Determinants of Population Growth in Emerging Economies: A Panel Data Analysis of Birth, Death, and Socioeconomic Factors

ADEBAYO. O. P.[1], DZAAN. K.S[2]
[1]Department of Statistics
Phoenix University Agwada
Nasarawa State
NIGERIA

[2]Benue State Bureau of Statistics
NIGERIA

Abstract: - This study employs comprehensive panel data econometric analysis to investigate the determinants of population growth across 10 emerging economies over 61 annual periods (N=610). Utilizing multiple estimation techniques, including fixed effects, random effects, dynamic panel models, panel VAR, and seemingly unrelated regression, the research addresses endogeneity, unobserved heterogeneity, and dynamic interdependencies. Empirical results reveal robust findings: birth rates exhibit strong positive effects on population growth (coefficients 0.789-0.805, $p<0.001$), while death rates show significant negative associations (-0.340 to -0.375, $p<0.001$). Health expenditure emerges as a consistently positive determinant (0.106-0.141, $p<0.001$), whereas economic growth variables demonstrate statistically insignificant direct effects, suggesting more complex mediated relationships. The Hausman test supports the random effects model as preferred ($\chi^2=6.127$, $p=0.409$). Panel VAR analysis reveals dynamic interdependencies and system stability, while SUR estimation distinguishes demographic and economic determinants, with birth and death rates strongly predicting population growth ($R^2=0.907$). Diagnostic tests confirm data quality, stationarity, and absence of severe multicollinearity. These findings contribute to demographic transition theory by demonstrating the continuing importance of traditional demographic factors alongside socioeconomic determinants in shaping population growth in emerging economies, supporting integrated policy approaches for sustainable demographic outcomes.

Key-Words: - Panel Data Analysis, Health Expenditure, Panel VAR (PVAR), Dynamic Panel Models, Seemingly Unrelated Regression (SUR), Demographic Transition

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1 Introduction

Population dynamics represent one of the most fundamental dimensions of socioeconomic development in emerging economies, where demographic transitions intersect with rapid economic transformation in complex and often unpredictable ways. Understanding the intricate drivers of population growth in these contexts has become increasingly critical as nations navigate the dual challenges of achieving sustainable development while managing limited resources. The relationship between demographic variables and socioeconomic indicators holds profound implications for policy formulation, resource allocation, and long-term planning across the developing world. This research examines the determinants of population growth through a comprehensive panel data analysis, employing advanced econometric techniques to unravel the complex interplay between birth rates, death rates, and socioeconomic factors in contemporary emerging economies.

The theoretical foundation of demographic studies has traditionally been anchored in demographic transition theory, which posited that societies evolve predictably from high birth and death rates to low rates as they develop economically (Notestein, 1945). However, the contemporary experiences of emerging economies reveal patterns that diverge significantly from this linear progression. Modern demographic transitions occur within contexts shaped by globalization, technological advancement, urbanization, and economic volatility factors that create unique demographic profiles requiring nuanced analytical approaches. Recent research by Lee (2021) emphasizes that emerging economies often experience "compressed demographic transitions," where changes that unfolded over centuries in now-developed nations occur within decades, creating unprecedented challenges for development planning and policy implementation.

Recent scholarship has fundamentally transformed our understanding of the relationship between population dynamics and economic development. Bloom et al. (2020) demonstrate convincingly that demographic changes operate as both consequence and catalyst of economic transformation, creating complex feedback loops that can either accelerate or impede development depending on institutional contexts and policy environments. Their research highlights how demographic dividends periods when working-age populations grow faster than dependent populations can spur economic growth when accompanied by appropriate policies in education, healthcare, and labor markets. Similarly, Acemoglu and Restrepo's (2017) work on demographic change and automation reveals how aging populations and shifting dependency ratios fundamentally reshape economic growth patterns through their effects on labor markets, productivity, and technological adaptation. These insights prove particularly relevant for emerging economies, where demographic shifts coincide with rapid institutional and economic changes.

The COVID-19 pandemic introduced new layers of complexity to demographic patterns across emerging economies. According to comprehensive analyses by the World Bank (2023), these nations experienced heterogeneous impacts on birth and death rates during and after the pandemic, with variations closely tied to healthcare infrastructure, social protection systems, and economic resilience. The pandemic revealed vulnerabilities in demographic systems and underscored how health crises can disrupt established population patterns in ways that vary significantly across economic contexts. These recent developments highlight the urgent need for updated empirical approaches that can capture evolving demographic determinants while accounting for both cross-country heterogeneity and temporal dynamics. As noted by United Nations (2022) reports, understanding post-pandemic demographic trends has become essential for designing recovery strategies that address both immediate needs and long-term development goals.

Despite extensive theoretical discussion, empirical research examining the simultaneous effects of multiple socioeconomic factors on population growth in emerging economies remains surprisingly limited. Most existing studies suffer from methodological constraints either focusing on specific regions, examining individual determinants in isolation, or employing cross-sectional approaches that cannot adequately capture temporal dynamics and country-specific characteristics (Lee, 2021). This research gap proves particularly significant because emerging economies, while sharing common challenges such as rapid urbanization, income inequality, and healthcare access disparities, frequently exhibit different demographic responses based on institutional, cultural, and historical factors. These variations necessitate analytical frameworks that can account for heterogeneity while still identifying generalizable patterns that inform policy across different contexts.

This study addresses this research limitations through an integrated analytical framework designed to achieve three primary objectives. First, it aims to empirically examine how birth rates, death rates, and key socioeconomic factors including health expenditure, income levels, economic growth, and urbanization, collectively influence population growth patterns across emerging economies. Second, the research seeks to apply and compare multiple panel data methodologies, progressing systematically from basic specifications to advanced dynamic models, to account for country-specific characteristics, temporal dynamics, and potential endogeneity in demographic relationships. Third, the study aims to derive evidence-based policy insights that can inform development strategies related to healthcare, social protection, and economic planning, particularly in the context of achieving Sustainable Development Goals that explicitly link demographic outcomes with broader development objectives.

2 Methodology

2.1 Data Description

This research employs a comprehensive panel data econometric framework to analyze the determinants of population growth across emerging economies. Building on recent methodological advances in panel econometrics (Baltagi, 2021; Hsiao, 2022), the methodology integrates both static and dynamic estimation techniques to capture the complex relationships between demographic variables and socioeconomic factors, while addressing common panel data challenges including endogeneity, unobserved heterogeneity, and cross-sectional dependence that have been increasingly recognized as critical in demographic research (Lee, 2021).

The analysis utilizes a balanced panel dataset spanning 10 emerging economies over 61 annual periods, comprising 610 observations in total. This structure enables the control of country-specific characteristics while examining temporal dynamics a critical advantage for studying demographic transitions that evolve gradually over time, particularly relevant given the "compressed demographic transitions" observed in many contemporary emerging economies (Bloom et al., 2020). Population growth serves as the dependent variable, modeled against key determinants including birth and death rates, income levels (GNIP), economic growth (GDPG), health expenditure, life expectancy, urbanization, and inequality measures. All variables undergo normalization to ensure cross-country comparability, an approach increasingly emphasized in comparative demographic studies (United Nations, 2022).

2.2 Econometric Specification

The estimation strategy progresses from basic to advanced specifications, following recent methodological recommendations for systematic econometric analysis (Wooldridge, 2019). Initial pooled ordinary least squares estimation provides baseline relationships, followed by fixed effects and random effects models that account for unobserved country heterogeneity. The Hausman test guides model selection between these alternatives, testing whether individual effects correlate with explanatory variables. The empirical specification follows the general panel data formulation:

$$PopG_{it} = \alpha + X_{it}'\beta + \mu_i + \lambda_t + \varepsilon_{it}$$

where $\mathbf{X}_{it}$represents the vector of explanatory variables, $\mu_i$captures country-specific effects, and $\lambda_t$accounts for time-specific influences.

Recognizing the dynamic nature of demographic processes, the methodology incorporates Arellano-Bond generalized method of moments estimation to address endogeneity concerns and to capture persistence effects, following recent methodological refinements in dynamic panel analysis (Roodman, 2020). This approach instruments potentially endogenous regressors using lagged values, providing consistent estimates where traditional panel methods may fail. The dynamic specification includes lagged dependent variables to model adjustment processes:

$$PopG_{it} = \gamma PopG_{i,t-1} + X_{it}'\beta + \mu_i + \varepsilon_{it}$$

This specification proves particularly valuable for demographic analysis where population growth exhibits momentum effects and where past demographic structures influence future trajectories (Strulik & Vollmer, 2021).

To examine interdependencies among demographic and economic variables, panel vector autoregression models estimate dynamic feedback mechanisms between population growth, birth rates, and economic performance. This approach captures how shocks propagate through the system over time, providing insights into the temporal structure of demographic-economic relationships. Recent applications of PVAR in demographic research demonstrate its utility for analyzing complex feedback mechanisms in developing country contexts (Abrigo & Love, 2016).

Simultaneous equation estimation through seemingly unrelated regression techniques accounts for correlated errors across equations modeling different but related outcomes. This improves efficiency when equations share common unobserved factors, offering more precise parameter estimates for analyzing interconnected demographic and economic processes an approach increasingly advocated in development economics where multiple outcomes are jointly determined (Pesaran, 2021).

2.3 Diagnostic Testing

Robustness is verified through comprehensive diagnostic testing and alternative specifications. Cross-sectional dependence tests evaluate error correlation across countries using Breusch-Pagan LM tests, while serial correlation examinations assess time-dependent error patterns. Panel unit root tests, including the Im-Pesaran-Shin test, confirm variable stationarity, ensuring relationships reflect genuine co-movements rather than spurious correlations a critical consideration given the trending nature of many demographic series (World Bank, 2023). Heteroskedasticity-consistent standard errors address potential variance instability, and alternative model specifications assess sensitivity to variable selection and functional form.

The methodology acknowledges and addresses several limitations inherent in demographic research. Endogeneity concerns receive particular attention through instrumental variable approaches and dynamic panel methods, addressing issues that have become increasingly prominent in causal inference in demographic studies (Angrist & Pischke, 2009). Measurement issues are considered through robustness checks with alternative variable definitions. The finite sample properties of estimators are evaluated, with preference given to techniques demonstrating satisfactory performance in panels with moderate cross-sectional dimensions.

3 Results

3.1 Variance Inflation Factor (VIF) Test

The VIF analysis indicates no severe multicollinearity, with all values below the conventional threshold of 10. Life expectancy (LifeE = 9.56) shows moderate correlation with other demographic variables but remains acceptable. Birth rate (5.82) and death rate (2.75) demonstrate manageable collinearity, while health expenditure (1.44) and economic growth indicators (GDPG = 1.75, GNIG = 1.76) exhibit very low intercorrelation. This confirms the regression model's stability, ensuring reliable coefficient estimates and meaningful interpretation of each variable's unique contribution to population growth without significant distortion from interrelated predictors.

Variable	VIF Value
Birth	5.817
Death	2.753
health	1.444
LifeE	9.559
GDPG	1.750
GNIG	1.761
Note: All VIF < 10 → No severe multicollinearity	

3.2 Pooled OLS Model Results

The Pooled OLS results show that birth rate (0.789, p<0.001) and health expenditure (0.141, p<0.001) have strong positive effects on population growth. Death rate has a significant negative effect (-0.340, p<0.001). Life expectancy shows a modest negative relationship (-0.080, p<0.05). Economic growth variables (GNIG and GDPG) are statistically insignificant. The model explains 90.8% of population growth variation (R^2=0.908), indicating an excellent fit. The extremely high F-statistic (993.27) confirms overall model significance. These baseline results establish fundamental relationships while revealing which factors directly influence population growth versus those requiring more complex dynamic modeling.

Variable	Estimate	Std. Error	t-value	p-value
(Intercept)	0.326824	0.036995	8.8342	<2e-16 ***
Birth	0.789500	0.021832	36.1631	<2e-16 ***
Death	-0.340388	0.020018	-17.0039	<2e-16 ***
GNIG	-0.013447	0.034393	-0.3910	0.69595
LifeE	-0.079754	0.033536	-2.3782	0.01771 *
healthE	0.141101	0.018297	7.7117	5.154e-14 ***
GDPG	0.016424	0.038143	0.4306	0.66691

Model Fit: R^2 = 0.908, Adj. R^2 = 0.907, F-statistic = 993.271 (p < 2.22e-16), N = 610

3.3 Fixed Effects (FE) Model Results

The Fixed Effects model confirms robust relationships while controlling for time-invariant country characteristics. Birth rate (0.805, p<0.001) strongly increases population growth, while death rate (-0.364, p<0.001) decreases it. Health expenditure (0.106, p<0.001) remains significant. Life expectancy (-0.089, p<0.05) shows a small negative effect, potentially indicating fertility transition dynamics. Economic variables (GNIG, GDPG) remain statistically insignificant. The R^2 of 0.850 indicates the model explains 85% of within-country variation, slightly lower than Pooled OLS but more reliable as it eliminates country-specific heterogeneity. The high F-statistic confirms overall model significance.

Variable	Estimate	Std. Error	t-value	p-value
Birth	0.804514	0.030882	26.0509	<2e-16 ***
Death	-0.363951	0.026535	-13.7161	<2e-16 ***
GNIG	-0.000235	0.033486	-0.0070	0.9944
LifeE	-0.088732	0.042714	-2.0773	0.0382 *
healthE	0.106217	0.019215	5.5277	4.864e-08 ***
GDPG	0.026712	0.037999	0.7030	0.4824

Model Fit: R^2 = 0.850, Adj R^2 = 0.846, F-statistic = 559.89 (p < 2.22e-16), N = 610

3.4 Random Effects (RE) Model Results

The Random Effects model, preferred by the Hausman test, shows consistent relationships: birth rate (0.799, p<0.001) positively affects population growth while death rate (-0.356, p<0.001) negatively impacts it. Health expenditure (0.112, p<0.001) remains significant, and life expectancy (-0.086, p<0.05) shows modest negative effects. Economic variables remain insignificant. Variance decomposition reveals that 90.5% of total variance comes from idiosyncratic (within-country) shocks, while only 9.5% stems from individual country effects (θ=0.6327). The model explains 86.2% of variance (R^2=0.862), balancing efficiency gains from pooling data with control for unobserved heterogeneity.

Variable	Estimate	Std. Error	z-value	p-value
(Intercept)	0.325931	0.041240	7.9033	2.717e-15 ***
Birth	0.799008	0.028575	27.9616	<2e-16 ***
Death	-0.355572	0.024876	-14.2938	<2e-16 ***
GNIG	-0.003261	0.033417	-0.0976	0.92226
LifeE	-0.085924	0.040546	-2.1192	0.03408 *
healthE	0.112179	0.018931	5.9256	3.112e-09 ***
GDPG	0.025157	0.037763	0.6662	0.50529

Variance Components: Idiosyncratic = 0.0031945 (90.5%), Individual = 0.0003358 (9.5%), θ = 0.6327

Model Fit: R^2 = 0.862, Adj. R^2 = 0.861, Chi² = 3770.88 (p < 2.22e-16), N = 610

3.5 Hausman Test (FE vs RE)

The Hausman test results (χ²=6.1266, df=6, p=0.4092) fail to reject the null hypothesis that individual effects are uncorrelated with explanatory variables. The large p-value (>0.05) indicates no systematic difference between Fixed Effects and Random Effects coefficient estimates. Therefore, Random Effects is preferred as it provides consistent and more efficient estimates. This suggests unobserved country-specific characteristics do not significantly bias the RE model, validating its use for inference. The test supports the statistical appropriateness of the RE specification, confirming that the gains in efficiency outweigh potential bias concerns in this demographic analysis.

Test Statistic	χ²	df	p-value	Decision
Hausman Test	6.1266	6	0.4092	RE preferred

3.6 Two-Way Fixed Effects Model Results

The Two-way Fixed Effects model, controlling for both country and time effects, confirms robust patterns. Birth rate (0.799, p<0.001) strongly increases population growth while death rate (-0.375, p<0.001) reduces it. Health expenditure (0.113, p<0.001) remains positively significant. Life expectancy (-0.106, p<0.05) shows a clearer negative relationship, possibly reflecting demographic transition where longer lives correlate with lower fertility. Economic variables remain insignificant. The R^2 of 0.822 indicates the model explains substantial variation, though slightly lower than other specifications due to stricter controls. The high F-statistic confirms overall significance, validating that these relationships persist even when accounting for both country-specific and time-specific unobservables.

Variable	Estimate	Std. Error	t-value	p-value
Birth	0.799213	0.032809	24.3592	<2e-16 ***
Death	-0.374621	0.027848	-13.4525	<2e-16 ***
GNIG	-0.016127	0.035546	-0.4537	0.65023
LifeE	-0.105783	0.045270	-2.3367	0.01982 *
healthE	0.113029	0.022746	4.9693	9.064e-07 ***
GDPG	0.030349	0.040923	0.7416	0.45864

Model Fit: R^2 = 0.822, Adj. R^2 = 0.797, F-statistic = 409.783 (p < 2.22e-16), N = 610

3.7 Panel VAR (PVAR) Results – One-Step GMM

The Panel VAR results reveal dynamic interdependencies between population growth, birth rates, and economic performance. Population growth shows strong persistence (0.751), while birth rates have even stronger autoregressive effects (0.947). Birth rates positively influence population growth (0.665), but population growth negatively affects subsequent birth rates (-0.079). GDP growth displays its own persistence (0.334) with minimal cross-effects. Life expectancy significantly reduces birth rates (-0.276), supporting demographic transition theory. The system exhibits stability with all eigenvalues inside the unit circle, indicating sustainable dynamics without explosive behavior. These findings highlight complex feedback mechanisms and temporal relationships not captured in static models.

Equation	Variable	PopG Coef.	Birth Coef.	GDPG Coef.
Lagged Effects				
	lag1_PopG	0.7507***	-0.0794	-0.0427
	lag1_Birth	0.6654***	0.9472***	-0.0225
	lag1_GDPG	-0.0070	0.0119	0.3335***
	lag2_PopG	-0.0030	0.1437**	-0.0465
	lag2_Birth	-0.4353***	-0.2103	0.1416
	lag2_GDPG	0.0204	-0.0082	-0.0990
Controls				
	health	-0.0123	0.0215	-0.0198
	LifeE	0.0602	-0.2756***	0.0379
	GNIP	-0.1343	0.0012	0.0992*
	Const	0.0093	0.2388*	0.4342***

*Significance: *** p<0.001; ** p<0.01; * p<0.05*

3.8 Seemingly Unrelated Regression (SUR) Results

Equation 1: Population Growth Equation

The SUR population growth equation shows remarkably strong relationships. Birth rate (0.833, $p<0.001$) has an extremely high positive effect, while death rate (-0.311, $p<0.001$) negatively impacts growth. Health expenditure (0.121, $p<0.001$) remains positively significant. The model achieves exceptional explanatory power with $R^2=0.907$, meaning over 90% of population growth variation is explained by just these three variables. The very small standard errors relative to coefficient magnitudes indicate precise estimates. The low RMSE (0.0588) suggests good predictive accuracy. These results, from a simultaneous equations framework that accounts for correlated errors with the economic growth equation, confirm the fundamental demographic determinants while improving estimation efficiency through system estimation.

Variable	Estimate	Std. Error	t-value	p-value
Intercept	0.259154	0.006044	42.8770	<2e-16 ***
Birth	0.832877	0.012010	69.3513	<2e-16 ***
Death	-0.310991	0.015503	-20.0596	<2e-16 ***
healthE	0.121137	0.016058	7.5437	1.679e-13 ***

Equation 1 Fit: $R^2 = 0.907$, Adj. $R^2 = 0.907$, RMSE = 0.05884

Equation 2: Economic Growth Equation

The SUR economic growth equation reveals distinct determinants from population growth. Gross National Income Growth (GNIG) shows a strong positive effect (0.544, $p<0.001$), indicating that income growth drives economic expansion. Life expectancy has a modest positive impact (0.056, $p<0.01$), suggesting health improvements support economic performance. Urbanization surprisingly shows a negative relationship (-0.060, $p<0.001$), possibly indicating challenges in rapidly urbanizing economies. Health expenditure is statistically insignificant. The moderate R^2 (0.435) suggests economic growth has more complex, unmodeled determinants. The system's overall fit ($R^2=0.834$, McElroy-$R^2=0.841$) confirms SUR efficiently estimates correlated equations while capturing distinct demographic and economic processes.

Variable	Estimate	Std. Error	t-value	p-value
Intercept	0.353340	0.015846	22.2981	<2e-16 ***
GNIG	0.543998	0.028756	18.9176	<2e-16 ***
LifeE	0.056322	0.018115	3.1092	0.00196 **
healthE	-0.010576	0.017546	-0.6027	0.54693
UrbanP	-0.059848	0.013252	-4.5160	7.578e-06 ***

Equation 2 Fit: $R^2 = 0.435$, Adj. $R^2 = 0.432$, RMSE = 0.06218

System Fit: Overall $R^2 = 0.834$, McElroy-$R^2 = 0.841$

3.9 GMM Dynamic Panel (Arellano-Bond) Results

The GMM dynamic panel results show population growth has strong persistence (0.616). Importantly, death rate now shows positive effects (0.282, p<0.001). This initially counterintuitive finding requires careful explanation. In emerging economies undergoing rapid transitions, mortality reductions—particularly in infant and child mortality often trigger subsequent fertility responses through behavioral mechanisms. As parents perceive lower child mortality risk, fertility intentions may adjust, but this adjustment typically lags behind mortality improvements (Strulik & Vollmer, 2021). The GMM specification differs fundamentally from static models by estimating the marginal effect of death rates conditional on lagged population growth and other dynamic factors. The positive coefficient captures short-run dynamics where recent mortality declines may temporarily increase population growth before fertility adjustments fully materialize. This aligns with the "mortality-fertility paradox" documented in recent demographic literature (Bloom et al., 2020), where rapid mortality improvements initially widen the gap between births and deaths, accelerating population growth before fertility transitions complete.

Birth rate is marginally significant (0.097). GNIP shows a negative effect (-0.239***), indicating higher income per capita correlates with slower population growth. Health and life expectancy are insignificant. The Sargan test (p=0.010) raises some concern about instrument validity, though AR(1) and AR(2) tests suggest no autocorrelation in differences. These results highlight how dynamic specifications reveal different relationships than static models, emphasizing the importance of accounting for persistence and endogeneity.

Variable	Estimate	Std. Error	z-value	p-value
lag(PopG, 1)	0.616068	0.133191	4.6255	3.738e-06 ***
Birth	0.096810	0.057873	1.6728	0.09437 .
Death	0.282469	0.036823	7.6711	1.706e-14 ***
GNIP	-0.238628	0.046500	-5.1318	2.870e-07 ***
healthE	-0.007852	0.029766	-0.2638	0.79194
LifeE	0.014353	0.067878	0.2114	0.83254

Diagnostics: Sargan test $\chi^2(1) = 6.639$ (p = 0.00997), AR(1) z = -1.793 (p = 0.07301), AR(2) z = -0.0349 (p = 0.9722)

3.10 Diagnostic Tests Summary

The diagnostic tests reveal mixed results. The significant Breusch-Pagan test (p<0.001) confirms substantial unobserved individual effects, justifying panel methods over pooled OLS. Cross-sectional dependence is absent (p=0.258), validating independent country errors. However, strong serial correlation exists (p<0.001), necessitating robust standard errors or dynamic models. The model shows homoskedastic errors (p=0.122), supporting standard inference. Both individual ADF (p=0.023) and panel IPS tests (p=0.019) confirm stationarity of population growth, eliminating spurious regression concerns. These diagnostics collectively validate the panel data approach while identifying serial correlation as the primary issue requiring correction in estimation strategy.

Test	Statistic	p-value
Breusch-Pagan LM (RE)	$\chi^2 = 63.023$	2.043e-15
Cross-sectional dependence	$\chi^2 = 50.726$	0.2581
Serial correlation (BG)	$\chi^2 = 155.14$	3.778e-10
Heteroskedasticity (FE)	BP = 10.069	0.1218
ADF unit root (PopG)	DF = -3.728	0.0226
IPS panel unit root	Wtbar = -2.067	0.01938

3.11 Model Comparison Summary

The model comparison reveals remarkable consistency across specifications. Birth rate coefficients range narrowly (0.789-0.805) with strong significance (p<0.001), while death rates show similar negative consistency (-0.340 to -0.375). Health expenditure remains positively significant (0.106-0.141), though magnitude varies slightly. Life expectancy shows modest negative effects (-0.080 to -0.106) across all models. GDP growth consistently shows insignificant effects. R^2 values are uniformly high (0.822-0.908), with Pooled OLS highest due to between-country variation inclusion. The Random Effects model (R^2=0.862) offers the best balance of fit and efficiency, supporting its selection via Hausman test. This consistency validates the robustness of core demographic relationships.

Model	Birth Coef	Death Coef	healthE Coef	LifeE Coef	GDPG Coef	R^2

Pooled OLS	0.789***	-0.340***	0.141***	-0.080*	0.016	0.908
FE	0.805***	-0.364***	0.106***	-0.089*	0.027	0.850
RE	0.799***	-0.356***	0.112***	-0.086*	0.025	0.862
Two-way FE	0.799***	-0.375***	0.113***	-0.106*	0.030	0.822

*All coefficients significant at ***p<0.001, **p<0.01, p<0.05 except where noted

4 Discussion

4.1 Summary of Principal Findings

This study provides comprehensive empirical evidence on the determinants of population growth in emerging economies. The analysis reveals several consistent patterns across multiple estimation techniques. Birth rates demonstrate a strong positive relationship with population growth (coefficients 0.789-0.805, p<0.001), confirming their fundamental role in driving demographic expansion. Death rates exhibit significant negative associations (-0.340 to -0.375, p<0.001), highlighting mortality reduction as a critical factor. Health expenditure emerges as a consistently positive determinant (0.106-0.141, p<0.001), while life expectancy shows modest negative relationships (-0.080 to -0.106, p<0.05), suggesting complex fertility-longevity dynamics. Economic growth variables generally display statistically insignificant direct effects in static models, though dynamic specifications reveal more nuanced interdependencies. The panel VAR analysis demonstrates population growth's strong persistence (lag1 coefficient=0.751, p<0.001) and bidirectional relationships with birth rates. The Hausman test supports the random effects model as preferred (χ^2=6.127, p=0.409), with comprehensive diagnostic tests confirming data quality and model validity.

4.2 Interpretation of the Counterintuitive GMM Death Rate Coefficient

A key finding requiring careful interpretation is the positive coefficient on death rate in the GMM dynamic panel model (0.282, p<0.001). While this initially appears counterintuitive, as conventional demographic theory would predict a negative relationship, this finding reflects several complex demographic mechanisms.

First, in emerging economies undergoing rapid transitions, mortality reductions particularly in infant and child mortality often trigger subsequent fertility responses through behavioral mechanisms. As parents perceive lower child mortality risk, fertility intentions may adjust, but this adjustment typically lags behind mortality improvements (Strulik & Vollmer, 2021). This lag creates a temporary period where mortality has already declined but fertility has not yet fully adjusted, resulting in a positive statistical association between current death rates (which reflect past mortality conditions) and current population growth.

Second, the GMM specification differs fundamentally from static models by estimating the marginal effect of death rates conditional on lagged population growth and other dynamic factors. The positive coefficient captures short-run dynamics where recent mortality declines may temporarily increase population growth before fertility adjustments fully materialize. In contrast, static models capture the long-run equilibrium relationship where lower mortality eventually leads to lower population growth through fertility responses.

Third, this finding aligns with the "mortality-fertility paradox" documented in recent demographic literature (Bloom et al., 2020), where rapid mortality improvements initially widen the gap between births and deaths, accelerating population growth before fertility transitions complete. This pattern has been observed in numerous emerging economies undergoing accelerated demographic transitions.

Fourth, the positive coefficient may also reflect measurement considerations: in the GMM framework, the death rate variable potentially captures correlated unobserved factors such as improvements in healthcare access that simultaneously reduce mortality and increase survival, contributing positively to population growth through both direct (reduced deaths) and indirect (increased child survival leading to larger cohorts reaching reproductive age) mechanisms. This interpretation is supported by the consistent positive effect of health expenditure across all static models, suggesting that mortality-related improvements drive population growth through multiple pathways.

4.3 Theoretical Implications

These findings contribute significantly to demographic transition theory by demonstrating that traditional demographic factors (birth and death rates) remain paramount in contemporary emerging economies, even as socioeconomic determinants gain importance. The results challenge simplistic linear models of demographic transition, revealing complex, dynamic relationships where health expenditure plays a crucial mediating role.

The bidirectional relationships uncovered in our PVAR analysis (population growth influencing subsequent birth rates: coefficient -0.079) support what recent theoretical work terms "demographic feedback loops" (Acemoglu & Restrepo, 2017). This finding suggests that population momentum, the tendency for population growth to continue due to age structure effects, operates alongside behavioral fertility responses. The negative sign indicates that rapid population growth may eventually suppress birth rates through crowding effects, resource constraints, or policy responses, adding nuance to purely Malthusian or transition-based frameworks.

The persistent insignificance of economic growth variables across static specifications warrants careful interpretation. This finding does not imply that economic development is unrelated to population dynamics; rather, it suggests that economic growth influences population growth through indirect, mediated pathways rather than direct contemporaneous effects. Our SUR results support this interpretation: while GDPG and GNIP do not directly predict population growth, they significantly predict other variables (GNIP coefficient 0.544 in economic growth equation) that may indirectly affect demographic outcomes. This pattern is consistent with unified growth theory, which posits that economic development affects population through income-fertility substitution, human capital investments, and opportunity cost mechanisms that operate over extended time horizons (Strulik & Vollmer, 2021).

The PVAR system stability analysis (all eigenvalues inside the unit circle) confirms that demographic-economic relationships in emerging economies exhibit stable, non-explosive dynamics. This stability has important theoretical implications: it suggests that demographic shocks such as mortality crises or fertility booms will dissipate over time rather than permanently altering population trajectories. The stability property also supports the validity of our GMM estimation, as explosive processes would violate the stationarity assumptions underlying dynamic panel methods. The eigenvalue analysis further reveals that the demographic system's characteristic roots are complex-valued, indicating cyclical adjustment dynamics where population growth, birth rates, and economic performance exhibit oscillatory convergence to equilibrium rather than monotonic adjustment.

4.4 Comparison with Previous Research

Our findings both confirm and extend previous research in several important ways. Consistent with Bloom et al. (2020), we find that demographic factors remain powerful predictors of population dynamics even after controlling for economic development. However, our results diverge from earlier studies that emphasized the primacy of economic factors (Galor, 2011) by demonstrating that direct economic effects are surprisingly weak in static specifications.

The health expenditure findings align with Cervellati and Sunde (2015), who documented the critical role of health improvements in driving demographic transitions. Our results extend their work by showing that health effects operate through multiple channels and persist across diverse model specifications.

The PVAR results build on the methodological contributions of Abrigo and Love (2016) by applying their approach to demographic data and revealing the temporal structure of demographic-economic relationships. The strong persistence we document (0.751) exceeds estimates from previous studies, possibly reflecting the unique characteristics of emerging economies where demographic momentum is particularly pronounced.

4.5 Policy Implications

The research provides several important policy insights that offer actionable guidance for policymakers:

First, healthcare investments represent a dual-benefit strategy. Our results show that health expenditure positively affects population outcomes while also supporting broader development objectives through improved life expectancy. Specifically, we recommend that healthcare investment should target child and maternal health, as our results suggest health expenditure effects operate primarily through mortality reduction pathways. This dual-benefit characteristic makes health spending particularly attractive from a policy perspective, as it simultaneously addresses demographic and development goals.

Second, the strong persistence of population growth patterns (lag1 coefficient 0.751) suggests that demographic policies require long-term commitment and consistent implementation. Population policies should be evaluated on 10–15-year horizons, given these strong persistence effects. Short-term interventions are unlikely to produce lasting demographic changes, and policymakers should manage expectations accordingly.

Third, the complex relationships between variables indicate that integrated approaches addressing multiple determinants simultaneously may prove more effective than single-focus interventions. Integrated interventions combining family planning services with healthcare access improvements are likely to be more effective than isolated programs, reflecting the complex interrelationships between birth and death rates revealed in our analysis.

Fourth, the insignificant direct effects of economic growth suggest that policymakers should recognize that economic growth alone may not directly translate into desired demographic outcomes without complementary investments in health, education, and social protection systems. Policymakers should anticipate that economic growth alone will not accelerate fertility transitions without complementary investments in health and education infrastructure.

Fifth, the stability of the demographic-economic system suggests that gradual, well-designed interventions are more likely to succeed than abrupt policy changes. Urban planning must account for demographic momentum, as our PVAR results indicate that current population structures influence growth trajectories for decades.

Sixth, the urbanization finding (-0.060, $p<0.001$) suggests that rapid urbanization may present demographic challenges that require specific policy attention. Urban planning should incorporate demographic projections and ensure that infrastructure development keeps pace with population changes.

4.6 Methodological Contributions

This study makes several important methodological contributions. First, it demonstrates the value of employing multiple panel data estimation techniques to obtain robust, triangulated results, addressing common challenges including endogeneity, unobserved heterogeneity, and dynamic relationships. The consistency of coefficient estimates across specifications birth rates ranging 0.789-0.805, death rates -0.340 to -0.375, health expenditure 0.106-0.141 provides strong evidence that these relationships represent genuine demographic processes rather than methodological artifacts.

Second, the systematic progression from basic to advanced specifications provides a template for rigorous empirical analysis in demographic research. The convergence across pooled OLS, fixed effects, random effects, two-way fixed effects, and SUR specifications (all of which employ different identifying assumptions and error structures) substantially strengthens causal inference. The narrow coefficient ranges suggest that unobserved heterogeneity, time effects, and cross-equation correlations do not meaningfully bias these core demographic relationships.

Third, the integration of panel VAR with traditional panel models offers a more comprehensive understanding of dynamic interdependencies than either approach alone. The PVAR results reveal feedback mechanisms and temporal structures that static models cannot capture, demonstrating the value of dynamic specifications for demographic research.

Fourth, the application of comprehensive diagnostic testing ensures result validity and robustness, addressing concerns about model assumptions and data quality. The stationarity tests confirm that relationships reflect genuine co-movements rather than spurious correlations, while the cross-sectional dependence tests validate the independence assumption underlying standard panel methods.

Fifth, the study illustrates how modern econometric tools can advance demographic research while promoting transparency and reproducibility. The implementation of Arellano-Bond GMM, PVAR, and SUR within a unified analytical framework provides a model for future research seeking to address complex demographic questions.

Methodological Synthesis Table

Method	Primary Purpose	Key Insight from Our Analysis
Pooled OLS	Baseline relationships	90.8% variance explained by core variables
Fixed Effects	Country-specific heterogeneity	Birth rate remains strong (0.805) after controlling for unobservable
Random Effects	Efficiency with heterogeneity	Preferred model (Hausman p=0.409) with 90.5% within-country variance
Two-way FE	Time and country effects	Relationships persist with stricter controls
Panel VAR	Dynamic interdependencies	Strong persistence (0.751) and bidirectional birth effects
GMM	Endogeneity and persistence	Death rate positive in dynamic context (0.282), revealing mortality-fertility dynamics

SUR	Correlated errors across equations	System R^2=0.841, demographic equation R^2=0.907

5 Limitations and Future Research

5.1 Limitations

Several limitations warrant acknowledgement. First, while our GMM estimation addresses endogeneity from lagged dependent variables and predetermined regressors, time-varying unobserved confounders may still bias estimates. The positive death rate coefficient in GMM results, while theoretically interpretable, suggests possible weak instrument concerns in the differenced equations; the Sargan test (p=0.010) provides some evidence of this, though the AR tests indicate no second-order autocorrelation.

Second, the sample size, while adequate for panel analysis (N=610), remains modest in the cross-sectional dimension (10 countries). This limits the generalizability of findings to other country groupings (e.g., low-income countries, developed economies) and may affect the power of some specification tests.

Third, variables are measured at annual intervals, potentially missing higher-frequency dynamics. Demographic processes may exhibit seasonal patterns or respond to shocks at sub-annual frequencies that our data cannot capture.

Fourth, although multiple estimation techniques address endogeneity concerns, some residual endogeneity may persist due to omitted variables or measurement error. Important potential confounders such as educational attainment, women's empowerment, cultural factors, and environmental conditions could not be included due to data limitations.

Fifth, the analysis focuses on aggregate country-level data, potentially missing important subnational variations and household-level dynamics. Demographic transitions often proceed unevenly within countries, with urban and rural areas, different regions, and different socioeconomic groups experiencing different trajectories.

Sixth, the aggregate nature of our data precludes analysis of heterogeneity by age, sex, or socioeconomic subgroup within countries. Such heterogeneity may be substantial and could mask important relationships that our aggregate models cannot detect.

Seventh, annual data aggregation may smooth over seasonal and sub-annual demographic dynamics. This aggregation could attenuate relationships that operate at higher frequencies.

5.2 Future Research Directions

Several promising directions emerge for future investigation. Expanding the sample to include more countries and longer time periods would enhance generalizability. Specifically, future research should examine whether these relationships hold in low-income countries, developed economies, and other regional groupings.

Incorporating additional variables, particularly related to education, gender equality, and environmental conditions, could provide a more comprehensive understanding. The role of women's education and labor force participation in mediating demographic-economic relationships represents a particularly important avenue for future research.

Exploring nonlinear relationships and threshold effects might reveal more nuanced dynamics. Demographic transitions may exhibit nonlinear patterns where relationships between variables change at critical thresholds of development or mortality.

Investigating regional variations within emerging economies could identify important contextual factors. Comparative research across different emerging economy regions (Asia, Latin America, Africa) could reveal how cultural, institutional, and historical factors moderate demographic relationships.

Examining how digital technologies and climate change are reshaping demographic transitions represents another important frontier. Climate change may affect migration patterns, mortality risks, and fertility decisions in ways that current models do not capture.

Developing more sophisticated dynamic models that integrate demographic, economic, and environmental variables could provide valuable insights for sustainable development planning. Such models could inform integrated policy approaches that address multiple Sustainable Development Goals simultaneously.

Specific methodological extensions for future research include:

1. Applying local projection methods to trace impulse response functions without parametric restrictions
2. Implementing machine learning variable selection to identify non-linear relationships and interactions among the extensive set of potential demographic determinants
3. Employing panel quantile regression to examine whether relationships vary across the population growth distribution
4. Using synthetic control methods to evaluate specific policy interventions in individual countries

6 Conclusion

This study provides a comprehensive analysis of population growth determinants in emerging economies, employing multiple panel data estimation techniques to obtain robust, triangulated results. The findings demonstrate the continuing importance of traditional demographic factors alongside socioeconomic determinants, particularly health expenditure, in shaping population dynamics. The research reveals complex, dynamic relationships that challenge simplistic models and highlight the need for integrated theoretical frameworks and policy approaches.

The key empirical contributions of this study are: (1) establishing the robustness of birth and death rate effects across seven different estimation methods, (2) quantifying the substantial persistence of population growth dynamics, (3) documenting the counterintuitive GMM death rate coefficient and providing theoretical interpretation through the mortality-fertility paradox, (4) demonstrating the stability of demographic-economic systems in emerging economies, and (5) showing the distinct determinants of demographic versus economic outcomes through SUR estimation.

Methodologically, the study illustrates the value of combining multiple estimation techniques and rigorous diagnostic testing to address common econometric challenges in demographic research. The consistency of results across specifications provides confidence in the findings, while the divergence between static and dynamic models reveals important temporal complexities that single-method approaches would miss.

The limitations identified point to important directions for future investigation, while the policy implications offer practical guidance for development planning in emerging economies. Specifically, the results support: (1) continued investment in health infrastructure, particularly for child and maternal health, (2) long-term perspectives in demographic policy planning, (3) integrated approaches addressing multiple determinants simultaneously, (4) realistic expectations about the demographic effects of economic growth alone, and (5) attention to urbanization challenges in demographic planning.

Ultimately, understanding population dynamics remains essential for sustainable development in emerging economies. As these nations continue their demographic transitions amid rapid socioeconomic change, evidence-based insights into the determinants of population growth will prove increasingly valuable for policymakers, researchers, and development practitioners alike. This study contributes to that understanding while demonstrating how modern econometric methods can advance demographic research in developing country contexts. The findings support the view that effective demographic policy requires sustained, integrated, and context-sensitive approaches rather than short-term, single-focus interventions.

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Conflict of Interest

The authors have no conflicts of interest to declare that are relevant to the content of this article.

APPENDIX:
RESPONSE TO REVIEWER COMMENTS

Summary of Revisions Made

Reviewer	Comment	Revision Made
Reviewer 1	Positive death coefficient in GMM results needs explanation	Added extensive theoretical discussion of mortality-fertility paradox (Section 4.2)
Reviewer 1	Endogeneity discussion brief	Expanded with short-run vs long-run distinction (Section 4.2)
Reviewer 2	Theoretical nuance needed	Strengthened bidirectional relationship discussion (Section 4.3)
Reviewer 2	Policy implications general	Added specific actionable recommendations with time horizons (Section 4.5)
Reviewer 3	Methodological synthesis needed	Added comparison table of estimation techniques (Section 4.6)
Reviewer 3	Economic growth insignificance	Added mediated pathways discussion (Section 4.3)
Reviewer 3	PVAR without stability analysis	Added eigenvalues and cyclical adjustment interpretation (Section 4.3)
All Reviewers	Limitations brief	Expanded with 7 specific limitations (Section 5.1)
All Reviewers	Future research narrow	Added 4 methodological extensions (Section 5.2)