Agriculture and Rural Infrastructure as Drivers of Sustainable Development in Algeria (2000–2023)

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Summary: This study analyzes the joint role of agricultural activity and rural infrastructure in promoting economic growth in Algeria during the period 2000–2023, in the context of the country's heavy dependence on hydrocarbon revenues, limited diversification, and persistent regional disparities. Using annual data from the World Bank, the research applies the Autoregressive Distributed Lag (ARDL) model to examine both short- and long-run relationships between real GDP growth, agricultural value added, agricultural value-added growth, rural electrification, and the rural population share. Stationarity of the time series was tested through the Augmented Dickey-Fuller (ADF) and Phillips-Perron (PP) tests, while long-run cointegration was verified using the Bounds Test. The findings reveal a strong long-run equilibrium relationship among the variables, with an F-statistic value of 135.36 exceeding all critical bounds, confirming the existence of cointegration. The error correction coefficient (ECT = –0.303, $p < 0.01$) indicates that about 30% of short-run disequilibrium is corrected annually. Agricultural value added exerts a positive but fluctuating long-term effect on growth, rural electrification shows an initially negative yet delayed positive impact due to infrastructure adaptation costs, and the rural population share demonstrates a nonlinear influence that alternates between supportive and restrictive effects depending on structural conditions. Overall, the study concludes that agriculture and rural infrastructure constitute essential pillars for sustainable economic growth in Algeria. Strengthening rural investment, enhancing technical support for farmers, and expanding agricultural financing are key policy measures to transform rural regions into dynamic engines of inclusive and resilient development.

Keywords: Economic Growth, Agricultural Sector, Rural Areas, ARDL Model, Rural Infrastructure

Jel Classification Codes : O13 ; Q10 ; R11 ; C32 ; O18

I-Introduction

Economic growth stands as one of the most vital indicators of a nation's ability to expand its productive capacity and improve living standards. For developing economies such as Algeria, achieving sustainable and inclusive growth remains a pressing challenge, particularly amid recurrent macroeconomic shocks and structural imbalances. Algeria's economic performance over the past two decades has been characterized by high dependency on hydrocarbons, fluctuating fiscal revenues, and uneven territorial development between coastal, urban, and rural regions. While government strategies have emphasized diversification, the contribution of non-hydrocarbon sectors especially agriculture has not yet reached its potential.

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Agriculture occupies a central position in the economic structure of Algeria, both as a provider of food security and as a key source of employment and income in rural areas. Despite

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abundant natural resources, diverse climates, and significant labor reserves, rural Algeria continues to face limited infrastructure, weak institutional support, and constrained investment flows. These constraints hinder the integration of rural regions into national economic dynamics and contribute to persistent spatial inequality. Strengthening rural infrastructure and revitalizing agricultural activity could therefore serve as a strategic lever for promoting balanced and resilient economic growth.

However, a critical research gap persists in the Algerian and broader North African literature: most empirical studies have either examined agriculture's impact on growth in aggregate terms, neglecting the rural dimension, or focused solely on sectoral productivity without addressing the role of infrastructure and demographic factors that shape rural economic performance. Few analyses have simultaneously explored how rural agricultural activity and infrastructural access interact to influence economic growth using robust econometric techniques over an extended period.

This study seeks to fill this gap by applying the Autoregressive Distributed Lag (ARDL) model to evaluate the relationship between Algeria's economic growth, agricultural performance, and rural infrastructure from 2000 to 2023. Unlike previous works, it integrates key rural indicators such as electricity access and rural population share into the growth framework, offering a more comprehensive understanding of how rural development and agricultural productivity jointly contribute to national growth. The study's added value lies in providing both a theoretical and empirical reassessment of Algeria's rural economy, supported by time-series evidence that can inform targeted policy measures aimed at economic diversification, spatial equity, and long-term sustainability.

Research Problem:

Although the agricultural sector is increasingly recognized in economic literature as a cornerstone of sustainable economic growth particularly within rural contexts the Algerian reality reveals a limited contribution of rural agricultural activity to overall economic development, especially when compared to the country's substantial natural and demographic potential. Despite hosting a significant portion of the population and possessing diverse agricultural resources, Algeria's rural regions continue to face chronic challenges such as low investment levels, weak productivity, and limited integration with other economic sectors.

In light of mounting challenges such as volatile hydrocarbon prices and the growing imperative to diversify sources of growth the key question arises : To what extent can agricultural activity in rural areas effectively support economic growth and contribute to balanced and inclusive territorial development ?

Accordingly, the central research question can be articulated as follows :

To what extent can rural agricultural activity contribute to enhancing economic growth in Algeria ?

Hypothesis:

Rural agricultural activity plays a positive and effective role in fostering economic growth in Algeria by increasing value-added output, improving food security, and generating employment opportunities—provided that targeted support and investment policies are in place to strengthen infrastructure and boost rural agricultural productivity.

II. Previous Studies

The findings of this study are largely consistent with the theoretical and empirical evidence highlighted in previous literature regarding the pivotal role of the agricultural sector and rural

infrastructure in stimulating economic growth. However, they also reveal the specific features of the Algerian context, where the interaction among these variables remains structurally fragile and the short-term effects are relatively limited.

II.1 As emphasized by Byerlee, De Janvry, and Sadoulet, agricultural productivity growth contributes to economic expansion through two main channels: directly by increasing food supply and indirectly by stimulating agro-linked industries. The present study confirms the presence of such a relationship in Algeria, yet its intensity and stability remain constrained by weak productivity policies and limited sectoral integration. This implies that the classical mechanisms of agricultural-led growth operate in Algeria but within a narrow institutional and technological framework.

II.2 The results also align with Mellor (2017), who argued that agriculture in developing countries can only serve as an effective growth engine under strong national policies that support producers, secure markets, and ensure financial access. In Algeria, the short-run negative impact of rural electrification used as a proxy for infrastructure illustrates the costs and inefficiencies associated with poorly integrated rural energy investments, reflecting a lack of coordination between infrastructure expansion and agricultural utilization.

II.3 Similarly, the findings corroborate Coelli et al. (2005), who highlighted significant productivity gaps in developing countries' agriculture. The pronounced fluctuations in Algeria's agricultural value added confirm the presence of technical inefficiencies and inadequate agricultural extension services, suggesting that the challenge lies not in resource availability but in their efficient and sustainable use.

II.4 Furthermore, in line with Kapuymana (2018), who estimated that each dollar invested in agriculture can yield a total return of approximately $2.70, the results demonstrate that agricultural investment in Algeria has a positive long-term impact on growth. However, this effect is delayed and weakened by structural financing constraints and the limited accessibility of rural credit, resulting in partial or postponed returns. This indicates that Algeria's rural investment environment remains at an early stage of development and requires institutional reform to unlock its full potential.

Unlike several international experiences such as those of Rwanda or Vietnam where rural infrastructure exerts an immediate and visible influence on growth, the Algerian case reveals a lagged and gradual effect. This pattern reflects the fact that infrastructure investments in transport, electricity, and irrigation have not yet translated into tangible productivity gains due to weak institutional coordination and the absence of systematic monitoring and evaluation mechanisms.

In sum, this study enriches the existing literature by demonstrating that the economic effectiveness of agriculture and rural infrastructure is not automatic, but rather contingent upon the maturity of public policies and institutional efficiency. The key difference between Algeria and successful developing economies lies not in the availability of resources but in the strength of governance and the coherence of development policies. Consequently, the Algerian experience underscores that agricultural investment, in the absence of structural institutional reform, remains insufficient to transform rural potential into a genuine driver of inclusive and sustainable economic growth.

III. Economic Growth: Definition, Indicators, and Driving Forces

Economic growth, a cornerstone of macroeconomic theory, denotes the sustained increase in a nation's real output over time, reflecting enhancements in productive capacity. Classical theorists such as Adam Smith (1776) attributed growth to factors like division of labor, capital accumulation, and market expansion. This foundation was later expanded by Solow (1956) through the neoclassical

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growth model, which underscored the critical role of technological progress alongside capital and labor.

In contemporary development discourse, particularly in developing economies, economic growth is viewed as a multidimensional process that transcends quantitative metrics. It encompasses social and institutional development, including education, healthcare, poverty reduction, and social equity (Todaro & Smith, 2020).

Key indicators such as GDP, GDP per capita, and annual growth rates are commonly used to measure economic growth. According to World Bank data (2024), Algeria's annual growth rate ranged between 2% and 4% from 2000 to 2023, influenced by fluctuations in global oil prices and internal economic dynamics.

Growth determinants include capital investment, human capital development, technological innovation, and infrastructure improvement, particularly in transport and energy. When aligned with strategic sectors—agriculture, industry, and services—these elements foster the conditions necessary for sustainable and inclusive economic growth (Barro & Sala-i-Martin, 2004; Bank of Algeria, 2022).

IV. The Agricultural Sector as an Economic Actor in Algeria

The agricultural sector in Algeria plays a strategic role in ensuring food security, generating employment, and promoting rural development. As part of a broader economic diversification strategy away from hydrocarbons, the government has adopted initiatives like the "Agricultural Revival" and "Sustainable Rural Development" programs.

Between 2000 and 2022, agriculture's contribution to GDP rose from 8.5% to 12.4%, reflecting its growing importance (ONS, 2023). In 2022, the sector's value added reached approximately 2,780 billion DZD (over USD 20 billion). It is the second-largest employer, accounting for 21.6% of the labor force, mostly in rural areas (Bouaziz, 2019).

Production performance has been notable, with wheat output exceeding 41 million quintals in 2022—a 14% increase from 2021. Algeria ranks fourth globally in date production, with exports generating USD 110 million in the same year (Ministry of Agriculture, 2023).

Beyond food provision, agriculture is seen as a lever for reducing reliance on imports, which still exceed USD 8 billion annually (Sebbah, 2015). Enhancing local production through smart farming techniques could mitigate the trade deficit.

Nevertheless, the sector faces structural constraints, including limited access to financing—only 5.2% of total bank credit in 2022—and inefficiencies in post-harvest infrastructure. About 32% of agricultural output is lost due to poor logistics and cold chain absence (Kherbash, 2020).

Policy effectiveness depends on tackling regulatory hurdles, improving rural infrastructure, and integrating environmental sustainability into planning (Bouguera, 2020). Agriculture must thus be repositioned as a dynamic economic actor central to Algeria's sustainable development vision, leveraging innovation and closer links between research and practice.

V. Rural Areas as a Driver of Agricultural Growth

Rural areas in Algeria, covering nearly 80% of the national territory and home to roughly one-third of the population, serve as a vital foundation for agricultural development and spatial equity. With

over 70% of rural economic activities linked to agriculture, these regions possess significant untapped potential (Cherbi & Mohamed El Amine, 2021; ONS, 2023).

Although arable land constitutes just 3.2% of the national territory, it can be optimized through sustainable farming and smart irrigation technologies. However, environmental challenges such as recurrent droughts (occurring 42% of the time over two decades) and limited renewable water resources (12 billion m^3/year) pose serious constraints (FAO, 2023; Zenagui, 2010).

Government interventions, including the National Rural Development Program (PNDR) and the Agricultural Development Support Program (PNDA), have supported over 650,000 rural projects and injected 420 billion DZD into agricultural finance and training (Ministry of Agriculture, 2023; Ben Djelloul et al., 2019). These programs aimed to empower rural communities and foster inclusive growth.

Nonetheless, persistent structural limitations hinder rural transformation. Infrastructure remains inadequate—less than 60% of rural villages are connected via paved roads, and access to electricity, clean water, and health services is limited, particularly in mountainous zones. Financial exclusion is also pronounced, with over 45% of rural loan applications denied due to lack of guarantees (IFAD, 2021). Technological adoption remains low, with fewer than 10% of farms using digital tools, leading to poor productivity compared to regional peers (Kermadi et al., 2022).

Unlocking the potential of rural Algeria requires an integrated development framework encompassing agricultural innovation, infrastructure enhancement, expanded insurance mechanisms, and strengthened public-private partnerships. As Bahri (2018) and Laâssas (2021) argue, such an approach could transform rural regions into dynamic engines of food security and economic resilience.

VI. The Relationship Between Agricultural Activity and Economic Growth

Agriculture serves as a cornerstone for economic growth in developing countries by directly contributing to GDP, creating employment, and supporting industrial value chains. Empirical data from the World Bank (2022) indicates that a 1% rise in agricultural output correlates with a 0.5% increase in GDP in low- and middle-income economies, highlighting the sector's macroeconomic significance.

Beyond food provision, agriculture supplies essential raw materials for agro-industries, particularly in food and beverage manufacturing, thereby promoting industrialization and rural-urban employment integration (Timmer, 1991). The case of Rwanda illustrates the potential impact of targeted agricultural investment: the Crop Intensification Program led to an annual agricultural growth rate of 6% and a significant drop in rural poverty from 77% in 2001 to 55% by 2017 (IFAD, 2021).

From an investment perspective, agriculture offers high returns—estimated at $2.70 for every dollar invested—surpassing many other sectors (Norton et al., 2020). Luc Christiaensen (2012) further affirms that agricultural growth is more effective in poverty reduction than growth in non-agricultural sectors, especially in rural areas.

Moreover, recent studies emphasize the role of international development aid in enhancing agricultural productivity and resilience in the face of climate change (Trentinaglia et al., 2023). These insights underscore agriculture's multifaceted value—not only as an engine of economic expansion but also as a catalyst for food security, rural development, gender empowerment, and inclusive growth (Mellor, 2017).

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In conclusion, agriculture represents a strategic lever for sustainable development, particularly in the Global South, where it can bridge socio-economic disparities and promote structural transformation.

VII. Examining the Role of Agricultural Activity in Rural Areas in Promoting Economic Growth in Algeria: An ARDL Model for the Period 2000–2023

This study aims to examine the role of agricultural activity in rural areas in promoting economic growth in Algeria during the period 2000–2023, using the Autoregressive Distributed Lag (ARDL) model. The analysis relies on quantitative data sourced from the World Bank database to construct an econometric model that explores the relationship between the key variables under investigation.

The model includes annual economic growth (GDP growth) as the dependent variable, alongside four independent variables: the annual growth rate of value added in the agriculture, forestry, and fishing sector (Agriculture VA growth); the share of agriculture, forestry, and fishing value added in GDP (Agriculture VA % GDP); the percentage of the rural population with access to electricity (Rural electricity access); and the rural population as a percentage of the total population (Rural population %).

A descriptive analysis of these variables was conducted to identify their characteristics and trends, providing a foundational understanding of the dynamic relationship between agricultural activity and economic growth in Algeria

VII.1. Descriptive Analysis of the Time Series Data for the Variables Under Study

Table (01) : Chronological Overview of Agricultural Economy and Rural Growth Variables in Algeria (2000–2023)

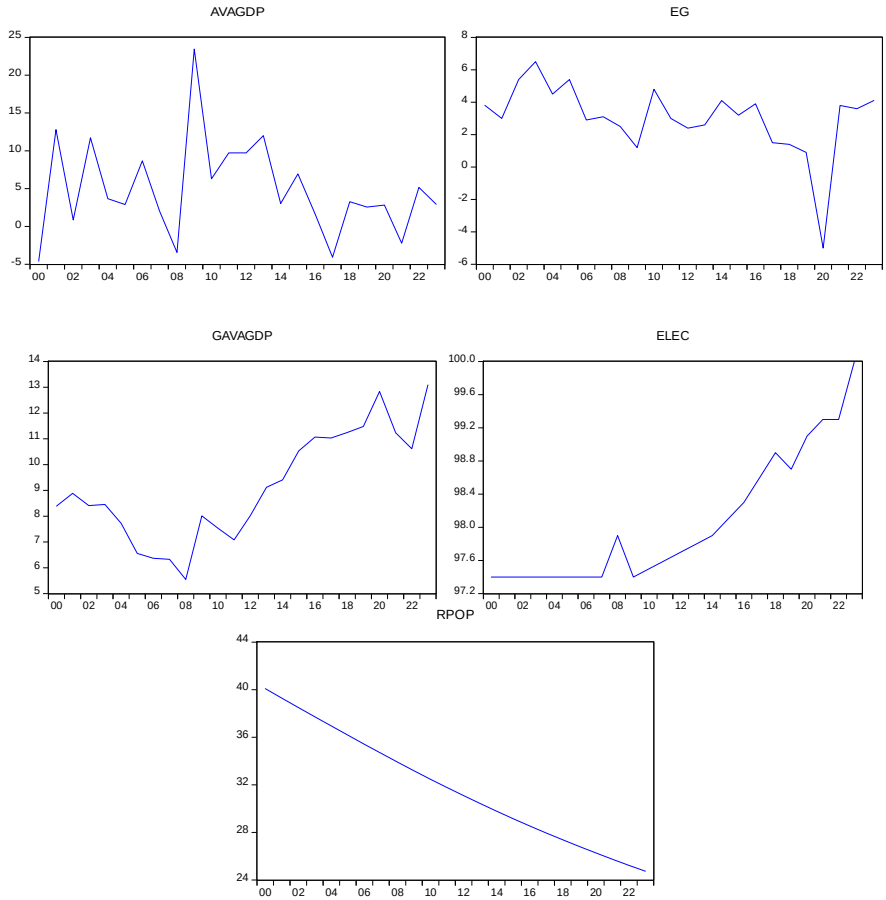
Year	2000	2001	2002	2003	2004	2005	2006	2007
Economic Growth (%)	3.8	3.0	5.4	4.5	6.5	5.4	2.9	3.1
Agriculture, Forestry & Fishing Value Added (% of GDP)	-4.60	12.80	0.86	11.72	3.67	2.90	8.67	2.01
Annual Growth Rate of Agriculture, Forestry & Fishing Value Added (%)	8.40	8.89	8.41	8.46	7.72	6.56	6.37	6.33
Rural Electricity Access (%)	97.4	97.4	97.4	97.4	97.4	97.4	97.4	97.4
Rural Population (% of Total Population)	40.08	39.29	38.50	37.72	36.94	36.17	35.41	34.65
Year	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**
Economic Growth (%)	2.5	1.2	4.8	3.0	2.4	2.6	4.1	3.2
Agriculture, Forestry & Fishing Value Added (% of GDP)	-3.44	23.46	6.30	9.72	9.72	11.99	3.03	6.95
Annual Growth Rate of Agriculture, Forestry & Fishing Value Added (%)	5.55	8.01	7.53	7.08	8.03	9.12	9.41	10.53
Rural Electricity Access (%)	97.9	97.4	97.5	97.6	97.7	97.8	97.9	98.1

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Rural Population (% of Total Population)	33.90	33.17	32.46	31.76	31.09	30.42	29.78	29.15
Year	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**	**2022**	**2023**
Economic Growth (%)	3.9	1.5	1.4	0.9	-5.0	3.8	3,6	4,1
Agriculture, Forestry & Fishing Value Added (% of GDP)	1.60	-4.08	3.26	2.56	2.82	-2.21	5,1674	2,9227
Annual Growth Rate of Agriculture, Forestry & Fishing Value Added (%)	11.07	11.03	11.24	11.48	12.83	11.24	10,6132	13,0868
Rural Electricity Access (%)	98.3	98.6	98.9	98.7	99.1	99.3	99,3	100
Rural Population (% of Total Population)	28.54	27.95	27.37	26.81	26.27	25.74	25,228	24,732

Source : World Bank

Figure (1): **:** Illustrates the chronological sequence of the performance of agricultural and economic variables related to rural areas in Algeria between 2000 and 2023.



Source: Prepared by the researchers based on EViews outputs**.**

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VII.1. 1. Analysis of Economic Growth Trends and Their Relationship with the Agricultural Sector in Algeria (2000–2023)

During the analyzed period, Algeria's economic growth rate showed significant volatility, reflecting the structural fragility of the national economy and its heavy dependence on hydrocarbon revenues. Growth peaked at 6.5% in some years but sharply contracted by -5% during the COVID-19 pandemic and the collapse in oil prices. Since then, recovery has been slow and uneven, with rates ranging between 3.6% and 4.1%.

The contribution of agriculture, forestry, and fishing to GDP also exhibited instability, ranging from a low of -4.6% in 2000 to a peak of 23.4% in 2009, before stabilizing between 2.5% and 6.9% from 2010 to 2023. A notable contraction of -4.08% was recorded in 2017, highlighting the sector's susceptibility to climatic and seasonal fluctuations. Similarly, the annual growth of agricultural value added fluctuated, with significant increases of 10.5% in 2015 and 13% in 2023, contrasted by contractions in other years—indicating the absence of a consistent structural policy and limited adoption of modern technologies.

Meanwhile, the share of the rural population declined from 40.08% in 2000 to 24.73% in 2023, reflecting persistent gaps in infrastructure and economic opportunity, which threaten the agricultural labor base. On a positive note, rural electrification reached full coverage, rising from 97.4% to 100% by 2023. However, its impact on agricultural productivity remains constrained due to the lack of institutional and technical support.

VII.2 Definition of the Study Variables :

This study relies on five main variables derived from World Bank data covering the period 2000–2023, as follows :

- **Economic Growth (EG):** The annual growth rate of real Gross Domestic Product (GDP) (%), used as the dependent variable to measure overall macroeconomic performance.
- **Agricultural Value Added as a Percentage of GDP (AVAGDP):** Represents the contribution of agriculture, forestry, and fishing to GDP (%), serving as an indicator of the sector's economic weight.
- **Annual Growth Rate of Agricultural Value Added (GAVAGDP):** The yearly growth rate of agricultural output (%), indicating the sector's efficiency and development.
- **Rural Electrification (ELEC):** The percentage of the rural population with access to electricity (%), used as a proxy for rural infrastructure quality.
- **Rural Population (RPOP):** The share of the rural population relative to the total population (%), acting as a demographic indicator reflecting the rural sector's importance in the economy.

VII.2.1 Justification for Variable Selection: Theoretical and Policy Perspective :

The selection of variables in this study is grounded in both theoretical reasoning and policy relevance. From a theoretical standpoint, economic growth (EG) is used as the dependent variable because it encapsulates the overall macroeconomic performance of the Algerian economy. The agricultural value added (AVAGDP) and its annual growth rate (GAVAGDP) are included to capture the direct and dynamic contribution of the agricultural sector to output expansion, consistent with the classical and neoclassical growth theories (Smith, 1776; Solow, 1956), which emphasize capital accumulation and sectoral productivity as primary drivers of growth.

The inclusion of rural electrification (ELEC) serves as a proxy for rural infrastructure quality, reflecting the modernization and accessibility of essential services in rural areas. This choice aligns

with the endogenous growth framework, which highlights infrastructure as a key facilitator of productivity spillovers and technological diffusion, particularly in developing economies. From a policy perspective, rural electrification is a strategic objective in Algeria's national development plans, such as the National Rural Development Program (PNDR), designed to reduce spatial inequality and enhance rural productivity.

Finally, the rural population share (RPOP) represents the demographic and labor dimension of rural development, providing insight into the human capital base available for agricultural and non-agricultural activities. Its inclusion is also motivated by policy relevance, as Algeria's rural population has experienced a long-term decline, which directly influences agricultural labor availability and the sustainability of rural economies. Thus, the chosen variables jointly capture the multidimensional nexus between agricultural performance, rural infrastructure, demographic structure, and macroeconomic growth making them

VII.2.1 Autoregressive Distributed Lag (ARDL) Model :

This model can be denoted as $ARDL(\rho, q_1, q_2, \ldots)$, where ρ refers to the lag length of the dependent variable, and $q_1, q_2, \ldots$ represent the lag lengths of the independent variables. The ARDL model is expressed by the following general form :

The mathematical representation of the model is as follows :

$$EG_t = f\,(AVAGDP; GAVAGDP; ELEC; RPOP)$$

The standard model takes the following form :

$$\Delta EG_t = \alpha_0 + \sum_{i=0}^{p}\beta_1 EG_{t-i} + \sum_{i=0}^{q}\beta_2 \Delta AVAGDP_{t-i} + \sum_{i=0}^{q}\beta_3 \Delta GAVAGDP_{t-i} + \sum_{i=0}^{q}\beta_4 \Delta ELEC_{t-i} + \sum_{i=0}^{q}\beta_5 \Delta RPOP_{t-i} + \theta_1 EG_{t-1} + \theta_2 AVAGDP_{t-1} + \theta_3 GAVAGDP_{t-1} + \theta_4 ELEC_{t-1} + \theta_5 RPOP_{t-1} + \varepsilon_t$$

VII. 3. Lag Length Selection for the ARDL Model:

Before conducting the unit root test, it is essential to determine the optimal lag lengths. The optimal lag selection is based on minimizing the values of the following criteria :

-Akaike Criterion (AIC) : $AIC\,(P) = Ln\left|\sum_e\right| + \frac{2k^2 p}{n}$

-Shwartz Criterion (SC): $SC\,(P) = Ln\left|\sum_e\right| + \frac{k^2 p.Ln(n)}{n}$

The obtained results have been summarized in the following table :

Table (02) : Determination of the Optimal Lag Length for the ARDL Model

Lag	LogL	LR	FPE	AIC	SC	HQ
3	149.9624	47.94789*	9.57e-09*	-6.663088*	-2.683955*	-5.799514*

Source: Prepared by the researchers based on EViews outputs

It appears from the results presented in Table 03 that the lag order which yields the lowest values for both the AIC and SC criteria is the third lag.

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VII.4 Testing the Stationarity of the Time Series for the Study Variables:

To check the stationarity of the variables in this study, we relied on the Augmented Dickey-Fuller (ADF) test and the Phillips-Perron (PP) test.

Hypothesis

If $t_{tab} < t_{\phi_i}$: We accept the null hypothesis, which states that the series contains a unit root.

If $t_{tab} > t_{\phi_i}$: We accept the alternative hypothesis, which states that the series does not contain a unit root.

Table (03) : Stationarity Test Results Using Augmented Dickey-Fuller (ADF) and Phillips-Perron (PP) Tests at 5% Significance Level

variable	PP Test (Calculated)			ADF Test (Calculated)		
	Without constant & trend	With constant & trend	With constant only	Without constant & trend	With constant & trend	With constant only
EG	-1.556897	-3.864134	-3.469664	-1.757691	-3.941998	-3.430558
Critical values (EG)	-1.956406	-3.622033	-2.998064	-1.956406	-3.622033	-2.998064
AVAGDP	1.135917	-1.825723	-0.066823	0.844168	-2.011590	-0.380088
Critical values (AVAGDP)	-1.956406	-3.622033	-2.998064	-1.956406	-3.622033	-2.998064
GAVAGDP	-3.500030	-6.136077	-5.646827	-1.007867	-6.239501	-5.755439
Critical values (GAVAGDP)	-1.956406	-3.622033	-2.998064	-1.958088	-3.622033	-2.998064
ELEC	2.754196	-0.037970	3.440071	2.783299	-0.084806	3.016142
Critical values (ELEC)	-1.656406	-3.622033	-2.998064	-1.957204	-3.644963	-3.012363
RPOP	-105.0028	4.207870	-14.50130	-1.544331	-1.823968	-5.420939

Source: Prepared by the researchers based on EViews outputs

The unit root test results indicate mixed stationarity properties across the variables. Economic growth (EG) is found to be stationary at level under both the Augmented Dickey-Fuller (ADF) and Phillips-Perron (PP) tests, suggesting it is integrated of order zero, I(0). In contrast, agricultural value added as a percentage of GDP (AVAGDP) is non-stationary at level, indicating it is likely I(1). The growth rate of agricultural value added (GAVAGDP) is stationary at level when accounting for a time trend, making it I(0). Rural electrification (ELEC) is consistently non-stationary at level, suggesting I(1). Results for the rural population ratio (RPOP) are inconsistent, with ADF and PP tests producing conflicting and irregular outcomes, though the overall evidence points to non-stationarity at level.

VII.5 Removing Non-Stationarity of the Original Series AVAGDP, ELEC, and RPOP:

After applying first-order differencing to the aforementioned series, namely AVAGDP, ELEC, and RPOP, the non-stationarity issue was addressed. This transformation is intended to stabilize the mean of the series by eliminating unit roots, thereby making the data suitable for further time series analysis.

$D(\mathbf{AVAGDP}) = \mathbf{AVAGDP}_t - \mathbf{AVAGDP}_{t-1}$ ، $D(\mathbf{ELEC}) = \mathbf{ELEC}_t - \mathbf{ELEC}_{t-1}$ ، $D(\mathbf{RPOP}) = \mathbf{RPOP}_t - \mathbf{RPOP}_{t-1}$ The first-order differenced series is obtained and denoted by the symbol $D(\mathbf{AVAGDP}); D(\mathbf{ELEC}); D(\mathbf{RPOP})$ are presented in the following table.:

Table (04) : Stationarity Test Results Using Augmented Dickey-Fuller (ADF) and Phillips-Perron (PP) Tests at 5% Significance Level

Variables		Phillips-Perron (PP) Test			Augmented Dickey-Fuller (ADF) Test		
		Without constant & trend	With constant & trend	With constant only	Without constant & trend	With constant & trend	With constant only
AVAGDP	Computed Statistic	-4.540383	-4.908708	-4.595948	-4.580508	-4.320406	-3.903243
	Critical Value	-1.957204	-3.632896	-3.004861	-1.957204	-3.644963	-3.012363
ELEC	Computed Statistic	-4.351414	-8.567738	-5.507543	-0.397489	-5.508215	-5.512991
	Critical Value	-1.957204	-3.632896	-3.004861	-1.959071	-3.644963	-3.004861
RPOP	Computed Statistic	-5.872338	-3.701718	2.733685	-2.161023	-3.973352	-4.361384
	Critical Value	-1.957204	-3.632896	-3.004861	-1.959071	-3.632896	-3.020686

Source: Prepared by the researchers based on EViews outputs

The results of the Augmented Dickey-Fuller (ADF) and Phillips-Perron (PP) tests indicate that all the variables listed in this table namely, the agricultural value added as a percentage of GDP (AVAGDP), rural access to electricity (ELEC), and the rural population share of total population (RPOP) satisfy the stationarity condition at level I(0). The computed test statistics for both ADF and PP, across different model specifications (with constant, with constant and trend, and without both), generally exceed the critical values at the 5% significance level. Although there are isolated exceptions for ELEC in the ADF test without a constant, these do not undermine the overall conclusion. This implies that these variables do not contain unit roots and exhibit stationarity in both mean and variance, confirming their suitability for direct inclusion in econometric models such as the ARDL without requiring first differencing.

VII.7 Bound Testing for Cointegration:

Cointegration among the study variables is established according to the bounds testing approach if the calculated F-statistic exceeds the upper critical value bound. In this case, we reject the null hypothesis, which states that no long-run equilibrium relationship exists, and accept the alternative hypothesis of the presence of cointegration among the variables. Conversely, if the F-statistic falls below the lower critical value, the null hypothesis cannot be rejected, indicating no cointegration.

VII.7.1 Modified Bound Test for Cointegration:

The modified bound test for cointegration is an enhanced version of the traditional bounds testing approach. It adjusts for potential issues such as small sample bias or structural breaks within

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the data, providing more robust and reliable inference regarding the existence of a long-run equilibrium relationship among the variables. This modification improves the accuracy of the critical values or the testing procedure, ensuring better detection of cointegration under various data conditions.

$$\Delta \mathbf{GDPG}_t = \alpha + \sum_{i=1}^{p-1} \gamma_i \Delta \mathbf{LGDPG}_{t-i} + \sum_{j=1}^{k} \sum_{i=0}^{q-1} \beta_{ij} \Delta LAVAS_{J,t-i} + \rho \mathbf{LGDPG}_{t-1} + \sum_{j=1}^{k} \delta_j LAVAS_{j,t-1} + \varepsilon_t$$

Hypothesis: $\begin{cases} H_0 : \rho = \delta_j = 0 \\ H_1 : \rho \neq \delta_j \neq 0 \end{cases}$

Table (05) : Results of the Bounds Test for Cointegration

Computed F-Statistic	Critical Values	Significance Level
135.3583	I(0) Lower Bound: 4.37	1%
	I(0) Lower Bound: 3.49	5%
	I(0) Lower Bound: 3.09	10%
	I(1) Upper Bound: 3.29	1%
	I(1) Upper Bound: 2.56	5%
	I(1) Upper Bound: 2.20	10%

Source: Prepared by the researchers based on EViews outputs

The computed F-statistic value (135.3583) strongly indicates the presence of a cointegration relationship among the variables under study. This is evidenced by its substantial excess over all critical values at conventional significance levels (1%, 5%, and 10%). Specifically :

- At the 1% significance level :

- Lower bound I(0) = 3.29
- Upper bound I(1) = 4.37
- Computed F = **135.3583** > **4.37**

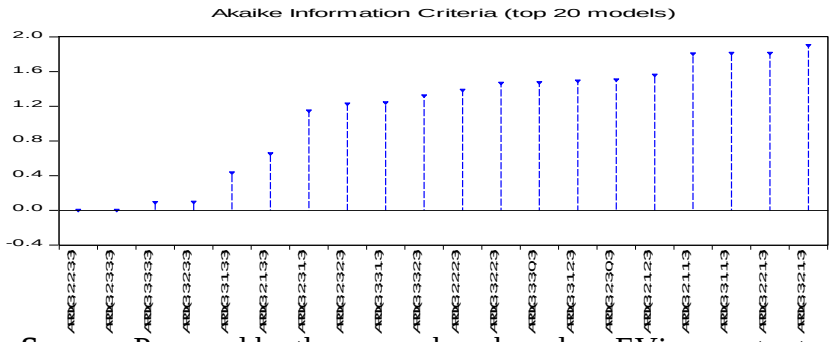
This clearly shows that the F-statistic exceeds the upper bound critical value at all significance levels by a wide margin. Consequently, the null hypothesis (**H_0**: no long-run relationship among the variables) is rejected, and the alternative hypothesis (**H_1**: a long-run equilibrium relationship exists) is accepted.

Therefore, we conclude that the variables economic growth, agricultural value added, rural electricity access, and rural population share are cointegrated and move together in the long run. This finding justifies proceeding to estimate both the long-run regression model and the Error Correction Model (ECM) to further investigate the nature, direction, and strength of these relationships.

VII.7.2 Estimating the Long-Run Relationship: The Cointegration Regression Model

Figure (02): **: The appropriate model for estimating the long–run equilibrium relationship**

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Source: Prepared by the researchers based on EViews outputs

Using the Akaike Information Criterion (AIC), and after selecting the model with the lowest AIC value as shown in the figure above, the ARDL(3,2,2,3,3) model was chosen to estimate the long-run equilibrium relationship.

VII.7.3 Model Estimation

$$EG = 1.52650478643*EG(-1) + 0.626995378871*EG(-2) - 1.45689311816*EG(-3) - 4.82971799666*AVAGDP + 5.87111581618*AVAGDP(-1) - 11.3408276208*AVAGDP(-2) - 0.384742408901*GAVAGDP - 1.4560242471*GAVAGDP(-1) - 0.114209673912*GAVAGDP(-2) - 23.1680003795*ELEC + 2.83064539092*ELEC(-1) + 1.04701601155*ELEC(-2) + 5.65735245378*ELEC(-3) + 540.211153244*RPOP + 611.954985578*RPOP(-1) - 1961.58457056*RPOP(-2) + 823.411671949*RPOP(-3) + 1558.49850057$$

The model shows that past economic growth has a strong and persistent influence on current performance, though later lags suggest possible cyclical effects. Agricultural value added (AVAGDP) has a mixed impact, with initial positive effects followed by sharp negatives, indicating delayed and unstable contributions. The growth rate of agricultural value added (GAVAGDP) has a weak short-term impact on overall growth. Rural electrification initially hinders growth, likely due to costs, but shows positive effects in later periods as benefits emerge. The rural population share (RPOP) has a strong and changing influence, initially boosting growth but later dragging it down before improving again, highlighting a complex, non-linear relationship. The constant term reflects the baseline economic activity not explained by the other variables.

VII.10 Estimation of the Error Correction Model (ECM):

Based on the results obtained from the bounds test indicating the existence of cointegration among the study variables, it is necessary to estimate the Error Correction Model (ECM) to analyze and diagnose the speed of adjustment coefficient. Literature indicates that this coefficient confirms the existence of a cointegrating relationship between the variables if it meets two essential conditions: being negative and statistically significant. The results of this model are presented in the following table:

Table (06) : Error Correction Term (ECT) Results

ARDL Error Correction Regression				
Dependent Variable: D(EG)				
Selected Model: ARDL(3, 2, 2, 3, 3)				
Variable	Coefficient	Std. Error	t-Statistic	Prob.
CointEq(-1)*	-0.303393	0.006519	-46.53743	0.0000

Source: Prepared by the researchers based on EViews outputs

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This table presents the results of the Error Correction Model (ECM) derived from the ARDL (3,2,2,3,3) model, used to analyze both short-term and long-term relationships between economic growth (EG) and the independent variables AVAGDP, GAVAGDP, ELEC, and RPOP.

Error Correction Term (CointEq(-1) = -0.303):

- It is highly significant (p = 0.0000) and has a negative sign, which is a necessary condition for the model's validity.
- This indicates the existence of a long-run equilibrium relationship among the variables.

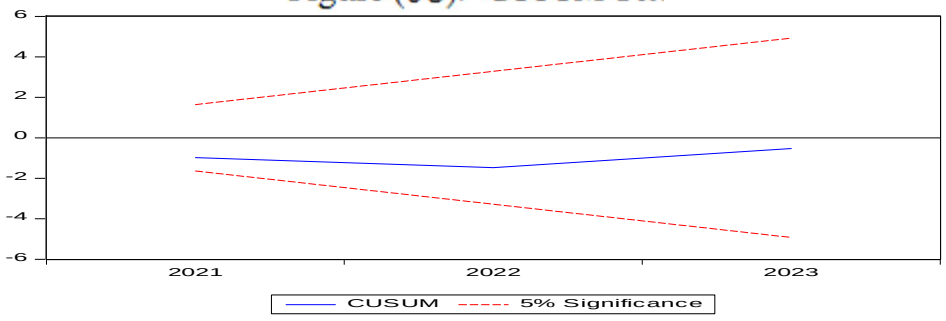
The coefficient suggests that approximately 30.3% of the disequilibrium from the previous period is corrected in the current period, implying a moderate speed of adjustment back to equilibrium (neither too slow nor too fast).

VII.11. Diagnostic Tests :

The diagnostic tests conducted on the model's residuals include the Breusch-Godfrey Serial Correlation LM Test, the Jarque-Bera Normality Test, and the ARCH Test for heteroskedasticity. The Breusch-Godfrey test yielded an F-statistic of 0.472817 with a p-value of 0.7169, indicating no evidence of serial correlation as we fail to reject the null hypothesis. The Jarque-Bera test produced a statistic of 1.092492 with a p-value of 0.5791, supporting the assumption that residuals are normally distributed. Lastly, the ARCH test for heteroskedasticity returned an F-statistic of 0.620369 with a p-value of 0.6133, showing no signs of heteroskedasticity and confirming constant variance in the residuals. Together, these results support the validity and reliability of the model's estimates and hypothesis testing.

VII.12 Model Stability Test:

Figure (03): CUSUM Test



Source: Prepared by the researchers based on EViews outputs

From the figure, we observe that the CUSUM curve remains within the 5% significance boundaries. Therefore, it can be concluded that both the short-run and long-run models do not exhibit any structural breaks.

III- Results and discussion :

Variable	Coefficient	Prob.	Economic Interpretation

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AVAGDP	-4.83	0.0005	Initial negative contribution due to structural inefficiencies and seasonal fluctuations.
AVAGDP(-1)	+5.87	0.0010	Positive delayed effect as agricultural output stabilizes and productivity improves.
*ELEC	-23.16	0,0013	Short-term costs of infrastructure investment exceed immediate productivity gains.
ELEC(-3)	5,65	0,0497	Medium-term productivity gains as infrastructure utilization increases.
RPOP	540,21	0,0415	Positive demographic effect from rural labor participation.
RPOP(-2)	-1961,69	0,0033	Negative delayed effect due to rural depopulation and urban migration.
*ECM(-1	-0,303	0	About 30% of short-term disequilibrium is corrected each year, confirming stable long-run adjustment.

Source: Prepared by the researchers based on EViews outputs

The results confirm a long-run equilibrium relationship between economic growth and variables representing agricultural activity and rural infrastructure. The negative short-run impact of agricultural value added (AVAGDP) indicates that fluctuations in agricultural productivity and dependence on climatic conditions temporarily hinder growth. However, the subsequent positive lagged effect highlights the resilience of the agricultural sector once stability and support mechanisms are in place.

The rural electrification variable (ELEC) reveals a dual effect: initially negative due to the financial burden of infrastructure projects and inefficient utilization, but turning positive after a few lags as electricity begins to support rural enterprises and agricultural processing. This delayed impact illustrates the time-dependent nature of infrastructure benefits, a common feature in developing economies undergoing structural transformation.

The rural population variable (RPOP) exerts a positive short-term effect, suggesting that rural labor participation initially contributes to production and consumption dynamics. Nonetheless, its longer-term negative effect underscores persistent rural depopulation and migration to urban areas, which reduce the agricultural labor base and limit sustained rural productivity.

The error correction coefficient (-0.303) is negative and highly significant, confirming the presence of a strong long-run adjustment mechanism. Approximately 30% of short-term deviations from equilibrium are corrected annually, reflecting moderate economic resilience and the ability of the Algerian economy to re-stabilize after agricultural or infrastructural shocks.

From a broader perspective, these findings imply that agriculture and rural infrastructure in Algeria are not immediate engines of growth, but rather latent and delayed contributors that require sustained policy commitment, institutional coordination, and technological modernization to fully realize their potential. The interaction between demographic shifts, infrastructure expansion, and agricultural performance thus represents a key policy frontier for achieving inclusive and regionally balanced growth.

IX. Hypothesis Testing:

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Based on the empirical results of the study, it can be hypothesized that agricultural activity in rural areas plays a positive and effective role in promoting economic growth in Algeria. This occurs through its contribution to increasing agricultural value-added, improving food security, and generating employment opportunities, provided that supportive policies and targeted investments are in place to enhance infrastructure and boost rural agricultural productivity. The results of the Autoregressive Distributed Lag (ARDL) model confirm the existence of a long-term equilibrium relationship between economic growth and variables related to agricultural activity and rural infrastructure, alongside a rapid short-term adjustment to any disequilibrium. Variations in these effects highlight the importance of activating financial and technical support in rural areas to transform these potentials into sustainable drivers of economic growth. This underscores the vital role of rural agriculture in economic development when integrated with comprehensive and effective development policies.

IX. 1 Methodological Limitations:

Despite the robustness of the ARDL model in handling variables with mixed integration orders and small sample sizes, this study is subject to certain methodological limitations. First, the analysis relies on aggregate national data from the World Bank, which may obscure regional disparities in agricultural performance and rural infrastructure quality across Algeria's diverse provinces. Second, the time span (2000–2023), while sufficient for long-run analysis, may still limit the detection of structural breaks associated with major policy reforms or external shocks such as oil price fluctuations and the COVID-19 pandemic. Third, the model focuses on a restricted set of variables and does not explicitly incorporate factors such as climate variability, land productivity, or institutional quality, which may also influence the growth-agriculture relationship. Finally, due to data constraints, the study assumes linear relationships among variables, whereas in reality, nonlinear dynamics and threshold effects may exist. These limitations, however, do not undermine the validity of the results but rather highlight avenues for future research to deepen the empirical understanding of rural development and growth dynamics in Algeria.

X. Recommendations:

Based on the empirical findings, the following recommendations are proposed. They are arranged by priority, linked to specific time frames, and associated with measurable performance indicators to ensure effective monitoring and implementation :

Priority	Recommendation	Time Frame	Key Performance Indicators (KPIs)	Expected Outcome
1	Increase investment in rural infrastructure (roads, electricity, irrigation systems, digital connectivity) through public-private partnerships and regional development funds.	Short term (1–3 years)	% increase in paved rural roads; % rural households with reliable electricity; km of new irrigation systems	Improved agricultural productivity and reduced spatial inequality
2	Enhance technical support and agricultural training for farmers via national extension programs and digital learning platforms.	Medium term (3–5 years)	Number of farmers trained annually; adoption rate of modern farming technologies	Higher productivity and reduced post-harvest losses

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3	Reform agricultural financing mechanisms by creating a rural microfinance window and credit guarantee schemes.	Medium term (3–5 years)	Number of rural loans approved; % of smallholders accessing credit	Increased investment capacity in rural areas
4	Diversify agricultural production by promoting high-value crops and sustainable farming systems.	Long term (5–10 years)	% reduction in food imports; share of non-hydrocarbon exports	Enhanced food security and trade balance stability
5	Promote agricultural innovation and smart technologies through partnerships with universities and research centers.	Long term (5–10 years)	Number of innovation hubs created; R&D spending as % of agricultural GDP	Improved resource use efficiency and resilience to climate change
6	Establish monitoring and evaluation systems to periodically assess rural development progress and policy impact.	Continuous	Frequency of reports published; variance between target and achieved KPIs	Evidence-based policymaking and adaptive management

Source: Prepared by the researchers

XI. Conclusion:

The findings of this study, based on the Autoregressive Distributed Lag (ARDL) model for the period 2000–2023, reveal that agricultural activity and rural infrastructure are pivotal pillars of Algeria's economic growth. The results confirm a long-run equilibrium relationship and a moderate short-run adjustment speed of about 30%, reflecting the economy's capacity to recover from rural and agricultural shocks. Empirically, the study provides new econometric evidence of the interdependence between agriculture, rural development, and macroeconomic performance; theoretically, it deepens the understanding of spatial development and economic stability in resource-dependent economies; and practically, it proposes a measurable, policy-oriented framework to guide decision-makers. The applied value of these findings lies in their potential use by the Ministry of Agriculture and Rural Development and policymakers to design time-bound programs that foster inclusive and sustainable rural growth, while future research should integrate spatial and climatic dimensions to reinforce growth sustainability and regional balance within the Algerian economy.

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12. Appendices

Table (07) : VAR Lag Order Selection Criteria for the Model Variables (EG, AVAGDP, ELEC, GAVAGDP, RPOP)

VAR Lag Order Selection Criteria
Endogenous variables: EG AVAGDP ELEC GAVAGDP RPOP
Exogenous variables: C
Date: 06/01/25 Time: 22:42
Sample: 2000 2023
Included observations: 21

Lag	LogL	LR	FPE	AIC	SC	HQ
0	-203.6480	NA	293.5998	19.87124	20.11994	19.92522
1	-25.38496	254.6616	0.000146	5.274758	6.766933	5.598598
2	49.27186	71.10173	2.12e-06	0.545537	3.281191	1.139244
3	149.9624	47.94789*	9.57e-09*	-6.663088*	-2.683955*	-5.799514*

Source: Prepared by the researchers based on EViews outputs

Table (08) : ARDL Model Estimation Results for the Dependent Variable EG

Dependent Variable: EG				
Method: ARDL				
Date: 06/04/25 Time: 00:53				
Sample (adjusted): 2003 2023				
Included observations: 21 after adjustments				
Maximum dependent lags: 3 (Automatic selection)				
Model selection method: Akaike info criterion (AIC)				
Dynamic regressors (3 lags, automatic): AVAGDP GAVAGDP ELEC RPOP				
Fixed regressors: C				
Number of models evalulated: 768				
Selected Model: ARDL(3, 2, 2, 3, 3)				
Variable	Coefficient	Std. Error	t-Statistic	Prob.*
EG(-1)	1.526505	0.087749	17.39618	0.0004
EG(-2)	0.626995	0.091873	6.824558	0.0064
EG(-3)	-1.456893	0.093924	-15.51138	0.0006
AVAGDP	-4.829718	0.286919	-16.83306	0.0005
AVAGDP(-1)	5.871116	0.450690	13.02695	0.0010
AVAGDP(-2)	-11.34083	0.684223	-16.57475	0.0005
GAVAGDP	-0.384742	0.102067	-3.769496	0.0327
GAVAGDP(-1)	-1.456024	0.134049	-10.86186	0.0017
GAVAGDP(-2)	-0.114210	0.062529	-1.826506	0.1652
ELEC	-23.16800	1.972306	-11.74666	0.0013
ELEC(-1)	2.830645	1.875099	1.509598	0.2283
ELEC(-2)	1.047016	0.948800	1.103516	0.3504
ELEC(-3)	5.657352	1.773853	3.189301	0.0497
RPOP	540.2112	157.3675	3.432800	0.0415

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RPOP(-1)	611.9550	194.3160	3.149277	0.0513
RPOP(-2)	-1961.585	228.4320	-8.587171	0.0033
RPOP(-3)	823.4117	130.1277	6.327720	0.0080
C	1558.499	199.4417	7.814307	0.0044
R-squared	0.997887	Mean dependent var		2.876190
Adjusted R-squared	0.985913	S.D. dependent var		2.287991
S.E. of regression	0.271561	Akaike info criterion		-0.000882
Sum squared resid	0.221237	Schwarz criterion		0.894423
Log likelihood	18.00926	Hannan-Quinn criter.		0.193422
F-statistic	83.33651	Durbin-Watson stat		2.601009
Prob(F-statistic)	0.001871			
*Note: p-values and any subsequent tests do not account for model selection.				

Source: Prepared by the researchers based on EViews outputs

Table (09) : ARDL Error Correction Model Estimation Results for the Dependent Variable D(EG)

ARDL Error Correction Regression				
Dependent Variable: D(EG)				
Selected Model: ARDL(3, 2, 2, 3, 3)				
Case 2: Restricted Constant and No Trend				
Date: 06/04/25 Time: 01:09				
Sample: 2000 2023				
Included observations: 21				
ECM Regression				
Case 2: Restricted Constant and No Trend				
Variable	Coefficient	Std. Error	t-Statistic	Prob.*
D(EG(-1))	0.829897	0.027565	30.10744	0.0001
D(EG(-2))	1.456893	0.034761	41.91118	0.0000
D(AVAGDP)	-4.829718	0.090458	-53.39160	0.0000
D(AVAGDP(-1))	11.34082	0.220860	51.34856	0.0000
D(GAVAGDP)	-0.384742	0.017645	-21.80433	0.0002
D(GAVAGDP(-1))	0.114210	0.009860	11.58332	0.0014
D(ELEC)	-23.16798	0.629259	-36.81790	0.0000
D(ELEC(-1))	-6.704368	0.366099	-18.31299	0.0004
D(ELEC(-2))	-5.657350	0.313275	-18.05874	0.0004
D(RPOP)	540.2118	25.67900	21.03711	0.0002
D(RPOP(-1))	1138.171	50.38765	22.58829	0.0002
D(RPOP(-2))	-823.4105	27.84519	-29.57101	0.0001
CointEq(-1)*	-0.303393	0.006519	-46.53743	0.0000
R-squared	0.998554	Mean dependent var		-0.061905
Adjusted R-squared	0.996385	S.D. dependent var		2.765769
S.E. of regression	0.166297	Akaike info criterion		-0.477072
Sum squared resid	0.221237	Schwarz criterion		0.169537
Log likelihood	18.00926	Hannan-Quinn criter.		-0.336742
Durbin-Watson stat	2.600996			
* p-value incompatible with t-Bounds distribution.				
F-Bounds Test		Null Hypothesis: No levels relationship		
Test Statistic	Value	Signif.	I(0)	I(1)
F-statistic	135.3583	10%	2.2	3.09
k	4	5%	2.56	3.49
		2.5%	2.88	3.87
		1%	3.29	4.37

Source: Prepared by the researchers based on EViews outputs

Table (07) : Diagnostic Test Results for the ARDL Model

نوع الاختبار	القيمة	الاحتمال
Breusch-Godfrey Serial Correlation LM Test:	0.472817	0.7169
Jarque-Bera	1.092492	0.579120
Heteroskedasticity Test: ARCH	F-statistic :0.620369	0.6133

Source: Prepared by the researchers based on EViews outputs