

A Vector Autoregression (VAR) Model of the Dynamic Interrelationships Between Gross Domestic Product and Selected Demographic Variables in Nigeria

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ABSTRACT

This paper examined the dynamic interrelationship between gross domestic product and selected demographic variables in Nigeria using a vector autoregression (VAR) model to capture the temporal interactions among the variables employing annual time series secondary data covering the period 1995-2025 (30 years). Augmented dickey-fuller unit-root test was employed to test the stationarity of the variables. Descriptive statistics was also employed to examine the distributional properties of the variables. The optimal lag selection criteria were used to determine the optimal lag of the study variables. The Granger causality analysis was employed to determine the causal relationship among the study variables. The results revealed that GDP and demographic variables showed dynamic interactions over time. The Granger causality analysis showed limited evidence that past values of the demographic variables simultaneously improve the estimation of GDP. The study concludes that demographic change alone cannot be enough to generate gross domestic product in Nigeria. We recommend that demographic factor should be considered alongside other economic factors when evaluating economic performance in Nigeria.

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INTRODUCTION

The relationship between demographic characteristics and economic growth has become increasingly important due to the demographic transitions occurring across both emerging and developed economies (Maduka *et al.*, 2018). Changes in population size, birth rates, death rates, life expectancy, urbanization, and population growth can significantly influence economic activities and development outcomes (Manyeki and Balaz, 2020).

Sher *et al.* (2017) investigated the impact of Population growth on economic development of Pakistan for period of 1975-2008 using ARDL approach to examine the population and economic development relationship. The results of the study indicate that Population growth had positive and significant contribution to economic growth but negatively affected by unemployment rate.

Akinlo and Salisu (2019) employed Autoregressive Distributed Lag (ARDL) bounds testing method to analyse the long-run relationship between demographic variables (fertility rate, age dependency ratio, and life expectancy) and economic growth in Nigeria from 1960 to 2017. The ARDL technique was deemed appropriate due to the mix of I(0) and I(1) variables and the small sample size.

Yusuf and Abdullahi (2020) employed Johansen co-integration and Vector Error Correction Model (VECM) to investigate long-run equilibrium and short-run dynamics between demographic factors and real GDP per capita in Nigeria. Olayemi and Oyelami (2021) studied the nonlinearity relationship in the demographic dividend-growth in West African countries from 1985-2018 employing panel threshold regression model. The study revealed that

demographic changes yielded growth dividends only in countries that surpassed certain thresholds of educational attainment and employment absorption capacity.

Barro (2017) studied the determinants of economic growth of 87 countries employing panel regression analysis. The study concluded that economic growth had positive relationship to investment ratio, rule of law, favorable terms of trade and increased openness but negative relationship to government expenditure, fertility rate and inflation.

Dewan and Hussein (2020) studied the determinants of economic growth developing countries from 1965-1997 employing fixed effects model (FEM) and random effects model (REM). The study showed that labour force growth, investment in physical and human capital, low level of inflation, open trade policies and improved technique of production affect economic growth positively, but adverse supply shocks in agricultural sector have a negative effect on economic growth.

Cancado (2025) studied the determinants of economic growth from 1952-2000 employing pooled ordinary least squares (POLS) model, fixed effect model (FEM), random effect model (REM) and Hausman-Taylor model. The study found that trade openness, investment and life expectancy had positive effects on economic growth whereas initial per capita GDP level, government expenditure and polity score have a negative effect on the growth rate of per capita GDP.

Wahyudi and Jantan (2022) studied the factors affecting economic growth of ASEAN-4 countries from 1980-2004. The study employed Solow-Swan and Mankiw-Romer-Weil models. Fixed effect model (FEM) and random effect model

(REM) were used to estimate the relationship between real GDP, real capital stock, labour force and adult literacy rate.

Ndambiri *et al.* (2022) studied the factors affecting economic growth of African countries from 1982-2000 employing generalized method of moments (GMM). The study revealed that physical, human capital formation and exports had vital contribution to economic growth. Government spending, foreign aid and nominal discount rate had negative and significant effect.

Lenka and Sharma (2024) examined foreign direct investment (FDI) inflows from 1991-2010. The study employed fixed effect model (FEM) and random effect model (REM) and panel corrected standard errors (PCSE) model. PCSE approach in generalized least square (GLS) was applied to remove multicollinearity, autocorrelation and heteroscedasticity in panel data. The result showed that FDI inflows results to a rise in economic growth.

Upreti (2019) studied the determinants of economic growth for 76 low-middle income countries for the following years (1995, 2000, 2005 and 2010). The study employed ordinary least squares (OLS). The study showed that high investment rates, exports, availability of abundant natural resources and a longer life expectancy had positive impact on per capita GDP growth for developing economies.

Samsuddin and Amar (2020) studied the dependence of economic growth of the G20 members from 2013-2018 employing pooled ordinary least squares (POLS), fixed effect model (FEM) and random effect model (REM). The study found that foreign direct investment (FDI) and economic growth had positive impact. Inflation and real GDP growth rate had significant negative effect. Population growth had positive and not significant effect whereas exchange rate and economic growth had positive and significant effect.

Omosanya and Lawal (2020) studied the relationship between GDP and FDI, inflation, imports, total investment, gross national savings, general government revenue, government expenditure and government gross debt for 11 sub-Saharan African Countries from 1980-2018. The study employed ordinary least squares (OLS) model, Least Squares Dummy Variable (LSDV) model, fixed effect model (FEM) and random effect model (REM).

Bătrancea *et al.* (2021) studied the relationship between GDP growth rate, gross domestic savings, gross capital formation, imports, exports, net FDI inflows and net FDI outflows for 34 African countries from 2001-2019. The study employed fixed effect model (FEM), random effect model (REM) and GMM estimators. Dauda *et al.* (2025) studied the impact of population growth and economic development in Nigeria using descriptive statistics, granger causality and autoregressive distributed lag (ARDL) approach. The study found that population growth rate had negative and insignificant impact on economic growth in Nigeria both in the short run and long run.

Existing studies of examine individual demographic variables, long-run relationships and little emphasizes to combined short-run dynamics among selected demographic variables and gross domestic product. Findings are mixed across countries and periods. This current study addresses these gaps by combining gross domestic product, population growth rate, fertility rate, death rate and life expectancy in Nigeria employing the vector autoregression (VAR).

The choice of gross domestic product is deliberate. Gross domestic product (GDP) measures the level of aggregate economic activity, while economic growth refers to the increase in output over time and is commonly measured by the growth rate of real GDP. This study used the term GDP to represent the economic variable analysed and does not equate

GDP with GDP growth. The VAR model allows the study to examine the dynamic interrelationships and temporal predictability among the study variables without imposing a predetermined direction of dependence.

The study addressed the following research questions: (i) what are the stationarity properties of GDP and the selected demographic variables in Nigeria? (ii) what is the appropriate lag length for the VAR model? (iii) What dynamic relationships exists among GDP and the selected demographic variables? (iv) Do the demographic variables Granger-cause GDP, and does the GDP Granger-cause the demographic variables? (v) is the estimated VAR model stable? The null hypotheses of the study are: (i) the variables contain unit root (ii) no statistically significant dynamic relationships among the variables (iii) the demographic variables do not Granger-cause GDP and (iv) GDP does not Granger-cause the demographic variables.

MATERIALS AND METHODS

Methods

The method of vector autoregression (VAR) model, stability condition, Granger causality analysis, Augmented Dickey-Fuller unit root test and optimal lag length were discussed in this section.

Vector Auto-regressive (VAR) Model

Consider the univariate autoregressive process of order p denoted by AR(p) as shown by Equation (1)

$$Y_t = c + \phi_1 Y_{t-1} + \phi_2 Y_{t-2} + \dots + \phi_p Y_{t-p} + e_t \quad (1)$$

where, c = intercept, ϕ_i = autoregressive coefficients, Y_{t-1} = lagged values of the variable and e_t = white-noise (Hamilton, 1994). The univariate autoregressive process can be extended to vector system resulting to the VAR model (Sims, 1980). A first-order VAR(1) can be written as shown in Equation (2) and (3) respectively

$$Y_t = \alpha_{10} + \alpha_{11} Y_{t-1} + \alpha_{12} Y_{t-1} + e_{1t} \quad (2)$$

$$X_t = \alpha_{20} + \alpha_{21} Y_{t-1} + \alpha_{22} Y_{t-1} + e_{2t} \quad (3)$$

Equation (2) shows that the current value of Y_t depends on its own previous value and that of X_t . Equation (3) showed that X_t relied on the lagged values of both Y_t and X_t (Sims, 1980).

$$Y_t = \begin{bmatrix} Y_t \\ X_t \end{bmatrix} \quad (4)$$

$$c = \begin{bmatrix} \alpha_{10} \\ \alpha_{20} \end{bmatrix} \quad (5)$$

$$A_1 = \begin{bmatrix} \alpha_{11} & \alpha_{12} \\ \alpha_{21} & \alpha_{22} \end{bmatrix} \quad (6)$$

$$e_t = \begin{bmatrix} e_{1t} \\ e_{2t} \end{bmatrix} \quad (7)$$

Equation (2) and (3) can be re-written as (8)

$$Y_t = \begin{bmatrix} \alpha_{10} \\ \alpha_{20} \end{bmatrix} + \begin{bmatrix} \alpha_{11} & \alpha_{12} \\ \alpha_{21} & \alpha_{22} \end{bmatrix} Y_{t-1} + \begin{bmatrix} e_{1t} \\ e_{2t} \end{bmatrix} \quad (8)$$

Equation (8) denotes the VAR(1) model (Lutkepohl, 2005). Extending Equation (8) to obtain the general VAR(p) model as shown by Equation (9)

$$Y_t = c + A_1 Y_{t-1} + A_2 Y_{t-2} + \dots + A_p Y_{t-p} + e_t \quad (9)$$

where, $Y_t = K \times 1$ vector of endogenous variables, $c = K \times 1$ vector of intercepts, $A_i = K \times 1$ matrix of coefficients at lag i and $e_t = K \times 1$ vector of error terms (Enders, 2015).

Stability Condition

The VAR(p) is said to be stable if the determinant condition is not equal to zero as shown by Equation (10)

$$|I_K - A_1 z - A_2 z^2 - \dots - A_p z^p| \neq 0 \quad (10)$$

Given that $|z| \leq 1$.

All the roots of Equation (11) must lie outside the unit circle (Enders, 2015).

$$|I_K - A_1 z - A_2 z^2 - \dots - A_p z^p| = 0 \quad (11)$$

The stability condition indicated that the impacts of temporary shocks eventually die out rather than producing permanent increasing fluctuations. Given the j^{th} equation of the VAR(p) system as shown by Equation (12)

$$Y_{jt} = c_j + \sum_{i=1}^p \sum_{k=1}^K \alpha_{jk,i} Y_{k,t-i} + e_{jt} \quad (12)$$

Equation (12) can be re-written as Equation (13)

$$Y_j = X\beta_j + e_j \quad (13)$$

The ordinary least squares (OLS) estimator is as shown by Equation (14)

$$\hat{\beta}_j = (X'X)^{-1}X'y_j \quad (14)$$

The standard VAR contains the same set of lagged regressors (Lutkepohl, 2005).

Granger Causality

Given that

$$Y_t = \alpha_0 + \sum_{i=1}^p \alpha_i Y_{t-i} + \sum_{i=1}^p \beta_i X_{t-i} + e_i \quad (15)$$

Testing if X Granger causes Y, the hypotheses is $H_0: \beta_1 = \beta_2 = \dots = \beta_p = 0$ Versus $H_1: \text{At least one } \beta_i \neq 0$. The Test statistic is as shown by Equation (16)

$$F = \frac{(SS_R - SSR_U)/p}{SSR_U/(T-2p-1)} \quad (16)$$

where, SS_R and SSR_U are the restricted and unrestricted residual sums of squares. Decision rule: if P-value < 0.05. we reject H_0 and conclude that X Granger causes Y else X does not Granger cause Y (Granger, 1969).

Augmented Dickey-Fuller (ADF) Unit Root Test Statistic

According Dickey and Fuller (1981) the Augmented Dickey-Fuller regression is as shown by Equation (17)

$$y = X\theta + e \quad (17)$$

where y = matrix of dependent variables, X = matrix of explanatory variables, θ = matrix of parameters and e = matrix of error terms. The OLS estimator is as shown by Equation (18)

$$\hat{\theta} = (X'X)^{-1}X'y \quad (18)$$

The coefficient corresponding to $Y_{t-1} = \hat{\gamma}$. The variance-covariance matrix of the OLS estimator is as shown by Equation (19)

$$\text{Var}(\hat{\theta}) = \sigma^2(X'X)^{-1} \quad (19)$$

Replacing the unknown σ^2 by the estimator gives Equation (20)

$$\text{Var}(\hat{\theta}) = \hat{\sigma}^2(X'X)^{-1} \quad (20)$$

But,

$$SE(\hat{\gamma}) = \sqrt{\hat{\sigma}^2(X'X)^{-1}} \quad (21)$$

Therefore,

$$T_{ADF} = \frac{\hat{\gamma}}{\sqrt{\hat{\sigma}^2(X'X)^{-1}}} \quad (22)$$

The position of the element corresponding to γ depends on how the regressors were ordered (Dickey and Fuller, 1979)

Optimal Lag Length Selection

The following optimal lag selection are discussed and employed in the analysis.

Log-likelihood (LL)

Consider the Var(p) VAR(p) such that

$$Y_t = A_1 Y_{t-1} + \dots + A_p Y_{t-p} + e_t \quad (23)$$

with $e_t \sim N(0, \Sigma)$. The conditional likelihood function is as shown by Equation (24)

$$L(A_1, \dots, A_p, \Sigma) = \prod_{t=p+1}^T (2\pi)^{-k/2} |\Sigma|^{-1/2} \exp \left[-\frac{1}{2} e_t' \Sigma^{-1} e_t \right] \quad (24)$$

taking the natural logarithm of Equation (23) gives Equation (24)

$$\ln L(\theta) = -\frac{kt}{2} \ln(2\pi) - \frac{T}{2} \ln |\Sigma| - \frac{1}{2} \sum_{t=1}^T e_t' \Sigma^{-1} e_t \quad (25)$$

At the maximum unlikelihood estimates, the estimated covariance matrix is approximately as shown by Equation (26)

$$\hat{\Sigma} = \frac{1}{2} \sum_{t=1}^T \hat{e}_t \hat{e}_t' \quad (26)$$

The maximized likelihood is based on the size of the error term covariance matrix (Lutkepohl, 2005).

Akaike Information Criterion (AIC)

According to Akaike (1974), the general form of the AIC is shown by Equation (27)

$$AIC = -2\ln L + 2m \quad (27)$$

where, L = the maximized log-likelihood and m = the number of estimated parameters. $-2\ln L$ measures lack of fit and $2m$ is a penalty for the model complexity. For a k-variable VAR(p)

$$m = k^2 p + k \quad (28)$$

therefore,

$$AIC(p) = -2\ln L_p + 2(k^2 p + k) \quad (29)$$

The criterion can be expressed as shown by Equation (30)

$$AIC(p) = \ln |\hat{\Sigma}_p| + \frac{2k^2 p}{T} \quad (30)$$

The optimal lag selected by AIC is as shown by Equation (31)

$$P_{AIC}^* = \arg \min_p \left[\ln |\hat{\Sigma}_p| + \frac{2k^2 p}{T} \right] \quad (31)$$

Schwarz Bayesian Information Criterion (SBIC)

According to Schwarz (1978) the general form is as shown by Equation (32)

$$BIC = -2\ln L + m \ln T \quad (32)$$

The BIC replaces the penalty $2m$ with $m \ln T$. For the VAR(p) we have Equation (33)

$$BIC(p) = -2\ln L_p + (k^2 p + k) \ln T \quad (33)$$

The normalized criterion is as shown by Equation (34)

$$SBIC(p) = \ln |\hat{\Sigma}_p| + \frac{k^2 p \ln T}{T} \quad (34)$$

$$P_{SBIC(p)}^* = \arg \min_p \left[\ln |\hat{\Sigma}_p| + \frac{k^2 p \ln T}{T} \right] \quad (35)$$

The penalty in Equation (35) increases with the sample size because $\ln T > 2$ for large T .

Hannan Quin Information Criterion (HQIC)

Hannan and Quinn (1979) developed a consistent model selection criterion. The general form is as shown in Equation (36)

$$HQ = -2\ln L + 2m \ln(\ln T) \quad (36)$$

From the VAR(p), the model is as shown in Equation (37)

$$HQIC(p) = -2\ln L_p + 2(k^2 p + k) \ln(\ln T) \quad (37)$$

Normalizing and removing constant gives Equation (38)

$$HQIC(p) = \ln |\hat{\Sigma}_p| + \frac{2k^2 p \ln(\ln T)}{T} \quad (38)$$

Hence, the HQIC penalty is as shown by Equation (39)

$$P_{HQ}^* = \arg \min_p \left[\ln |\hat{\Sigma}_p| + \frac{2k^2 p \ln(\ln T)}{T} \right] \quad (39)$$

This penalty is between that of AIC and SBIC for large samples (Lutkepohl, 2005).

Final Prediction Error (FPE)

For a univariate autoregressive model, the final prediction error is as shown by Equation (40)

$$FPE(p) = \hat{\sigma}_p^2 \left(\frac{T+p+1}{T-p-1} \right) \quad (40)$$

$\hat{\sigma}_p^2$ measures the in-sample prediction error and $\left(\frac{T+p+1}{T-p-1} \right)$ adjusts the estimation uncertainty resulting from additional parameters. In a multivariate VAR(p) model, the criterion is expressed as shown in Equation (41)

$$FPE(p) = \left(\frac{T+n_p}{T-n_p} \right) |\hat{\Sigma}_p| \quad (41)$$

n_p = the number of estimated dynamic coefficients per equation. The optimal lag is as shown by Equation (42)

$$P_{FPE}^* = \arg \min_p FPE(p) \quad (42)$$

The FPE picks the lag length linked with the smallest estimated out-of-sample prediction error (Lutkepohl, 2005).

Data

the study used aggregated annual secondary time-series data sourced from an unpublished research work by Aniah-Betieng (2025). The dataset consists of aggregated annual observations for Nigeria covering the period 1995-2025 (30 years) giving a total of 30 annual observations each for GDP and demographic variables. The demographic variables are population growth rate (PGR), fertility rate (FR), death rate (DR) and life expectancy (LE). The economic growth variable

is gross domestic product (GDP). The software for estimation is STATA 14.0

RESULTS AND DISCUSSION

Results

The results of the descriptive statistics and normality measures, Augmented Dickey-Fuller (ADF) unit root test, optimal lag selection-order criteria, gross domestic product (GDP) equation, population growth rate (PGR) equation, fertility rate (FR) equation, death rate (DR) equation, life expectancy (LE) equation, Granger causality Wald tests and eigenvalue stability condition are presented on Table 1 to 10 in this section.

Table 1: Descriptive Statistics and Normality Measures

Variables	Mean	Range	SD	Skewness	Kurtosis	P-value
GDP	117.2001	804.6000	102.1190	3.6288	20.1075	0.0000
PGR	309.8714	961.4000	246.9742	1.3238	3.9473	0.0000
FR	95.7592	170.8400	31.4335	0.5129	4.5581	0.0000
DR	103.5482	555.3700	62.8714	4.1057	26.4617	0.0000
LE	58.8737	457.4281	45.58524	4.3594	37.8896	0.0000

GDP = Gross Domestic Product, PGR = Population Growth rate, FR = Fertility Rate, DR = Death Rate and LE = Life Expectancy and SD = Standard Deviation

Table 2: Augmented Dickey-Fuller (ADF) Unit Root test

Variables	Test Stat.	Critical value	Order
GDP	-14.973	-2.885	I(0)
PGR	-9.861	-2.885	I(0)
FR	-5.519	-2.885	I(0)
DR	-6.083	-2.885	I(0)
LE	-12.053	-2.885	I(0)

GDP = Gross Domestic Product, PGR = Population Growth Rate, FR = Fertility Rate, DR = Death Rate and LE = Life Expectancy

Table 3: Optimal Lag Selection-Order Criteria

Lag	LL	LR	Df	P	FPE	AIC	HQIC	SBIC
0	-4992.03				1.4e+20	60.57	60.6082	60.6641
1	-4878.7	226.64	25	0.000	4.8e+19*	59.4994*	59.7287*	60.0642*
2	-4859.13	39.148	25	0.036	5.1e+19	59.5652	59.9855	60.6005
3	-4851.36	15.531	25	0.928	6.3e+19	59.7741	60.3854	61.28
4	-4831.23	40.268	25	0.027	6.7e+19	59.8331	60.6354	61.8096
5	-4819.14	24.181	25	0.509	7.9e+19	59.9896	60.9829	62.4367

Table 4: Gross Domestic Product (GDP) Equation

Variables	Coefficient	Std. Err.	Z	p> z	95% C. I.
GDP	-0.1217	0.0746	-1.63	0.103	-0.2678 0.0245
PGR	0.0011	0.0311	0.03	0.973	-0.0598 0.0619
FR	-0.2599	0.2663	-0.98	0.329	-0.7819 0.2621
DR	0.0271	0.1590	0.17	0.865	-0.2847 0.3388
LE	0.0012	0.0253	0.05	0.963	-0.0483 0.0507
Cons.	152.6256	28.9293	5.28	0.000	95.9252 209.3261

R-Square = 0.0200, P-Value = 0.6054

Table 5: Population Growth Rate (PGR) Equation

Variables	Coefficient	Std. Err.	Z	p> z	95% C. I.
GDP	-0.0743	0.1735	-0.43	0.668	-0.4144 0.2658
PGR	0.2891	0.0723	4.00	0.000	0.1474 0.4308
FR	0.2988	0.6196	0.48	0.630	-0.9157 1.5132
DR	0.0102	0.3700	0.03	0.978	-0.7151 0.7354
LE	-0.0537	0.0587	-0.91	0.361	-0.1688 0.0615

Variables	Coefficient	Std. Err.	Z	p> z	95% C. I.
Cons.	223.2733	67.3092	3.32	0.001	91.3497 355.197

R-Square = 0.0894 and p-Value = 0.0038

Table 6: Fertility Rate (FR) Equation

Variables	Coefficient	Std. Err.	Z	p> z	95% C. I.
GDP	-0.0143	0.0166	-0.86	0.388	-0.0468 0.0182
PGR	0.0002	0.0069	0.03	0.975	-0.0133 0.0138
FR	0.7209	0.0592	12.17	0.000	0.6049 0.8371
DR	-0.0351	0.0354	-0.99	0.321	-0.1045 0.0342
LE	0.0005	0.0056	0.09	0.927	-0.0105 0.0115
Cons.	31.7864	6.4345	4.94	0.000	19.1751 44.3977

R-Square = 0.4902 and p-value = 0.0000

Table 7: Death Rate (DR) Equation

Variables	Coefficient	Std. Err.	Z	p> z	95% C. I.
GDP	-0.0110	.03546	-0.31	0.756	-0.0805 0.0585
PGR	0.0147	0.0148	0.99	0.320	-0.0143 0.0436
FR	0.0782	0.1266	0.62	0.537	-0.1700 0.3264
DR	0.5502	0.0756	7.28	0.000	0.4020 0.6984
LE	0.0024	0.0120	0.20	0.842	-0.0211 0.0259
Cons.	34.4822	13.7555	2.51	0.012	7.5219 61.4426

R-Square = 0.2863 and p-Value = 0.0000

Table 8: Life Expectancy (LE) Equation

Variables	Coefficient	Std. Err.	Z	p> z	95% C. I.
GDP	-0.1149	0.2197	-0.52	0.601	-0.5456 0.3157
PGR	-0.1039	0.0915	-1.14	0.256	-0.2834 0.0755
FR	1.2555	0.7846	1.60	0.110	-0.2823 2.7933
DR	0.2084	0.4685	0.44	0.656	-0.7099 1.1268
LE	0.0875	0.0744	1.18	0.239	-0.0583 0.2333
Cons.	262.4425	85.2301	3.08	0.002	95.3947 429.4903

R-Square = 0.0372 and p-Value = 0.2328

Table 9: Granger Causality Wald Tests

Null hypothesis	Chi-square	Df	P-value
GDP does not granger cause PGR	0.00115	1	0.973
GDP does not granger cause FR	0.95239	1	0.329
GDP does not granger cause DR	0.02892	1	0.865
GDP does not granger cause LE	0.00217	1	0.963
GDP does not granger cause ALL	1.0124	4	0.908
PGR does not granger cause GDP	0.18351	1	0.668
PGR does not granger cause FR	0.2325	1	0.630
PGR does not granger cause DR	0.00076	1	0.978
PGR does not granger cause LE	0.83414	1	0.361
PGR does not granger cause ALL	1.1802	4	0.881
FR does not granger cause GDP	0.74367	1	0.388
FR does not granger cause PGR	0.00097	1	0.975
FR does not granger cause DR	0.98574	1	0.321
FR does not granger cause LE	0.00846	1	0.927
FR does not granger cause ALL	1.7902	4	0.774
DR does not granger cause GDP	0.09627	1	0.756
DR does not granger cause PGR	0.98925	1	0.320
DR does not granger cause FR	0.38112	1	0.537
DR does not granger cause LE	0.03948	1	0.842
DR does not granger cause ALL	1.7265	4	0.786
LE does not granger cause GDP	0.27368	1	0.601
LE does not granger cause PGR	1.2898	1	0.256
LE does not granger cause FR	2.5605	1	0.110
LE does not granger cause DR	0.1979	1	0.656
LE does not granger cause ALL	5.1201	4	0.275

Table 10: Eigenvalue Stability Condition

Eigenvalues	Modulus
0.7050915	0.705092
0.572388	0.572388
0.3156751	0.315675
-0.1249298	0.12493
0.05794945	0.057949

Discussion

The results presented on Table 1 to 10 are discussed in this section. The descriptive statistic and normality measures presented on Table 1 revealed that the mean of GDP and demographic variables (PGR, FR, DR and LE) are positive with PGR recording the highest average (309.8714), range (961.4000) and SD (246.9742) whereas LE recorded the lowest mean (58.8737 years), range (457.4281) and SD (45.5852) among the demographic variables. The distributions are positively skewed to the right and leptokurtic in nature (less flat top) indicating extreme fat tails. The GDP and demographic variables of the study are non-normal since P-values < 0.05 level of significance resulting to the rejection of the null hypothesis which state that the distributions are normally distributed.

The Augmented Dickey-Fuller (ADF) test for unit root presented on Table 2 showed that economic growth (GDP) and the demographic variables (PGR, FR, DR and LE) are stationary at I(0) since the absolute value of the test statistic for each variable in the study are greater than their corresponding absolute critical values at 5% level of significance. This implies that the VAR model is appropriate for the study.

The optimal lag selection-order criteria presented on Table 3 showed that the optimal lag length selected is 1 indicating that the lag length is appropriate for the VAR model. The lowest Akaike information criteria (AIC = 59.4994*), final prediction error (FPE = 4.8e+19*), Hannan-Quinn information criteria (HQIC = 59.7287*) and Schwarz Bayesian information criteria (SBIC = 60.0642*) are on lag 1. All the lag-selection criteria (AIC, FPE, HQIC and SBIC) select lag 1. Therefore, the reported information criteria, the VAR model is specified with lag one.

The gross domestic product (GDP) equation presented on Table 4 showed that the equation is not statistically significant at 5% level of significance. The GDP and FR are negative and not statistically significant at 5% level of significance. PGR, DR and LE are positive and not statistically significant at 5% level of significance and their confidence intervals contain zero. The coefficient of determination (R-square = 2.00%) of the GDP equation showed that 2.00% of the variations in the GDP (dependent variable) are explained by the lagged GDP, PGR, FR, DR and LE (explanatory variables) at 5% level of significance. the lagged Gross domestic product (GDP = -0.1217) and fertility rate (FR = -0.2599) had negative coefficient and not statistically significant. The lagged Population growth rate (PGR = 0.0011) and death rate (DR = 0.0271) had positive coefficient and not statistically significant. A unit change in the lagged GDP and FR will decrease the GDP by 0.1217 and 0.2599 respectively whereas PGR and DR will increase the GDP by 0.0011 and 0.0271 respectively while holding other lagged variable constant. Therefore, there is insufficient evidence that the lagged values of GDP, PGR, FR, DR and LE significantly improve the prediction of GDP within the specified VAR model.

The population growth rate (PGR) equation presented in Table (5) revealed that the PGR equation is statistically significant at 5% level of significance. Population growth rate

(PGR = 0.2891) is positive and statistically significant at 5% level of significance and the confidence interval do not contain zero whereas gross domestic product (GDP = -0.0743) and life expectancy (LE = -0.0537) are negative and not statistically significant. Fertility rate (FR = -0.2988) and death rate (DR = 0.0102) are positive and not statistically significant at 5% level of significance and the confidence interval contain zero at 5% level of significance. Only 8.94% of the variations in the dependent variable (PGR) are explained by the lagged variables (GDP, PGR, FR, DR and LE). The lagged GDP and LE had negative coefficient whereas lagged PGR, FR and DR had positive coefficient. A unit change in the lagged GDP and LE will decrease the PGR by 0.0743 and 0.0537 respectively. While keeping other lagged variables constant. These shows that there is insufficient evidence that the lagged values of GDP, PGR, FR, DR and LE significantly improve the prediction of GDP within the specified VAR model.

The fertility rate (FR) equation presented on Table 6 indicated that the equation is significant since the P-value (0.0000) < 0.05. The lagged gross domestic product (GDP = -0.0143) and death rate (DR = -0.0351) are negative and not statistically significant at 5% level of significance. Population growth rate (PGR = 0.0002), and life expectancy (LE = 0.0005) are positive and not statistically significant at 5% level of significance and their confidence interval contain zero whereas fertility rate (FR = 0.7209) is positive and statistically significant at 5% level of significance and its confidence interval do not contain zero. The coefficient of determination (R-square = 0.4902) showed that 49.02% of the variation in the dependent variable (FR) are explained by the lagged variables (GDP, PGR, DR and LE). A unit change in the lagged GDP and DR will decrease the FR by 0.0143 and 0.0351 respectively whereas a unit change in the lagged PGR, FR and LE will increase the FR by 0.0002, 0.7209 and 0.0005 respectively while holding other lagged variables constant. The lagged GDP and DR had negative estimated coefficient whereas PGR, FR and LE had positive estimated coefficient. These variables have different coefficient signs, the results do not provide sufficient statistical evidence that their lagged values significantly predict fertility rate. The results indicated that past fertility rate provides significant predictive information for current fertility rate, whereas the other lagged variables do not.

The death rate (DR) equation presented on Table (7) depicted that the equation is significant since the P-value = 0.0000 < 0.05 level of significance. The lagged gross domestic product (GDP = -0.0110) is negative and not statistically significant at 5% level of significance. Population growth rate (PGR = 0.0147), fertility rate (FR = 0.0782) and life expectancy (LE = 0.0024) are positive and not statistically significant at 5% and their confidence interval contain zero whereas the lagged death rate (DR = 0.5502) is positive and statistically significant at 5% level of significance and the confidence interval do not contain zero. The coefficient of determination (R-square = 0.2863) showed that 28.63% of the variation in DR are explained by the lagged GDP, PGR, FR, DR and LE. The lagged PGR, FR, DR and LE have positive estimated

coefficients, while lagged GDP has a negative estimated coefficient. A unit change in the lagged PGR, FR, DR and LE will positively increase the DR by 0.0147, 0.0782, 0.5502 and 0.0024 respectively whereas a unit change in the lagged GDP will negatively decrease the DR by -0.0110 holding other lagged variables constant. The results provide statistical evidence of persistence in DR, while the other lagged variables do not significantly predict DR within the specified vector autoregression (VAR) model.

The life expectancy (LE) equation presented on Table (8) revealed that the equation is not significant since $p\text{-value} = 0.2328 > 0.05$ level of significance. The lagged gross domestic product (GDP = -0.1149), population growth rate (PGR = -0.1039) are negative and not statistically significant at 5% level of significance. Fertility rate (FR = 1.2555), death rate (DR = 0.2084) and life expectancy (LE = 0.0875) are positive and not statistically significant at 5% level of significance and their confidence interval contain zero. The R-Square = 0.0372 showed that 3.72% of the variation in the dependent variable (LE) are explained by the lagged GDP, PGR, FR and DR. The estimated coefficients of lagged GDP and PGR are negative whereas the estimated coefficients of lagged FR, DR and LE are positive. Lagged GDP and PGR have negative estimated coefficients, but neither is statistically significant at 5% level of significance. The lagged FR, DR and LE have positive estimated coefficients, but none is statistically significant at the 5% level of significance. This implies that there is insufficient evidence that the lagged values of GDP, PGR, FR, DR and LE significantly predict current life expectancy within the specified VAR model.

The Granger causality Wald test presented on Table (9) revealed that there is insufficient evidence that population growth rate (PGR), fertility rate (FR), death rate (DR) and life expectancy (LE) Granger predict GDP at 5% level of significance. There is insufficient evidence that GDP, FR, DR and LE Granger predict PGR at 5% level of significance. There is insufficient evidence that GDP, PGR, DR and LE Granger predict FR at 5% level of significance. There is insufficient evidence that GDP, PGR, FR and LE Granger predict DR 5% level of significance whereas there is also insufficient evidence that GDP, PGR, FR and DR Granger predict LE at 5% level of significance. Since all the $p\text{-values}$ exceed 0.05, the null hypothesis of no Granger predictability is not rejected at 5% level of significance. This implies that the gross domestic product and demographic variables do not exhibit unidirectional or bidirectional Granger predictive relationship among the variables in the study.

The eigenvalue stability condition on Table (10) revealed that all the modulus of all estimated eigenvalues is less than one. Since the modulus of every eigenvalue is below one, the VAR model satisfies the stability condition.

Limitation of the Study

This study is limited by the availability and quality of secondary data from the unpublished research work by Aniah-Betieng (2025). The study considers only gross domestic product (GDP) and demographic variables, excluding other important demographic variables. The VAR and Granger causality identify dynamic interrelationships rather than causation. The study is restricted to Nigeria and should be generalized with care.

CONCLUSION

The study is restricted to the application of vector autoregression (VAR) model. The study determined the dynamic relationship between GDP and demographic variables in Nigeria. The findings indicated dynamic

interactions among the study variables and limited evidence of Granger predictability. This indicated that demographic fluctuations do not frequently predict GDP or vice versa in the short-run.

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