African Development Review

WILEY

African Development Review
Revue africaine de développement

ORIGINAL ARTICLE OPEN ACCESS

Economic Growth in ECOWAS: Linear and Nonlinear Dynamics of Domestic Investment, Trade Openness, Inflation, and Infrastructure Access

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Received: 15 June 2025 | **Revised:** 4 October 2025 | **Accepted:** 7 October 2025

Funding: The authors received no specific funding for this work.

Keywords: economic growth | ECOWAS | FDI | inflation | trade

ABSTRACT

This study investigates the effects of domestic investment, trade openness, inflation, and electricity access on economic growth in nine ECOWAS countries from 2000 to 2023. Pooled mean group autoregressive distributed lag (PMG-ARDL) and nonlinear pooled mean group autoregressive distributed lag (PMG-NARDL) models are applied to capture long-run relationships and asymmetric adjustments. Results show that domestic investment supports income growth, but its effect weakens when combined with electricity access, reflecting infrastructure inefficiencies. Trade openness produces mixed outcomes: linear estimates indicate a negative long-run link, while nonlinear results reveal that increases in openness stimulate growth, whereas contractions reduce income. Inflation also behaves asymmetrically, as disinflation enhances growth while rising inflation exerts weaker adverse effects. The trade–inflation interaction suggests that inflation may ease some negative impacts of trade exposure. Foreign direct investment displays asymmetry as well, with declines associated with stronger growth, possibly due to greater domestic resource mobilization. Unemployment and population growth produce inconsistent effects across models. By applying linear and nonlinear panel ARDL methods, this study evaluates macroeconomic and structural drivers of growth in West Africa. The findings point to reforms in electricity infrastructure, balanced trade liberalization, and inflation stabilization to sustain growth in ECOWAS economies.

1 | Introduction

Economic growth in West Africa remains uneven and constrained by structural and macroeconomic challenges. Despite the Economic Community of West African States (ECOWAS) promoting regional integration and development, member countries continue to face limited productive investment, high unemployment, weak industrial capacity, and persistent inflation volatility (AfDB 2020; Emeka et al. 2024; Olaoye and Aderajo 2020; UNECA 2015). Infrastructure gaps, especially in electricity access, restrict firm productivity, discourage investment, and weaken public service delivery (IEA 2022; Onye et al. 2022). Trade openness, often advanced as a growth strategy, has produced mixed results in ECOWAS due to shallow domestic production structures, limited export diversification, and import dependence (Rodrik 2017; UNCTAD 2021). These weaknesses increase vulnerability to external shocks, imported inflation, and supply-side bottlenecks, limiting the region's capacity to translate reforms into sustained growth.

While capital accumulation, macroeconomic stability, and trade openness are widely recognized as growth drivers (Barro and Sala-i-Martin 1995; Sachs and Warner 1997), such relationships may not hold in structurally constrained economies. In ECOWAS, investment produces limited returns when infrastructure deficiencies—such as unreliable electricity—undermine productivity. Similarly, trade liberalization can expose fragile economies to external price shocks and instability, especially where institutional capacity is weak (Abusomwan and Izevbigie 2024; Easterly and Levine 2003; Mahawiya et al. 2022; Mbate 2013). These conditions suggest that investment, trade, and inflation effects on growth depend on structural and institutional factors, calling for a more integrative approach.

This study examines how domestic investment, trade openness, inflation, and electricity access affect economic growth in nine ECOWAS countries between 2000 and 2023. It investigates whether the effects of investment and trade are shaped by structural and macroeconomic conditions through interaction terms capturing electricity access and inflation. Using pooled mean group autoregressive distributed lag (PMG-ARDL) and nonlinear PMG-ARDL (PMG-NARDL) models, the analysis considers both long-run relationships and asymmetric short- and long-run adjustments.

The study advances existing work by (i) introducing interaction terms that account for conditional effects of structural and macroeconomic variables, (ii) applying nonlinear estimation techniques that capture asymmetric growth responses, and (iii) employing updated panel data covering 2000–2023, reflecting recent global shocks and regional dynamics. The findings inform investment, trade, monetary, and infrastructure policy design in West Africa.

2 | Literature Review

2.1 | Theoretical Framework

Economic growth theory increasingly incorporates macroeconomic, structural, and institutional factors that influence capital accumulation and productivity. Neoclassical models emphasize capital deepening and exogenous technological progress, while endogenous growth theories indicate human capital, innovation, and spillovers in sustaining long-run growth (Acemoglu and Robinson 2012; Hausmann et al. 2005). Recent approaches further recognize the importance of infrastructure quality, institutional strength, and macroeconomic stability in developing economies.

Traditional growth frameworks, however, often assume frictionless capital markets, full factor utilization, and minimal structural constraints-conditions rarely met in ECOWAS economies. Persistent infrastructure gaps, weak institutions, and inflation volatility limit the effectiveness of conventional growth inputs, necessitating models that consider structural and policy interactions.

Infrastructural deficits, especially unreliable electricity supply, reduce the productive use of capital. Access to electricity improves firm-level productivity, lowers transaction costs, and enhances capital efficiency. The infrastructure-led growth hypothesis posits that essential services in energy, transport, and communications strengthen private investment productivity, especially in low-income economies (Calderon and Serven 2010). Consequently, the growth impact of domestic investment depends not only on the amount of capital but also on the availability of complementary infrastructure.

Domestic investment expands production capacity, but its effects are contingent on infrastructure, labor absorption, and institutional quality (Dabla-Norris et al. 2016; Mijiyawa 2015). Without adequate capacity, capital accumulation may fail to generate output. Inflation further complicates growth by distorting prices, increasing uncertainty, and discouraging long-term investment. Research suggests threshold effects, where moderate inflation is tolerable, but high inflation undermines capital formation and macroeconomic stability (Seleteng et al. 2013). In open economies, inflation can increase competitiveness and reduce trade benefits. Trade openness is linked to technological diffusion, market expansion, and efficiency, but these benefits depend on institutional readiness, supportive policies, and macroeconomic stability (Dabla-Norris et al. 2016; Rodrik 2017). Unemployment and population trends also shape growth; rapid population growth without sufficient employment can lower per capita income and strain resources (ILO 2020).

This study hypothesizes that the growth effects of domestic investment and trade openness are conditional on electricity access and inflation stability. Interaction terms in linear and nonlinear models test whether infrastructure enhances investment productivity and whether inflation volatility modifies trade effects, capturing asymmetric responses and structural heterogeneity in ECOWAS economies.

2.2 | Empirical Review

Empirical literature on the drivers of economic growth has evolved, covering macroeconomic, structural, and institutional factors across regions. In Africa and ECOWAS, findings vary depending on variables, methods, and periods. This section reviews studies on trade openness, investment, inflation, infrastructure, and institutional quality, emphasizing relevance to ECOWAS. Abendin and Duan (2021) examined the digital economy's role in trade-growth links in 53 African countries (2000–2018), finding trade supports growth when accompanied by digital development. Ngouhouo et al. (2021) analyzed domestic institutions in 36 Sub-Saharan African countries (1996–2017), showing that government effectiveness, regulatory quality, and rule of law enhance trade openness. Hussen (2023) investigated institutional dimensions in 31 Sub-Saharan countries (1991–2015), indicating that investment-promoting, democratic, and regulatory institutions foster growth, while conflict-prevention institutions have limited effect. Olaoye et al. (2022) assessed foreign capital, debt, aid, and FDI in 15 ECOWAS countries (2008–2018), showing external inflows may crowd out government spending and are less effective under weak institutions.

Gyasi et al. (2024) examined exchange rates and global value chain participation in African countries (1990–2018), finding stronger governance reduces exposure to currency fluctuations. Adjei and Kajurová (2022) analyzed consumption determinants in 25 Sub-Saharan African countries (2005–2018), revealing that trade and interest rates reduce consumption, with consumption inertia remaining significant. Abaidoo and

Agyapong (2023) examined governance and financial development in 36 Sub-Saharan countries (1996–2019), finding governance enhances financial development, while macroeconomic volatility weakens it.

Darkwah et al. (2023) studied trade openness-inflation in ECOWAS (1970–2020), finding that openness supports long-run growth but may reduce short-run performance due to import dependence. Okoro et al. (2020) examined regional and non-regional trade effects on ECOWAS growth (2007–2017), showing regional trade supports growth, while non-regional trade does not; domestic investment contributes positively, while unemployment, population growth, and exchange rate depreciation constrain it.

Mamba (2021) investigated open trade policies in ECOWAS, finding growth benefits under strong governance but harm under weak institutions. Aladejare (2019) compared ECOWAS and COMESA, showing ECOWAS growth is driven by macroeconomic factors, while COMESA relies on resource prices. Mamba and Balakin (2023) examined deep regional trade agreements (RTAs) in 11 ECOWAS countries, finding deeper RTAs increase foreign value-added with limited domestic effect. Okunlola et al. (2024) assessed government expenditure in 15 ECOWAS countries (1999–2021), showing spending supports growth when paired with effective corruption control. Abdullahi et al. (2025) analyzed financial development, trade openness, and urbanization (1980–2022), finding strong positive links moderated by institutional factors. Obasaju et al. (2019) studied intermediate tariffs and intraregional exports (2000–2015), showing tariffs are not significant for exports within ECOWAS. Balogun et al. (2024) examined sustainable development in 10 ECOWAS countries (1987–2020), finding poverty undermines long-run sustainability, while human capital supports it; trade has no direct effect but positively moderates the poverty–sustainability relationship.

Despite extensive analysis, most studies treat trade openness, inflation, and investment independently, often neglecting their interaction. In particular, trade–inflation interactions, domestic investment, and electricity access are underexplored. Many prior studies also rely on linear or static methods, which may not capture asymmetric or nonlinear short- and long-run effects. To address these gaps, this study examines the joint and individual effects of domestic investment, trade-inflation interactions, and electricity access on ECOWAS growth (2000–2023). By applying PMG and PMG-NARDL estimators, it captures long-run equilibrium relationships and asymmetric short-run dynamics, integrating updated data from recent global crises, providing a current and policy-relevant assessment.

3 | Methodology

3.1 | Data Source

This study employs annual data covering the period from 2000 to 2023 for nine-member countries of the Economic Community of West African States (ECOWAS). The data set is obtained from the World Development Indicators (WDI) provided by the World Bank. Nigeria, Cabo Verde, and Liberia are excluded from the analysis due to substantial data gaps across key variables. In addition, Mali, Niger, and Burkina Faso are omitted as a result of their recent withdrawal from ECOWAS, which affects the consistency and comparability of their inclusion in a regional study. A detailed description of the variables is in Table 1.

3.2 | Model Specification

Drawing from the endogenous growth theory (Romer 1990) and structuralist perspectives, this study model's economic growth as a function of domestic investment, trade openness, macroeconomic stability, and infrastructure quality. GFCF are proxies for domestic investment, capturing capital accumulation and its contribution to long-run output. Infrastructure quality is represented by ATCOP, an enabler of production, investment utilization, and service delivery. Given that reliable electricity remains a major constraint in many ECOWAS countries, it serves as a proxy for broader infrastructure conditions. TOP reflects external sector dynamics, while inflation captures the macroeconomic environment influencing the efficiency of investment and trade. To account for conditional effects, the model includes two interaction terms. The interaction between TOP and inflation assesses whether price stability modifies the growth effects of trade. Similarly, the interaction between GFCF and ATCOP the complementarity between infrastructure and capital in supporting productivity (Calderon and Serven 2010). The core model is in Equation (1).

TABLE 1 | Variables description.

Variable	Acronyms in the equations	Detail
Gross domestic product per capita growth	GDPPCG	Annual growth rate
Foreign direct investment	FDI	Net inflows % GDP
Gross fixed capital formation	GFCF	% of GDP
Inflation	INFLA	Consumer price index
Unemployment	UNEM	% of the total labor force
Trade openness	TOP	Exports plus imports % of GDP
Population growth rate	POPG	Annual growth %
Access to electricity	ATCOP	% of the population

Source: World Bank 2025 (https://data.worldbank.org/).

$$
\begin{aligned}
GDPPCG_{it} = \alpha &+ \beta_1 GFCF_{it} + \beta_2 TOP_{it} + \beta_3 INFLA_{it} \\
&+ \beta_4 (TOP_{it} \times INFLA_{it}) + \beta_5 ATCOP_{it} \\
&+ \beta_6 (GFCF_{it} \times ATCOP_{it}) + \beta_7 FDI_{it} \\
&+ \beta_8 UNEM_{it} + \beta_9 POPG_{it} + \mu_i + \varepsilon_{it},
\end{aligned} \tag{1}
$$

where

a is representing the constant;

β_1 coefficient associated with GFCF;

β_2 coefficient associated with TOP;

β_3 coefficient associated with inflation;

β_4 coefficient of the interaction term TOP x INFLA;

β_5 coefficient associated with ATCOP;

β_6 coefficient of the interaction term GFCF x ATCOP;

β_7 coefficient associated with FDI;

β_8 coefficient associated with UNEM;

β_9 coefficient associated with POPG;

μ_i is the captures country-specific effects;

ε_{it} is the error term;

Subscript i = country, t = time.

3.3 | Cross-Sectional Dependence Test

To ensure valid panel estimation and avoid biased inference, this study tests for cross-sectional dependence (CSD), which may arise from unobserved common factors or contemporaneous shocks across countries. Given the panel structure ($T = 24$; $N = 9$), the Breusch-Pagan LM test (Breusch and Pagan 1980) is most appropriate, as it is designed for panels where the time dimension exceeds the cross-sectional dimension ($T > N$). To strengthen the robustness of the diagnosis, the Pesaran scaled LM test (Pesaran et al. 2008) and the Pesaran CD test (Pesaran et al. 2004) are also applied. While these tests are generally used in panels with larger N, they remain valid and informative in small-to-moderate N condition. Applying all three tests provides a comprehensive, cross-validated assessment of CSD, which guides the selection of appropriate econometric estimators. The Breusch–Pagan LM test statistic is in Equation (2).

$$
LM = \sum_{i=1}^{N-1} \sum_{j=i+1}^{N} T_{ij} \hat{\rho}_{ij}^2 \sim \chi^2_{\frac{N(N-1)}{2}}, \tag{2}
$$

where LM is the test statistic, T_{ij} is the time overlap between cross-sections i and j, and $\hat{\rho}_{ij}$ is the sample correlation coefficient between cross-sections i and j. The LM follows a chi-square distribution with $\frac{N(N-1)}{2}$ degrees of freedom. The cross-sectional dependence (CD) test statistic is in Equation (3).

$$
CD = \sqrt{\frac{2T}{N(N-1)}} \sum_{i=1}^{N-1} \sum_{j=i+1}^{N} \hat{\rho}_{ij} \xrightarrow{d} N(0,1), \tag{3}
$$

where CD indicates the cross-sectional dependence statistic, T is the time, N is the number of cross-sections and $\hat{\rho}_{ij}$ is the sample correlation coefficient between cross-sections i and j. The bias-corrected Pesaran LM test is in Equation (4).

$$
LM_{adj} = \sqrt{\frac{2}{N(N-1)}} \sum_{i=1}^{N-1} \sum_{j=i+1}^{N} \frac{(T-K)\hat{\rho}_{ij}^2 - \mu_{Tij}}{\sqrt{v_{Tij}}} \xrightarrow{d} N(0,1), \tag{4}
$$

where K shows the number of regressors, μ is the bias-corrected mean and v is the variance of T_{ij}.

3.4 | Panel Stationarity Test

Before estimation, the stationarity of panel series is assessed to support the choice of appropriate econometric techniques. Both first-generation panel unit root tests, which assume cross-sectional independence, and conventional time-series tests are applied for robustness. The Levin, Lin, and Chu (LLC) test (Levin et al. 2002) assumes a common unit root process across cross-sections, while the Im, Pesaran, and Shin (IPS) test (Im et al. 2003) allows for individual unit root processes. Additionally, the ADF-Fisher test (Dickey and Fuller 1981) and the PP-Fisher test (Perron 1988) are used as Fisher-type tests that combine individual statistics across countries. These complementary approaches provide a thorough assessment of stationarity under varying assumptions of heterogeneity and dynamic structure. The LLC test, based on the augmented Dickey–Fuller (ADF) regression, is in Equation (5).

$$
\Delta y_{it} = a_i + p y_{i,t-1} + \sum_{j=1}^{p} \theta_{ij} \Delta y_{i,t-j} + \varepsilon_{it}, \tag{5}
$$

Null hypothesis: H_0: $p = 0$ (Unit root in all series);

Alternative hypothesis: H_1: $p < 0$ (all series are stationary).

It pools the data and imposes a common autoregressive parameter p but allows for individual fixed effects a_i and lag dynamics. Unlike LLC, the IPS test allows individual unit root processes, meaning each cross-sectional unit may have a different autoregressive coefficient in Equation (6).

$$
\Delta y_{it} = a_i + p y_{i,t-1} + \sum_{j=1}^{pi} \theta_{ij} \Delta y_{i,t-j} + \varepsilon_{it} \tag{6}
$$

Null hypothesis: H_0: $pi = 0 \;\; \forall\, i$ (Unit root in all series)

Alternative hypothesis: H_1: $p < 0$ for some i

The IPS test calculates the average of the individual ADF statistics and compares it to critical values derived under the null. The ADF-Fisher test is based on combining the p-values of individual ADF unit root tests using Fisher's chi-squared method in Equation (7).

$$\chi^2 = -2\sum_{i=1}^{N} \ln\,(pi), \tag{7}$$

where pi is the p-value from the ADF test for unit i. Under the null hypothesis of unit root, χ^2 follows a chi-square distribution with $2N$ degrees of freedom. Similar to the ADF-Fisher test, but it uses the Phillips–Perron (PP) test statistics from each cross-sectional unit. The PP test is non-parametric and adjusts for serial correlation and heteroskedasticity in the error term in Equation (8).

$$\chi^2 = -2\sum_{i=1}^{N} \ln\,(P_i^{pp}). \tag{8}$$

The Fisher statistic follows a chi-square distribution under the null of non-stationarity.

3.5 | Panel Cointegration Test

To examine the existence of a long-run equilibrium relationship among variables, panel cointegration tests are conducted. Two widely used first-generation tests are employed: the Kao (1999) test and the Pedroni (2004) test. Both extend the Engle–Granger methodology to panel data but differ in handling heterogeneity and residual dynamics. The Kao test assumes homogeneity in the cointegrating vector across cross-sections and examines the stationarity of residuals from a pooled regression. In contrast, the Pedroni test allows heterogeneity in intercepts and slope coefficients across countries. The panel regression estimated for the Kao test is in Equation (9).

$$y_{it} = a_i + \beta_1 x_{1it} + \beta_2 x_{2it} + \ldots + \beta_k x_{kit} + \varepsilon_{it}. \tag{9}$$

Then, it tests the null hypothesis of no cointegration by checking whether the residuals ε_{it} are nonstationary using a panel ADF-type test in Equation (10).

$$\Delta\varepsilon_{it} = p\varepsilon_{i,t-1} + \sum_{j=1}^{p} \theta_j \Delta\varepsilon_{i,t-j} + \varepsilon_{it} \tag{10}$$

H_0: $p = 0$ (no cointegration);

H_1: $p < 0$ (cointegration exists).

Equation (11) estimates the Pedroni test.

$$y_{it} = a_i + \delta_i t + \beta_{1it} x_{1it} + \beta_{2it} x_{2it} + \ldots + \beta_{kit} x_{kit} + \varepsilon_{it}. \tag{11}$$

The test involves checking the stationarity of the residuals ε_{it}.

3.6 | Panel Causality Test

To assess the direction of causality among the variables across countries, this study applies the panel Granger causality test developed by Dumitrescu and Hurlin (2012). This method extends the traditional Granger causality framework to heterogeneous panel data, allowing for country-specific causal relationships while maintaining the panel structure. The Dumitrescu–Hurlin test specification is in Equation (12).

$$y_{i,t} = \sum_{k=1}^{K} a_i^{(k)} y_{i,t-k} + \sum_{k=1}^{K} \beta_i^{(k)} x_{i,t-k} + \varepsilon_{i,t} \tag{12}$$

The K represents the lag length. However, the panel for the test is a balanced panel. $a_i^{(k)}$ denotes the autoregressive parameter, and $\beta_i^{(k)}$ represents the regression coefficient, which may vary across entities (i). The panel-level Wald statistic is in Equation (13).

$$W_{N,T}^{Hnc} = \frac{1}{N}\sum_{i=1}^{N} W_{i,T}. \tag{13}$$

The $W_{N,T}^{Hnc}$ represents the Wald statistic and N is the number of cross-sections. The test calculates individual Wald statistics for each unit and averages them to produce a standardized Z-bar statistic. It is valid under heterogeneity and appropriate for unbalanced panels with moderate time dimensions. The null and alternative hypotheses for the panel are stated as follows:

H_0: X does not Granger-cause Y for any unit in the panel.

H_1: X Granger-causes Y for at least one unit in the panel.

3.7 | Estimation Technique

To estimate both long-run and short-run relationships while accounting for dynamic heterogeneity across countries, this study employs the pooled mean group (PMG) estimator (Pesaran et al. 1999). The PMG estimator is suitable for panels where the time dimension exceeds the cross-sectional dimension ($T = 24$, $N = 9$). It constrains long-run coefficients to be identical across countries but allows short-run coefficients, error variances, and intercepts to differ, reflecting that countries may adjust differently in the short term while following a common long-run path. The panel autoregressive distributed lag (ARDL) framework captures both immediate and lagged effects of explanatory variables on economic growth. PMG estimation is valid for variables integrated of order zero [I(0)] or one [I(1)], confirmed through unit root tests, provided none are I(2). This framework also accommodates cointegration, allowing stable estimation of long-run relationships in the presence of mixed stationarity. To explore nonlinearities in the effects of investment, trade, and inflation, the study also applies the nonlinear PMG-ARDL (PMG-NARDL) model (Shin et al. 2014). This model decomposes explanatory variables into positive and negative partial sums, capturing whether increases and decreases in drivers affect growth differently. Interaction terms between domestic investment and electricity access, and between trade openness and inflation, are included to examine conditional effects, assessing whether infrastructure quality enhances investment productivity and whether inflation alters trade's growth impact. The baseline panel ARDL model is presented in Equation (14).

Due to data gaps, Nigeria, Cabo Verde, and Liberia are excluded. Mali, Burkina Faso, and Niger are also excluded because of recent ECOWAS withdrawal, which affects regional comparability. While these exclusions maintain panel consistency, they may introduce modest sample selection bias and limit representativeness for the entire ECOWAS region.

$$y_{it} = a_i + \sum_{j=1}^{k} \beta_{ij} y_{it-j} + \sum_{j=1}^{k} \delta_{ij} X_{it-j} + \mu_i + \varepsilon_{it} \tag{14}$$

Where y_{it} is the dependent variable, a_i denotes the unit-specific intercept, β_{ij} is the lag coefficient of the dependent variable y_{it-j}, X_{it-j} represents the independent variables with δ_{ij} as their corresponding coefficients, μ_i captures the fixed effects and ε_{it} indicates the error term in the estimated model in the PMG-ARDL. This can be reparameterized into an error correction in Equation (15).

$$\Delta y_{it} = \lambda_i (y_{i,t-1} - \theta_i x_{i,t-1}) + \sum_{j=1}^{p-1} \psi_{ij} \Delta y_{i,t-j} + \sum_{j=0}^{q-1} \delta_{ij} \Delta x_{i,t-j} + \mu_i + \varepsilon_{it}, \tag{15}$$

where

λ_i is the speed of adjustment toward long-run equilibrium,

θ_i is the long-run coefficient (constrained to be homogeneous under PMG),

Δ indicates first differences,

μ_i captures fixed effects.

The long-run nonlinear panel ARDL model is in Equation (16).

$$y_{it} = c + \lambda\left(y_{it-1} - \theta^{+} X^{+}_{it-1} - \theta^{-} X^{-}_{it-1}\right) + \sum_{p=1}^{p} a_p \Delta y_{it-p} + \sum_{q=0}^{Q} \left(\beta^{+}_{q} \Delta X^{+}_{it-q} + \beta^{-}_{q} \Delta X^{-}_{it-q}\right) + \varepsilon_{it} \tag{16}$$

Where X^{+}_{it} and X^{-}_{it} represent the positive and negative changes in the explanatory variables capturing asymmetry. The parameters $\theta^{+}$and θ^{-} denote the long-run coefficients for positive and negative shocks, respectively.

4 | Results

Table 2 presents descriptive statistics for the selected variables. GDPPCG shows both periods of strong expansion and sharp contraction, with the distribution skewed toward lower values. ATCOP is generally high but exhibits wide variation, reflecting disparities in population coverage. FDI includes several extreme values, concentrated at the upper end. GFCF shows a more clustered distribution with occasional spikes, indicating variable investment activity. INFLA frequently reaches increased levels, with a tendency toward higher values over the sample period. POPG is relatively stable, though some unusually high rates occur. TOP is generally high, with several extreme observations. UNEM remains modest but occasionally rises to elevated levels.

The correlation matrix in Table 3 shows mostly weak to moderate relationships among the variables. GDPPCG has weak positive links with FDI, GFCF, and TOP, minimal ties with ATCOP and INFLA, and a slight negative link with UNEM. ATCOP is positively related to GFCF and TOP, suggesting that better electricity access coincides with greater investment and trade. FDI is weakly positive with most variables but slightly negative with POPG, and aligns most closely with UNEM and GFCF. GFCF is positively associated with ATCOP and TOP, but negative with INFLA, POPG, and UNEM, indicating stability and lower unemployment. INFLA correlates positively with FDI, TOP, and UNEM, but negatively with GFCF and POPG. POPG is mainly negative, especially with ATCOP, GFCF, and TOP. TOP is positive with FDI, GFCF, and ATCOP, while

TABLE 2 | Descriptive statistics.

	GDPPCG	ATCOP	FDI	GFCF	INFLA	POPG	TOP	UNEM
Mean	1.702	40.73	3.073	19.01	7.587	2.570	57.18	4.208
Median	2.197	39.75	2.087	18.77	4.661	2.521	54.79	3.730
Maximum	19.43	89.50	20.72	52.41	47.64	5.905	116.0	10.45
Minimum	−22.31	1.100	−2.574	1.096	−3.502	1.309	22.97	0.690
Std. Dev.	3.865	20.31	3.313	6.520	8.871	0.444	17.225	2.245
Skewness	−0.778	0.117	2.199	0.707	2.007	3.717	1.061	1.127
Kurtosis	13.17	2.250	9.657	6.150	7.353	28.87	4.732	4.060
Sum	367.8	8799	663.8	4107.5	1638.9	555.1	12352	908.9
Sum Sq. Dev.	3212	88760	2360	9140	16920	42.42	63793	1085
Observation	216	216	216	216	216	216	216	216

Source: Authors calculations.

TABLE 3 | Correlation matrix of the variables (minimum significant correlation = 0.134; T = 216, a = 0.05).

GDPPCG	1							
ATCOP	0.084	1						
FDI	0.178	0.153	1					
GFCF	0.125	0.391	0.292	1				
INFLA	0.057	−0.040	0.142	−0.131	1			
POPG	0.001	−0.187	−0.092	−0.144	−0.221	1		
TOP	0.165	0.373	0.211	0.364	0.198	−0.196	1	
UNEM	−0.136	0.093	0.244	−0.194	0.259	0.002	0.204	1

Source: Authors calculations.

TABLE 4 | Results of the cross-sectional dependence and slope of homogeneity test.

Test	Statistic	*p* value
Breusch-Pagan LM	36.189	0.459
Pesaran CD	1.154	0.248
Pesaran Scaled LM	0.022	0.982
Slope of homogeneity		
Delta	2.020	0.043
Delta adj.	2.555	0.011

Source: Authors calculations.

UNEM is mildly positive with INFLA, FDI, and TOP, but negative with GFCF.

4.1 | Cross-Sectional Dependence Test Results

Table 4 shows no strong evidence of cross-sectional dependence across countries. All three tests-Pesaran CD, Breusch–Pagan LM, and Pesaran Scaled LM-produce high *p*-values, indicating that residuals across cross-sectional units are not significantly correlated. However, slope homogeneity tests reveal that coefficients differ across countries. Both the Delta and adjusted Delta statistics are statistically significant, confirming heterogeneity in the relationships among variables across ECOWAS member states.

4.2 | Panel Unit Root Test Results

Table 5 shows that most variables are nonstationary at level but become stationary after first differencing, indicating they are integrated of order one [I (1)]. At level, GDPPCG, ATCOP, POPG, and FDI fail to reject the null of a unit root under most tests. GFCF and UNEM produce mixed results, with some tests indicating stationarity but not consistently. TOP appears weakly stationary under the LLC test, but this is not confirmed by other tests. After first differencing, all variables reject the unit root null hypothesis across LLC, IPS, ADF, and PP tests at the 1% significance level, confirming stationarity in first differences. No series is integrated of order two [I (2)], satisfying the requirements for PMG and PMG-NARDL estimation, which allow I (0), I (1), or a mix of both, provided no variable is I (2) (Pesaran et al. 1999; Shin et al. 2014). These integration properties are consistent with prior PMG-ARDL applications. For example, Azmi et al. (2023), Iorember et al. (2022), and Shaari et al. (2020) employed PMG-ARDL with variables found to be I (1), confirming the methodological validity of this approach. Thus, the data set aligns with established empirical practice.

4.3 | Panel Cointegration Results

Table 6 shows the results of the Kao cointegration test. All statistics strongly reject the null hypothesis of no cointegration. The modified Dickey–Fuller *t*, Dickey–Fuller *t*, and augmented Dickey–Fuller *t* statistics, along with their unadjusted forms, are all substantially negative, confirming the existence of a long-run equilibrium relationship among the variables.

Table 7 presents the Pedroni cointegration test results, which confirm the existence of a long-run relationship among the variables. The modified variance ratio, Phillips–Perron *t*, and augmented Dickey–Fuller statistics are all substantially negative. Although the modified Phillips–Perron *t* statistic is positive, it still supports the presence of cointegration. These results indicate a stable long-run equilibrium among the variables.

4.4 | PMG-ARDL and PMG-NARDL Estimated Results

Table 8 shows the PMG-ARDL results. In the long run, GFCF positively and significantly affects economic growth in ECOWAS. However, the interaction between GFCF and ATCOP (GFCFAE) is negative, suggesting that investment's effect weakens when electricity access increases, likely due to infrastructure quality or sectoral allocation issues. The trade-inflation interaction (TDINFLA) is positive, indicating that higher trade openness reduces inflation's negative effect on growth. Trade openness alone has a negative long-run association, reflecting ECOWAS economies' import dependence and limited export capacity. Unemployment shows a positive long-run coefficient, likely due to growth in capital-intensive sectors with low labor absorption, while short-run unemployment is negative, consistent with theory. Population growth negatively

TABLE 5 | Panel unit root test on the variables.

Variable	Level	LLC	IPS	ADF	PP
GDPPCG	0	−0.243	2.402	8.271	9.260
ΔGDPPCG	1	−9.768***	−7.725***	81.919***	101.370***
GFCF	0	−2.663***	−1.190	29.398**	22.687
ΔGFCF	1	−9.523***	−8.412***	90.318***	248.143***
FDI	0	0.701	−0.281	34.801**	32.923**
ΔFDI	1	−6.021***	−8.099***	97.012***	488.954***
ATCOP	0	−0.624	3.597	11.461	0.861
ΔATCOP	1	−16.143***	−15.876***	189.760***	830.110***
POPG	0	5.143	−0.004	21.344	11.221
ΔPOPG	1	−6.368***	−8.554***	130.841***	121.444***
TOP	0	−1.992**	−1.164	24.253	27.236*
ΔTOP	1	−11.121***	−12.205***	143.762***	177.079***
UNEM	0	−1.827**	−1.109	21.702	20.451
ΔUNEM	1	−7.408***	−7.299***	87.575***	119.123***

Note: ***, 1%, **5%, * 10%, significance level.
Source: Authors calculations.

TABLE 6 | Kao cointegration test.

Kao cointegration	Statistic	*p* value
modified Dickey–fuller *t*	−15.216	0.000
Dickey Fuller *t*	−12.068	0.000
Augmented Dickey–fuller t	−8.500	0.000
Unadjusted modified Dickey–fuller *t*	−17.476	0.000
Unadjusted Dickey–fuller t	−12.231	0.000

Source: Authors calculations.

TABLE 7 | Pedroni cointegration test.

Test	Statistic	*p* value
Modified variance ratio	−3.571	0.000
Modified Phillips–Perron *t*	1.878	0.030
Phillips–Perron *t*	−6.047	0.000
Augmented Dickey–fuller *t*	−6.493	0.000

Source: Authors calculations.

affects short-run growth, showing strain on capital and services. The error correction term (ECT) is negative and significant (−0.6148), indicating that 61.5% of deviations from the long-run path adjust within one period, confirming stability. Figure 1 summarizes these results.

Table 9 presents the PMG-NARDL results, which separate positive and negative changes to capture asymmetric growth effects. Long-run results show that negative shocks to FDI are positively associated with growth, suggesting that reduced reliance on foreign capital may encourage domestic investment and improve resource efficiency. GFCF has a negative long-run effect for both positive and negative changes, indicating that fluctuations in capital formation do not immediately translate into higher output, possibly due to inefficiencies or misallocation. In the short run, positive investment shocks have a favorable but temporary impact. TOP displays clear asymmetry: reductions harm growth, while increases support it, showing the costs of inward-looking policies and the benefits of liberalization. Inflation also behaves asymmetrically: declines enhance long-run growth, while increases have no significant effect. Short-run disinflation continues to promote growth, emphasizing the role of price stability. POPG shows dual effects: long-run changes positively relate to growth, reflecting demographic adjustments, whereas short-run increases reduce output, likely due to immediate pressures on infrastructure and services. The error correction term (ECT) is negative and significant (−0.687), implying that 68.7% of deviations from the long-run path adjust within one period, confirming a stable equilibrium. Figure 2 summarizes these results.

4.5 | Panel Causality Test Results

The causality test results in Table 10 reveals the directional relationships among the variables. Unidirectional causality runs from GDPPCG to ATCOP, suggesting that higher per capita output supports greater infrastructure investment and energy availability in ECOWAS countries. GDPPCG also Granger-causes UNEM, indicating that output expansion affects labor market conditions through job creation or changes in labor force participation. GFCF exhibits unidirectional causality toward economic growth, confirming that GFCF contributes to output expansion over time and supporting the role of capital accumulation as a growth driver. Additionally, POPG and GDPPCG display bidirectional causality. This reciprocal relationship implies that demographic expansion influences output levels, while growth affects population dynamics through mechanisms such as fertility decisions, migration, and improvements in health and education services.

TABLE 8 | Estimated coefficients from the PMG-ARDL model.

Long run	Coefficient	Std. Error	*t*-Statistic	*p* value
ATCOP	0.103	0.056	1.827	0.070
FDI	0.026	0.139	0.187	0.851
GFCF	0.890	0.132	6.732	0.000
GFCFAE	−0.010	0.002	−4.593	0.000
INFLA	−0.360	0.210	−1.711	0.090
POPG	1.245	1.048	1.187	0.237
TDINFLA	0.011	0.004	2.876	0.005
TOP	−0.115	0.029	−3.915	0.000
UNEM	0.571	0.268	2.126	0.036
Constant	−7.628	1.878	−4.061	0.000
Short-run				
ECT (−1)	−0.615	0.150	−4.097	0.000
ΔGDPPCG (−1)	−0.259	0.158	−1.635	0.105
ΔATCOP	−0.026	0.239	−0.110	0.912
ΔFDI	0.380	0.560	0.678	0.499
ΔGFCF	−0.580	0.552	−1.050	0.295
ΔGFCFAE	−0.003	0.019	−0.179	0.858
ΔINFLA	−0.331	0.870	−0.381	0.703
ΔPOPG	−16.14	5.167	−3.125	0.002
ΔTDINFLA	0.003	0.014	0.188	0.850
ΔTOP	0.102	0.088	1.157	0.250
ΔUNEM	−2.866	1.497	−1.913	0.058

Source: Authors calculations.

4.6 | Discussion

The empirical results confirm that domestic investment significantly contributes to economic growth in ECOWAS countries. PMG-ARDL estimates show a positive long-run relationship between gross fixed capital formation and income growth. However, the interaction between domestic investment and electricity access suggests that the positive effect of investment weakens as electricity coverage expands, indicating that improvements in electricity availability do not automatically enhance capital productivity if inefficiencies in energy supply persist (Aladejare 2019; Calderon and Serven 2010). For policymakers, these findings imply that investment policies should be complemented by efforts to improve the reliability, efficiency, and targeting of energy infrastructure. The interaction between trade openness and inflation indicates that inflation moderates the growth effects of trade openness. A positive coefficient on the interaction term suggests that trade integration can offset some negative effects of domestic price instability (Olaoye and Aderajo 2020). However, the negative long-run coefficient on trade openness in the PMG-ARDL model indicates that ECOWAS economies may not fully benefit from liberalization due to structural weaknesses, including import dependence, limited industrial competitiveness, and narrow export bases. These findings emphasize the need for policies that combine trade liberalization with macroeconomic stabilization and improvements in supply chains.

PMG-NARDL results reveal asymmetric effects. Increases in trade openness support growth, while reductions lower income, indicating the importance of maintaining open trade regimes in small, import-reliant economies (Okoro et al. 2020; Rodrik 2017). Disinflation supports growth, whereas inflation increases exert weaker adverse effects (Darkwah et al. 2023; Seleteng et al. 2013). Declines in FDI are associated with stronger growth, suggesting that domestic resource mobilization may compensate for reduced foreign inflows, where institutional constraints limit the efficiency of external investment (Olaoye et al. 2022). Unemployment and population growth show mixed effects. Unemployment exhibits both positive and negative associations with growth depending on the model, reflecting labor market rigidities, dual-sector dynamics, and informal sector activity. Population growth demonstrates a nonlinear relationship with income: both increases and decreases can be associated with growth depending on the period, reflecting demographic transitions, labor force participation, and household demand shifts. Panel causality results reinforce the role of domestic investment as a direct driver of income growth. Additionally, economic growth contributes to improvements in electricity access and influences unemployment dynamics. The bidirectional causality between growth and population growth shows the two-way interaction between demographic change and

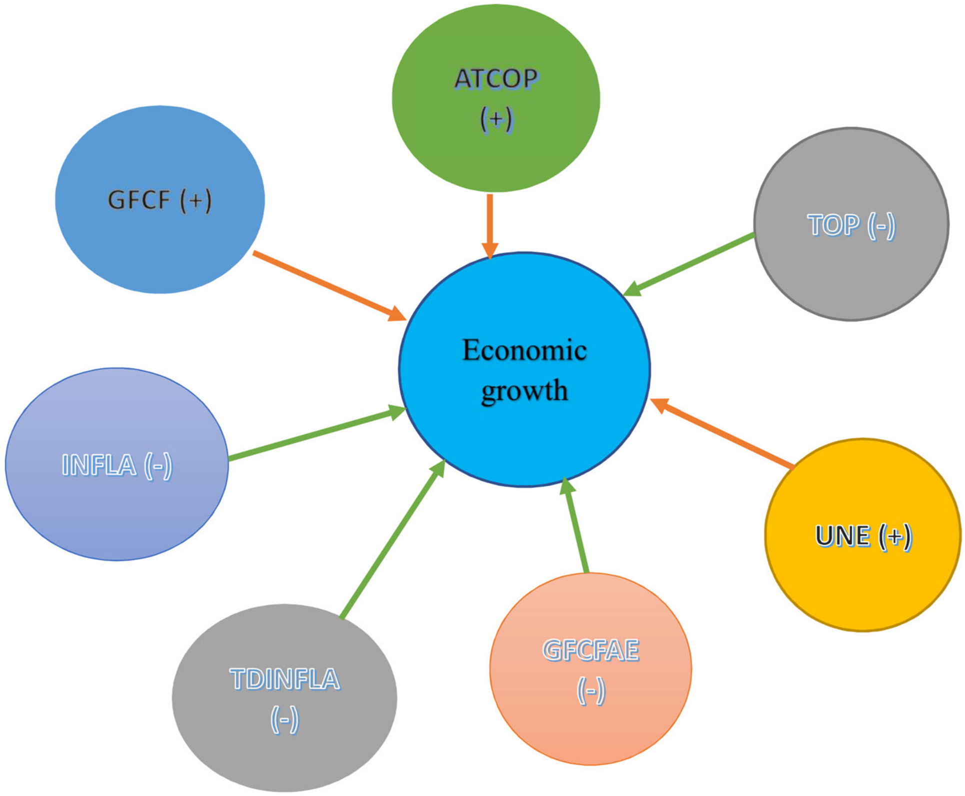

FIGURE 1 | Summary of the long-run coefficients of the PMG estimated model.

economic performance. These results underline the need for integrated policies that simultaneously address investment, infrastructure, labor markets, and demographic planning.

5 | Conclusion and Policy Implications

This study examined the effects of domestic investment, trade openness, inflation, and electricity access on income growth in ECOWAS countries from 2000 to 2023. Using PMG-ARDL and PMG-NARDL estimators, the results show that domestic investment positively affects growth, but its effectiveness declines when combined with higher electricity access, indicating infrastructure constraints. Trade openness exhibits both linear and nonlinear effects: linear estimates suggest higher openness is associated with lower income, whereas nonlinear results indicate that increases in openness promote growth, while reductions constrain income. Inflation has asymmetric effects, with disinflation supporting growth, while moderate increases produce weaker adverse impacts. The interaction between trade openness and inflation suggests that trade integration can partly offset inflationary pressures. FDI shows an asymmetric pattern, where declines in foreign inflows are associated with stronger growth, emphasizing the importance of domestic resource mobilization and potential inefficiencies in external capital allocation. The effects of unemployment and population growth vary across models, reflecting complex labor market structures and demographic dynamics.

Policy implications are clear. Strengthening electricity infrastructure is essential to enhance the growth impact of investment, through targeted reforms, renewable energy development, improved grid reliability, and rural electrification. ECOWAS could benefit from regional coordination, drawing on examples such as the Eastern Africa Power Pool, which has improved reliability and private sector participation. Maintaining growth-supportive macroeconomic conditions requires disinflationary policies and inflation-targeting frameworks, supported by regionally coordinated fiscal and monetary surveillance, as practiced under the West African Economic and Monetary Union (WAEMU) convergence framework. Trade policy should preserve openness while building domestic production capacity, focusing on industrial upgrading and export diversification. Regional initiatives, such as harmonizing customs procedures and improving transport corridors, can strengthen the benefits of trade integration; the ASEAN Single Window offers a replicable model for ECOWAS under the African Continental Free Trade Area (AfCFTA). Labor market policies that promote technical education, labor mobility, and job quality are critical for absorbing demographic pressures. Investment in vocational training aligned with industrial priorities can improve workforce productivity. Coordinated reforms across investment, infrastructure, trade, and macroeconomic policy are more effective than fragmented national efforts in promoting sustained growth in ECOWAS.

5.1 | Limitations and Future Research

This study relies on annual panel data from nine ECOWAS countries due to data availability, excluding others such as Cabo Verde, Liberia, and Nigeria. This selection may limit the generalizability of the findings to the entire region. The analysis focuses on selected macroeconomic and structural variables-domestic investment, trade openness, inflation, and electricity

TABLE 9 | Estimated coefficients from the PMG-NARDL model.

Long run	Coefficient	Std. Error	*t*-Statistic	*p* value
FDI^{-}	0.473	0.090	5.258	0.000
FDI^{+}	0.041	0.095	0.437	0.662
$GFCF^{-}$	−0.415	0.096	−4.295	0.000
$GFCF^{+}$	−0.587	0.115	−5.096	0.000
TOP^{-}	−0.263	0.035	−7.411	0.000
TOP^{+}	0.179	0.031	5.739	0.000
$INFLA^{-}$	0.221	0.052	4.198	0.000
$INFLA^{+}$	−0.049	0.038	−1.285	0.200
$POPG^{-}$	4.323	0.609	7.088	0.000
$POPG^{+}$	5.411	0.625	8.657	0.000
Constant	0.666	0.411	1.620	0.106
Short-run				
ECT (−1)	−0.687	0.275	−2.495	0.013
ΔGDPPCG (−1)	−0.050	0.136	−0.366	0.714
ΔFDI^{-}	1.790	1.482	1.208	0.228
$\Delta GFCF^{-}$	0.726	0.450	1.612	0.108
$\Delta GFCF^{+}$	0.202	0.113	1.782	0.076
ΔTOP^{-}	0.365	0.259	1.408	0.160
$\Delta INFLA^{-}$	−0.574	0.293	−1.952	0.052
$\Delta POPG^{-}$	−6.584	6.705	−0.981	0.327
$\Delta POPG^{+}$	−37.04	15.72	−2.356	0.019

Source: Authors calculations.

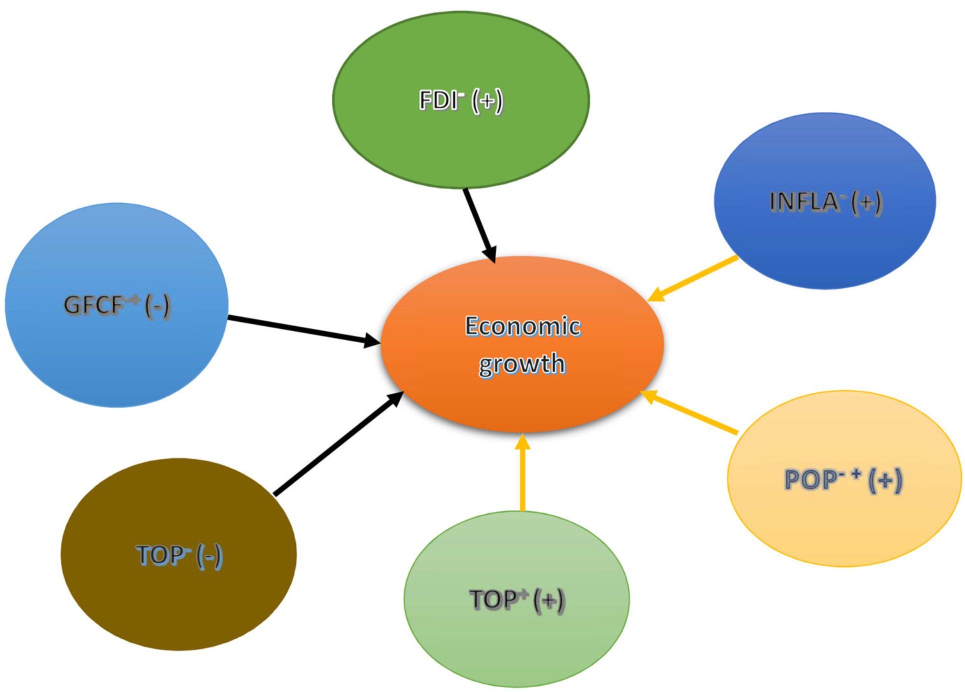

FIGURE 2 | Summary of the long-run coefficients of the PMG-NARDL estimated model.

TABLE 10 | Pairwise Dumitrescu Hurlin panel causality test.

Null Hypothesis	W-Stat	Zbar-Stat.	*p* value	Conclusion
ATCOP ↛ GDPPCG	3.693	0.165	0.868	None
GDPPCG ↛ ATCOP	7.478	3.410	0.001	Unidirectional
FDI ↛ GDPPCG	3.755	0.218	0.827	None
GDPPCG ↛ FDI	3.070	-0.367	0.713	None
GFCF ↛ GDPPCG	6.376	2.465	0.013	Unidirectional
GDPPCG ↛ GFCF	3.423	-0.065	0.947	None
INFLA ↛ GDPPCG	3.745	0.210	0.833	None
GDPPCG ↛ INFLA	2.454	-0.896	0.370	None
POPG ↛ GDPPCG	6.663	2.711	0.006	Bidirectional
GDPPCG ↛ POPG	6.767	2.800	0.005	Bidirectional
TOP ↛ GDPPCG	3.789	0.248	0.804	None
GDPPCG ↛ TOP	4.265	0.655	0.511	None
UNEM ↛ GDPPCG	4.043	0.466	0.641	None
GDPPCG ↛ UNEM	6.206	2.320	0.020	Unidirectional

Source: Authors calculations.

access-while other relevant factors, including institutional quality, fiscal dynamics, and sectoral productivity, were not included. Using country-level aggregate data may also mask subnational or sector-specific variations that influence economic performance. Future research could address these gaps by incorporating institutional indicators, such as governance quality or regulatory efficiency, to assess their moderating effects on trade, investment, and inflation-growth dynamics. Additionally, given the conditional impacts of infrastructure and inflation observed in this study, further work might explore how sectoral characteristics interact with macroeconomic policies to shape long-term development outcomes in ECOWAS.

Acknowledgments

Open access publishing facilitated by Mendelova univerzita v Brne, as part of the Wiley - CzechELib agreement.

Ethics Statement

The authors have nothing to report.

Consent

All authors have read and agreed to the publication of the manuscript.

Conflicts of Interest

The authors declare no conflicts of interest.

Data Availability Statement

Data will be made available upon request from the corresponding author.

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