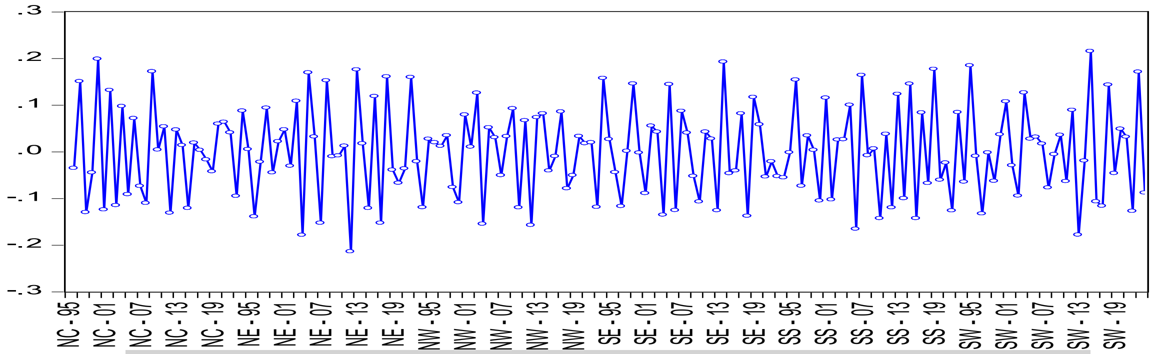

Figure 4: Time Plot of Log Life Expectancy at Birth in Nigeria (First Difference Series)

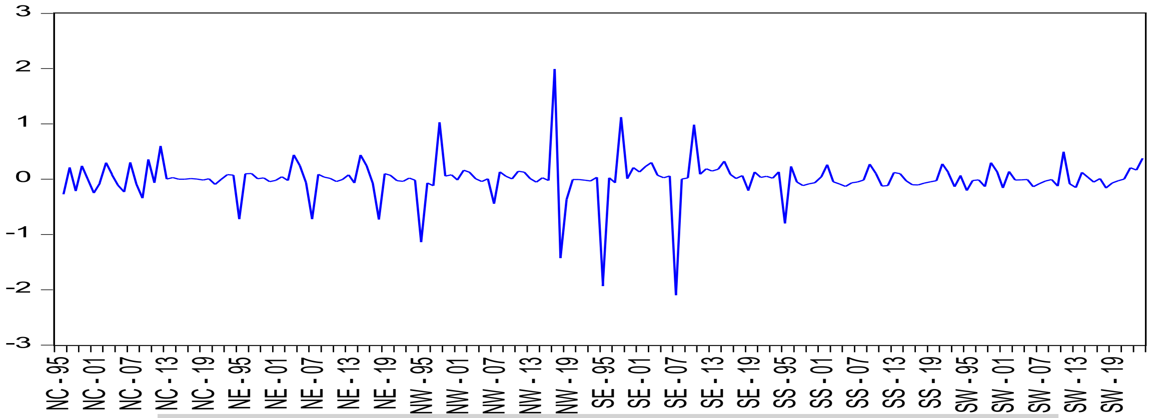

Figure 5: Time Plot of Log Urbanization Rate in Nigeria (First Difference Series)

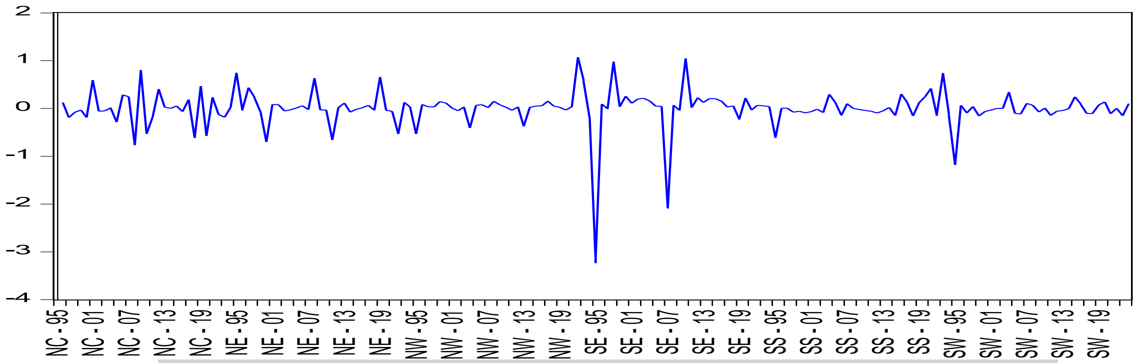

Figure 6: Time Plot of Log Dependency Ratio in Nigeria (First Difference Series)

When the first difference of the log-transformed series was examined (Figures 4-6), the plots stabilized considerably across the variables, revealing constant variance and rapid oscillations around zero, and the absence of systematic upward or downward movements. This behavior is consistent with covariance stationarity in their first differences, implying that each variable follows an integrated process of order one, I(1). The panel unit root test results reported in Table 2 show that at levels, none of the variables are stationary under either the LLC or IPS tests. LHDI has LLC statistics of −1.02897 (p =

0.1517) with intercept and 1.16023 (p = 0.8770) with trend, both of which fail to reject the null hypothesis of a unit root. Similarly, LLEB, LFR, LUR, LDR, and LFLP all return insignificant p-values at levels, confirming the presence of non-stationarity.

Table 2: Panel Unit Root Test Results of the Log Panels

Variable	Option	Levin, Lin and Chu (LLC)	
		LLC Stat.	**p-value**
	Log Panels in Levels		
LHDI	Intercept only	-1.02897	0.1517
	Intercept & trend	1.16023	0.8770
LLEB	Intercept only	-1.12789	0.2468
	Intercept & trend	-2.60902	0.4962
LUR	Intercept only	-1.97021	0.5115
	Intercept & trend	-0.29187	0.4728
LDR	Intercept only	0.44452	0.6717
	Intercept & trend	0.34627	0.6554
	Log Panels First Difference		
∇LHDI	Intercept only	-3.15966	0.0008
	Intercept & trend	-3.54947	0.0006
∇LLEB	Intercept only	-5.67438	0.0000
	Intercept & trend	-5.27058	0.0000
∇LUR	Intercept only	-5.93138	0.0000
	Intercept & trend	-4.41066	0.0000
∇LDR	Intercept only	-5.08790	0.0000
	Intercept & trend	-5.53166	0.0000

When the variables are transformed into their first differences, strong stationarity emerges across all variables and test specifications. ∇LHDI has LLC = –3.15966 (p = 0.0008) and IPS = –4.14947 (p = 0.0000) under intercept, and similarly significant values when trend is included. The same pattern holds for ∇LLEB, ∇LUR and ∇LDR, all of which have test statistics that are highly significant at 1% level. These findings indicate that the study variables are integrated of order one, I(1). In other words, they are non-stationary in levels but become stationary after first difference. This implies that conventional regression on variables in levels could produce spurious results, but cointegration techniques can be applied to explore the existence of long-run equilibrium relationships among the variables. The Pesaran Cross-sectional Dependence (CD) test result, reported in Table 3, produced a z-value of 2.974 with a corresponding p-value of 0.003, which is statistically significant at the 5% level. Therefore, the null hypothesis of cross-sectional independence is rejected.

Table 3: Pesaran Cross-sectional Dependence (CD) Test Result

Test Statistic	z-value	p-value	Decision (5% level)
Pesaran CD	2.974	0.003	Reject H_0: Cross-sectional dependence exists

Indicating the presence of cross-sectional dependence among the panel units. This result implies that shocks or disturbances affecting one cross-sectional unit may also influence others, suggesting interdependence across geopolitical zones or regions in the dataset. The results of Johansen Fisher cointegration test reported in Table 4 show that both the trace and maximum eigenvalue test statistics strongly reject the null hypothesis of no cointegration at the 1% significance level for all hypothesized cointegration ranks.

Table 4: Johansen Fisher Panel Cointegration Test Results

Hypothesized No. of CE(s)	Fisher Stat.* (from trace test)	p-value	Fisher Stat.* (from max-eigenvalue test)	p-value
None*	246.9	0.0000	118.4	0.0000
At most 1*	159.8	0.0000	80.63	0.0000
At most 2*	95.17	0.0000	44.88	0.0000
At most 3*	59.54	0.0000	30.19	0.0026
At most 4*	42.63	0.0000	24.35	0.0182
At most 5*	47.59	0.0000	47.59	0.0000

The Fisher statistics for “None,” “At most 1,” “At most 2,” “At most 3,” “At most 4,” and “At most 5” are all highly significant ($p < 0.05$). This provides robust evidence that there exists more than one cointegrating relationship among the variables, implying a stable long-run association between human development indicators and the selected demographic factors in Nigeria. From the result of lag length selection for panel VAR reported in Table 5, all information criteria (AIC, BIC, HQC, and FPE) decrease as the lag length increases from 0 to 3, indicating improved model fit with the inclusion of additional lags. The minimum values across all criteria occur at lag 3, suggesting it is the optimal lag order for the panel VAR. Beyond lag 3, the criteria slightly increase at lag 4, implying that additional lags do not contribute meaningfully to the model’s explanatory power.

Table 5: Lag Length Selection for Panel VAR (Basis for Panel VECM)

Lag	LogL	AIC	BIC	HQC	FPE
0	-1525.83741	4.77832	4.81677	4.79365	0.00948
1	-1008.29488	3.16203	3.28279	3.21146	0.00184
2	-947.12852	2.99371	3.19676	3.07822	0.00149
3	-894.28417	2.86594	3.15128	2.98554	0.00122
4	-898.78291	2.90918	3.27682	3.06487	0.00129

Therefore, lag 3 is selected as the optimal lag, ensuring that both short-term dynamics and the long-run equilibrium relationships are adequately captured without over-fitting. Thus AIC, BIC, HQC, and FPE all attain their minimum at Lag 3, confirming Lag 3 as the optimal lag length for the Panel VAR. The FMOLS results reported in Table 6 reveal that all the explanatory variables are statistically significant in explaining variations in human development. Life expectancy at birth (LLEB) exerts a positive and significant impact on human development ($\beta = 0.2146$, $p < 0.01$), indicating that improvements in life expectancy contribute positively to human well-being.

Table 6: Parameter Estimates of Fully Modified Least Squares (FMOLS)

Variable	Coefficient	Std. Error	t-Statistic	p-value
LLEB	0.214564	0.015040	14.26622	0.0000
LUR	-0.326142	0.027686	-11.78003	0.0000
LDR	-0.070933	0.028496	-2.489208	0.0138
R-squared	0.948730			
Adjusted R-sqr.	0.944216			
D-Watson stat	1.725625			

Urbanization rate (LUR) showed negative and highly significant effects ($\beta = -0.4509$ and -0.3261, respectively; $p < 0.01$), suggesting that higher urbanization reduces the level of human development. Dependency ratio (LDR) also carried a negative and significant coefficient ($\beta = -0.0709$, $p < 0.05$), implying that a larger dependent population places pressure on resources, thereby reducing development outcomes. he model’s goodness-of-fit is high, with an R-squared value of 0.9487 and an adjusted R-squared of 0.9442, indicating that the explanatory variables jointly account for about 94% of the long-run variations in human development across Nigeria’s regions. The Durbin-Watson (DW) statistic (1.73) suggests that there is no serious autocorrelation problem, strengthening the reliability of the estimates. The FMOLS estimates confirm that reducing urbanization while promoting life expectancy is a critical driver of sustainable human development in Nigeria.

Conclusion

This study investigates the impact of demographic indicators on human development across the six geopolitical zones in Nigeria using advanced panel econometric techniques. Descriptive statistics and graphical analyses revealed substantial variability and pronounced non-stationarity in the level series of all variables, followed by strong covariance stationarity in their first differences confirming that the indicators followed I(1) processes and validating the use of cointegration and FMOLS. The panel unit root results from both first-generation (LLC) confirmed that the variables were non-stationary in levels but became stationary after first difference. The Johansen Fisher panel cointegration tests strongly indicated the presence of multiple long-run equilibrium relationships among HDI and the demographic indicators. The FMOLS model demonstrated excellent goodness-of-fit ($R^2 = 0.9487$), confirming that the selected demographic indicators jointly explain most long-run variations in human development across regions in Nigeria

References

[1] Figueiras A, Caamano F., Gestal-Otero J. J. (2020). **Sociodemographic Factors related to Self-Medication in Spain**. *European Journal of Epidemiol*, 16(1): 19-26.

[2] Isola W. A. and Alani R. A. (2022). **Human Capital Development and Economic**

Growth: Empirical Evidence from Nigeria. *Asian Economic and Financial Review*, **2**(7):813-827

[3] Reyes G. E. and Useche A. J. (2019). **Competitiveness, Economic Growth and Human Development in Latin American and Caribbean Countries 2006-2015: A Performance and Correlation Analysis**. *Competitiveness Review*, 29(2):139-159.

[4] Akintunde T.S., Satope B. F. and Akanbi B. E. (2016): **The Impact of Life Expectancy on Economic Growth in Nigeria**. *The International Journal of Health Economics*, **2**(6):45-56

[5] Sakiru O. K., Ismail I. A. B., and Samah B. A., (2017). **Socio-Demographic Factors that Influence Job Satisfaction among Academicians in Public Universities**. *Canada International Conference on Education,* 4(7): 222-226.

[6] Ademola O. Y. (2019). **Economic Growth and Demographic Dividend Nexus in Nigeria: A Vector Autoregressive (VAR) Approach**. *Asian Social Science*, 15(2): 37-59.

[7] Risikat O. S. D. and Onyebuchi I. (2022). **Human Development and Macroeconomic Shocks in Nigeria: An Empirical Investigation**. *Journal of Social, Behavioural, and Health Sciences,* 16(1): 371-391.

[8] Saheed O. O. and Adedokun A. S. (2021). **Demographic Transition and Economic Growth in Nigeria**. *A Journal of Research and Development*, 8(1):38-55.

[9] Olabisi O. E., and Effiong U. J. (2023). **Socio-Economic Indicators and Economic Growth: A Study of Nigeria and South Africa**. *Oradea Journal of Business and Economics*, 8(1): 72-81.

[10] Phillips P. C., and Hansen B. E. (1990). **Statistical Inference in Instrumental Variables Regression with I(1) Processes**. *Review of Economic Studies*, 57(1): 99-125.

[11] Engle R. F., and Granger C. W. J. (1987). **Co-integration and Error Correction: Representation, Estimation and Testing**. *Econometrica,* 55(2): 251-276.

[12] Stock J. H. and Watson M. W. (1993). **A Simple Estimator of Cointegrating Vectors in Higher Order Integrated Systems**. *Econometrica*, 61(4): 783-820.

[13] Pedroni P. (2000). **Fully Modified OLS for Heterogenous Cointegrated Panels**. *Advances in Econometrics*, 15, 93-130.

Cite this article

Aniah-Betiang E.I., Kuhe D.A., Uba T., and Peter O. (2026). Modeling the Impacts of Demographic Indicators on Human Development in Nigeria: A Fully Modified Ordinary Least Square (FMOLS) Regression Approach. FUAM Journal of Pure and Applied Science, **6**(**2**):50-56