



Impact of Investment on the Growth of Agricultural Production in Algeria - An Econometric Study over the Period 1990 – 2022

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Received: 31/03/2025

Accepted: 08/05/2025

Published: 30/06/2025

Abstract:

This study examines the impact of agricultural investment on sectoral growth in Algeria from 1990 to 2022. Using an Autoregressive Distributed Lag (ARDL) model, we analyse the short- and long-term effects of agricultural investment, labour, and irrigated land on domestic agricultural production.

The findings confirm the existence of a long-run relationship among the variables, indicating that investment significantly enhances agricultural production growth. In the short run, investment has an immediate positive effect, while agricultural labour and irrigated land exhibit mixed impacts. However, in the long run, all three variables positively contribute to agricultural growth, with investment playing the most dominant role.

Keywords: Agricultural sector, Algeria, ARDL, Economic growth, investment

Jel Classification Codes: Q18, E22, C32.

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1. Introduction

Agriculture is one of the most important sectors in the Algerian economy, contributing to food security, rural employment, and income generation. It also plays a crucial role in supplying raw materials to manufacturing industries and boosting exports. However, the sector's growth is hindered by resource limitations, traditional practices and heavy reliance on food imports.

Over the last two decades, serious concerns have emerged regarding the development of agriculture in Algeria, prompting the Algerian government to make substantial investments in the sector, with a focus on food security, import reduction, and economic diversification.

Against this backdrop, agricultural investment in Algeria has followed a dynamic trajectory, shaped by economic policies, financial support and rural development initiatives aimed at enhancing productivity and economic resilience.

Problem Statement:

Understanding the impact of investment on the Algerian agricultural production growth is essential for optimizing resource allocation. Despite the recognized benefits, there is limited empirical research analysing the long-term effects of investment on the sector.

Research Objectives and Questions:

This study aims to examine the impact of investment on agricultural production in Algeria from 1990 to 2022. Given Algeria's commitment to economic emergence and food security by 2030, verifying the existence and dynamics of this relationship is crucial. Accordingly, the research problem is formulated as follows: **How does investment affect the growth of agricultural production in Algeria?**

Hypotheses:

To address this research question, the following hypotheses have been formulated:

H1: Investment positively influences agricultural domestic production in both the short and long run.

H2: Irrigated land and agricultural labour amplify the positive impact of investment on domestic agricultural production.

Methodology:

To assess whether investment influences the growth of agricultural production in Algeria, we will estimate an Autoregressive Distributed Lag (ARDL) model, which captures temporal effects such as adjustment delays and expectations in explaining a variable.

Our study is structured as follows: First, we provide a brief overview of the literature review on the existing relationship between agricultural sector growth and investment. Second, we present an overview of the agricultural sector in Algeria. The econometric results will be discussed in the third section. Finally, we conclude with some findings and suggestions.

2. Literature Review

Agricultural investment has long been a focal point in economic and political debates in Algeria. Several studies have examined the impact of investment on the growth and productivity of the agricultural sector. Recent research highlights its significant role in sectoral expansion and its potential for economic diversification.

Ghedjati and Almi (2024) investigated the effects of agricultural investment on per capita agricultural production in Algeria using an ARDL approach for the period 2000-2022. Their econometric analysis revealed a positive correlation between investment and increased agricultural output per capita, emphasizing its importance in rural development.

Focusing on foreign direct investment (FDI), Hammache (2023) found that FDI has a moderate but positive impact on Algerian agricultural productivity, suggesting that its promotion could benefit the sector.

Through an ARDL analysis covering 1990-2021, Aberkane and Belhadj (2023) observed that agricultural investment in Algeria has contributed to a slight increase in exports. However, they noted that the sector still faces significant structural challenges. In a related study, Abdelmalek (2023) analysed the date sector from 1995 to 2017

and found that export support policies have contributed to the growth of agricultural exports, particularly for the Deglet Nour variety. While this variety holds substantial export potential, its contribution to foreign currency revenues remains marginal compared to hydrocarbon exports.

Mimouni (2023) explored the impact of agricultural development plans on agricultural production in Algeria between 2000 and 2019. Using a non-parametric hypothesis test, the study compared the average production of several crops over two periods—before and after the implementation of various agricultural plans. The findings indicate that development plans have improved agricultural production, yet they underscore the need for better resource management to achieve sustainable growth. The study recommends intensified investment to further enhance agricultural productivity.

Boukella (2008) examined Algeria's agricultural policies, focusing on food dependency and food security. The study assessed the extent to which agricultural investments and support policies have reduced reliance on food imports. While progress has been made, food dependency remains high, necessitating more targeted investments to strengthen self-sufficiency.

From an economic growth perspective, Mostefai Y. (2024) analysed the role of agriculture in Algeria's economic growth from 1991 to 2022. Using variables such as agricultural GDP and employment, the study applied an ARDL model to explore long-term relationships. The findings revealed a positive correlation between agricultural growth and overall economic expansion, suggesting that agriculture can serve as a key driver of economic diversification and resilience to economic shocks.

These studies collectively highlight the critical role of investment in revitalizing Algeria's agricultural sector, despite persistent structural barriers.

Research on other countries also underscores the importance of investment in the agricultural sector.

Mamdouh (2017) analysed the impact of investment on agricultural output in Egypt, hypothesizing that agricultural investment positively influences agricultural GDP and, consequently, sectoral growth. Using a VAR model, the study examined the causal relationship between agricultural investment and GDP, revealing a long-term, one-directional equilibrium relationship, with real agricultural investment positively impacting GDP. Variance decomposition analysis further confirmed that higher agricultural investment fosters sectoral growth.

Ali and Attala (2015) investigated the effect of investment on Egypt's Gross Domestic Product and agricultural sector. Using econometric models, including the Flexible Accelerator Model, the Koyck Distributed Lag Model, the VAR model, and the Granger causality test, their study found a long-term equilibrium relationship, with agricultural investment positively influencing agricultural GDP. However, they noted that the limited share of agricultural investments within total investments constrains their impact on broader economic development.

In the case of Iraq, Al-Abbasi (2021) employed a multiple regression model to assess the relationship between agricultural investment, employment, and production growth. The findings showed that investment and employment significantly enhance livestock production. However, the impact on crop production was negative, attributed to low investment allocations and the absence of effective policies to attract investment in the agricultural sector.

3. Evolution of the Agricultural Sector in Algeria During the Period 1990–2022

3.1 The Agricultural Sector's Contribution to the National Economy

The development of Algeria's agricultural sector between 1990 and 2022 reflects the state's efforts to strengthen food security, promote economic diversification, and reduce dependency on hydrocarbons.

3.1.1 Contribution to GDP

Agriculture has consistently played a significant role in Algeria's GDP, contributing an average of 10% over the past two decades. Once a marginalized sector in the 1990s, agriculture has evolved into a more dynamic player in the national economy. Its share of GDP increased from 5.5% in 2008 to 12.8% in 2020, reaching 13.2% in 2023 (World Bank, n. d.).

Investments in programs such as the National Agricultural and Rural Development Program (PNDAR) and Agricultural Renewal have boosted productivity and structured Algerian agriculture, focusing on irrigation, mechanization, and yield improvements in major crops such as wheat (MIMOUNI, 2023). These investments have contributed to stable agricultural production despite climate fluctuations.

3.1.2 Contribution to Employment

The agricultural sector has been a key source of employment in Algeria, particularly in rural areas. Between 1990 and 1999, agriculture was the second-largest provider of jobs, following the administration sector, employing an average of 20% of the total workforce (Bédrani, Chehat, & Ababsa, 2001).

However, since 2004, employment in agriculture has declined, reaching 9.74% of the total workforce in 2022 (World Bank, n. d.). This decline is primarily due to young people's reluctance to work in the sector and the increasing mechanization of agricultural activities.

3.1.3 Contribution to Exports

While agricultural exports remain modest compared to hydrocarbons, they have gradually increased, particularly in high-value crops such as citrus fruits and dates (notably the internationally valued Deglet Nour variety). Exports rose from \$126.9 million in 1990 to nearly \$1.404 billion in 2021. However, their overall contribution remains limited, accounting for only 6.25% of total exports in 2021 (Arab Organisation for Agricultural Development, 2022).

3.1.4 Meeting National Needs

Despite improvements in agricultural performance, Algeria remains dependent on imports for key food products, particularly cereals and

vegetable oils. While investment programs have boosted national production, they have not fully offset import dependency, especially for strategic crops like cereals. However, the domestic production of vegetables, fruits, and dairy products now meets a large portion of national demand, thanks to better irrigation management and crop diversification. In 2014, Algeria's agricultural production reached \$35 billion, covering 72% of the country's food needs (Haddouche, 2016). This level rose to 75% in 2022 (Algerian Radio, 2023).

3.2 Evolution of Agricultural Investment in Algeria

Agricultural investment in Algeria has undergone several phases of transformation between 1990 and 2022, driven by structural reforms, national programs, and increased efforts toward self-sufficiency and food security.

3.2.1 The Early 1990s

In the early 1990s, Algerian agriculture suffered from low yields and limited investment, primarily due to economic difficulties such as declining oil revenues and structural adjustment programs. Agricultural production remained largely traditional, with limited technological advancements or infrastructural support (National Economic and Social Council (CNES), 1999).

3.2.2 The 2000s

In 2000, the National Program for Agricultural and Rural Development (PNDA) marked a turning point in agricultural investment. This program aimed to modernize infrastructure, expand irrigated land, and encourage the use of agricultural machinery (Ghedjati & Almi, 2024).

By 2002, PNDA evolved into PNDAR (National Program for Agricultural and Rural Development), with a broader focus on supporting private investment and improving agricultural services in rural areas (MIMOUNI, 2023). Through PNDAR, Algeria significantly increased investments in agriculture, leading to higher production of cereals, olives, and citrus fruits. These efforts accelerated the sector's growth, outpacing other economic sectors and

contributing to a relative stabilization of imports (Ministry of Agriculture and Rural Development, 2012).

3.2.3 The 2010s

During this decade, Algeria expanded public investments and introduced incentives for local farmers, alongside technological advancements in irrigation and crop management. The government's priorities focused on strengthening and expanding the productive base, intensifying agricultural and agro-food production, enhancing protection mechanisms for national production, conserving and improving natural resources, and developing human capacities and technical assistance (Ministry of Agriculture and Rural Development, 2012).

A key initiative during this period was the Agricultural Renewal Policy, which sought to enhance national food security and reduce import dependency, particularly for staple products like wheat and milk. This decade also saw a greater push for sustainable agricultural practices, emphasizing food security as a national priority, promoting resilient farming techniques in response to climate change, and encouraging investments in sustainable irrigation and advanced mechanization (Bessaoud, Pellissier, Rolland, & Khechimi, 2019).

3.2.4 2020 and Beyond

With rising global food prices and the effects of the COVID-19 pandemic, Algeria adopted a more diversified strategy to strengthen its agricultural and agro-industrial sectors. The country continues to prioritize agricultural investment to achieve its food security goals by 2030. Recent policies emphasize resilience and sustainability, with investments focused on climate-smart agriculture, improved seed varieties, and Renewable energy applications in farming to enhance resource efficiency and productivity, particularly in response to water scarcity challenges (Ferrah, 2021).

4. Empirical study

4.1 Data and model specification

4.1.1 Data Presentation: The data used in this study are obtained from the Arab Organization for Agricultural Development (AOAD) statistical books and the National Office for Statistics (ONS). These annually observed data cover the period 1990 to 2022.

The table below provides details on the variables of interest.

Table 1: Variables used in the study

Variables	Description	Expected effects	Sources
GADP	gross domestic agricultural production (Million Algerian Dinars)		Arab Organization for Agricultural Development (AOAD)
GFCF	gross fixed capital formation represents investment (Million Algerian Dinars)	Positive	National Office for Statistics (ONS)
IRLA	irrigated land (thousand hectares)	Positive	Arab Organization for Agricultural Development (AOAD)
ALAB	agricultural labor (Worker)	Positive	Arab Organization for Agricultural Development (AOAD)

Source: Elaborated by the author.

4.1.2 Model Specification

To assess the impact of investment on the performance of Algeria's agricultural sector and determine whether it serves as an effective tool for enhancing food security, we employ an Autoregressive Distributed

Lag (ARDL) model. This model, which falls within the class of dynamic models, is particularly useful for capturing temporal effects in explaining variable relationships.

In an ARDL model, the dependent variable (Y_t) is explained by its lagged values and by the current and lagged values of independent variables (X_t).

$$Y_t = a_0 + \sum_{i=1}^p a_i Y_{t-i} + \sum_{j=0}^q b_j X_{t-j} + e_t \dots (1)$$

With (e_t): error term; (b_j) represents the short-term effect of X on Y.

If we consider the following long-term or equilibrium relationship

$Y_t = \alpha + \beta X_t + u_t$, we can calculate the long-term effect of X on Y

(denoted as β) as follows: $\beta = \frac{\sum b_j}{1 - \sum a_i}$

As part of this study, which examines the impact of investment on agricultural sector growth in Algeria, we specify the following functional form:

$$GADP = f(GFCF, IRLA, ALAB) \dots (2)$$

The general version of the ARDL model can be expressed as:

$$GADP_t =$$

$$a_0 + \sum_{i=1}^p a_{1i} GADP_{t-i} + \sum_{j=0}^q a_{2i} GFCF_{t-j} + \sum_{j=0}^q a_{3i} IRLA_{t-j} + \sum_{j=0}^q a_{4i} ALAB_{t-j} + e_t \dots (3)$$

Estimation is carried out using the Ordinary Least Squares (OLS) method. Following this, an F-test is performed to test the existence of a long-term relationship between the variables. The model associated with the bounds cointegration test follows the unrestricted error correction version of the ARDL model specification:

$$\Delta GADP_t = B + b_1 GADP_{t-1} + b_2 GFCF_{t-1} + b_3 IRLA_{t-1} + b_4 ALAB_{t-1} + \sum_{i=1}^p a_{1i} \Delta GADP_{t-i} + \sum_{j=0}^q a_{2i} \Delta GFCF_{t-i} + \sum_{j=0}^q a_{3i} \Delta IRLA_{t-i} + \sum_{j=0}^q a_{4i} \Delta ALAB_{t-i} + \theta u_{t-1} + e_t \dots (4)$$

Pesaran's cointegration bounds test is used to verify the following hypotheses:

$H_0: b_1 = b_2 = b_3 = b_4 = 0$, (This implies that all coefficients are null, indicating the absence of cointegration between the variables of interest.)

$H_1: \exists b_i \neq 0$ (This suggests that at least one coefficient is statistically significant, implying the presence of cointegration between the variables.)

The calculated test statistic is compared to the critical values, leading to three possible cases:

- If the Fisher value exceeds the upper bound, cointegration exists between the two variables.
- If the Fisher value is below the lower bound, no cointegration is present.
- If the Fisher value falls between the two bounds, no definitive conclusion can be drawn.

If a cointegration relationship is established, the long-term model can be specified (as mentioned above), and the error correction version of the ARDL model is given by:

$$\Delta GADP_t =$$

$$a_0 + \sum_{i=1}^p a_{1i} \Delta GADP_{t-i} + \sum_{j=0}^q a_{2j} \Delta GFCF_{t-j} + \sum_{j=0}^q a_{3j} \Delta IRLA_{t-j} + \sum_{j=0}^q a_{4j} \Delta ALAB_{t-j} + \theta u_{t-1} + e_t \dots (4)$$

Where u_{t-1} is the error correction term resulting from the verified long-term equilibrium relationship, and θ is a parameter indicating the speed of adjustment to the equilibrium level after a shock. The sign of θ must be negative and significant to ensure the convergence of the dynamic process toward long-term equilibrium.

The ARDL Bound Testing approach is chosen over other cointegration techniques for several reasons:

- Suitability for Small Sample Sizes: According to Pesaran et al. (2001), the ARDL approach is more appropriate for studies with small sample sizes. In contrast, Johansen's cointegration technique requires a large sample size to obtain reliable results.
- Flexibility in Handling Different Data Orders: The ARDL model can be applied when variables are all I(1), all I(0), or a combination of both, unlike conventional cointegration tests that require variables to be of the same order of integration.
- Robustness in Estimating Long-term Coefficients: The ARDL model provides a consistent estimator of long-term relationships, regardless

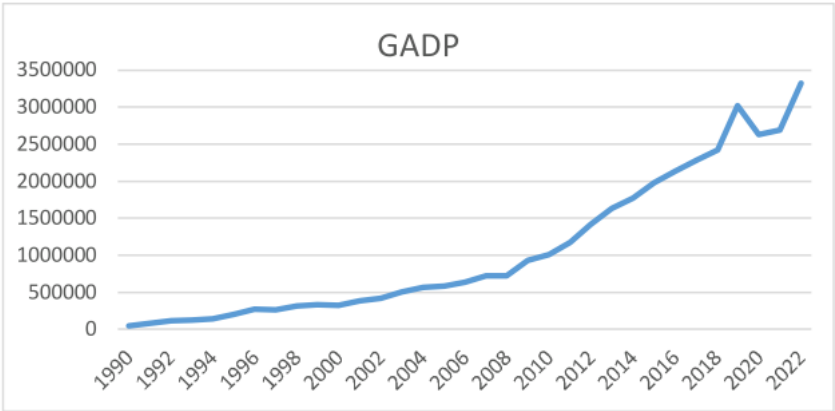
of whether the variables are purely I(0), purely I(1), or mutually cointegrated as stated by Pesaran et al., 2001 (Hechmy, 2016).

4.1.3 Descriptive Analysis of Variables

Graphical visualization of the variables allows us to observe their variations over the period from 1990 to 2022.

a. Gross Domestic Agricultural Production (GADP): Gross Domestic Agricultural Production (GADP) represents the agricultural sector’s contribution to the economy in terms of total value produced. The data reveal a consistent upward trend from 1990 to 2022, with the mean GADP indicating substantial overall growth in agricultural output. The lowest value occurred in 1990, reflecting modest production levels, while the highest value in 2022 highlights significant progress. This growth trend can be attributed to investments in agricultural infrastructure, technological advancements, and policy reforms aimed at boosting productivity. However, the high standard deviation suggests that growth was not uniform, likely due to fluctuations in investment levels, weather conditions, and global market dynamics.

Fig. 1: Evolution of Gross Domestic Agricultural Production (1990–2022)



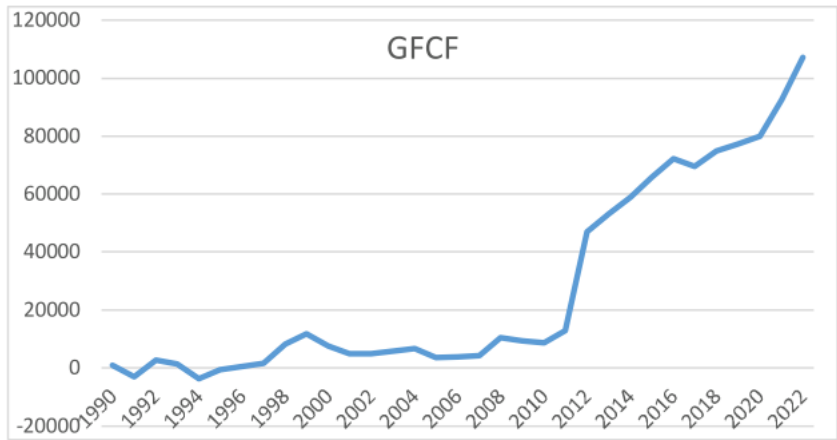
Source: Elaborated by the author based on AOAD data .

b. Gross Fixed Capital Formation (GFCF): Gross Fixed Capital Formation (GFCF) measures investment in agriculture and exhibits

considerable volatility throughout the study period, with an average annual growth rate of 7.8%. While the mean and median values suggest moderate investment levels, the data reveal significant variability.

Periods of negative values indicate instances of disinvestment, potentially due to economic and security crises in the 1990s. In contrast, peak values correspond to increased capital inflows, particularly in recent years, aimed at modernizing the agricultural sector. The large gap between minimum and maximum values, along with a high standard deviation, suggests substantial fluctuations in agricultural investment, which may have influenced production levels in certain years.

Fig. 2: Evolution of Gross Fixed Capital Formation (1990–2022)

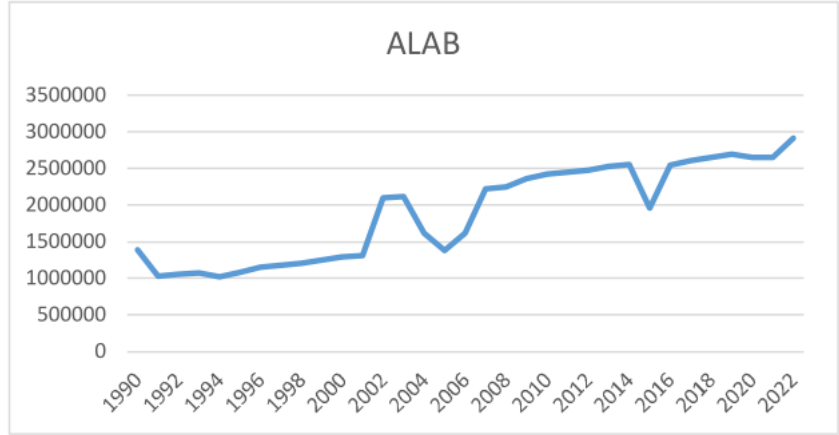


Source: Elaborated by the author based on ONS data

c. Agricultural Labour (ALAB): The trend in Agricultural Labor reflects the dynamic nature of the agricultural labour market, influenced by economic, structural, and environmental factors. The long-term upward trend highlights the sector’s role in labour absorption, while fluctuations may indicate policy adjustments, technological shifts, or external economic factors. However, agricultural labour as a share of total employment has steadily declined, with a negative average annual growth rate of -2.4%. This

trend reflects structural transformations in the economy, including urbanization, industrialization, and increased mechanization in agriculture. While the sector employed approximately 20% of the workforce in 1990, this figure dropped to below 10% by 2022 (Trading Economics, n. d). This decline suggests a transition toward capital-intensive agricultural practices, requiring fewer workers while maintaining or increasing productivity.

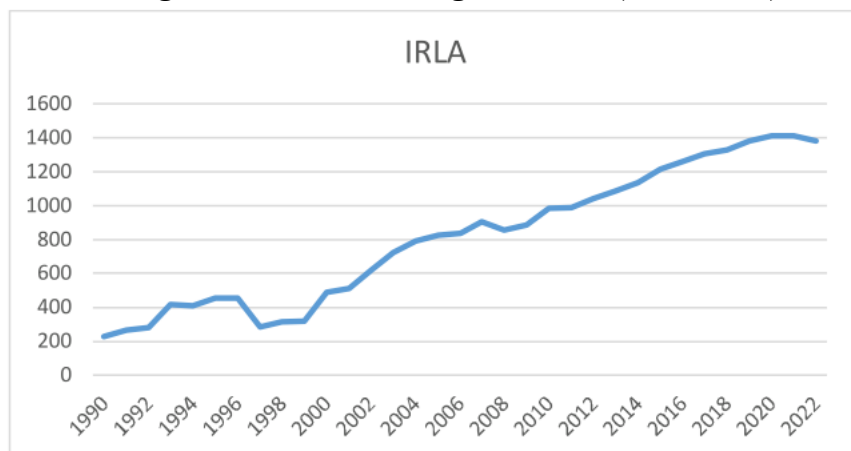
Fig. 3: Evolution of Agricultural Labor (1990–2022)



Source: Elaborated by the author based on AOAD data.

d. Irrigated Land (IRLA): Irrigated land, measured in millions of hectares, has steadily expanded, reflecting ongoing efforts to improve irrigation infrastructure in Algeria. The average values indicate continuous growth, with a relatively smooth progression and no significant anomalies. This trend aligns with policies aimed at enhancing agricultural productivity in arid and semi-arid regions. The maximum recorded value of 1.413 million hectares marks a peak in irrigation investments, while the minimum values at the beginning of the period reflect modest initial infrastructure. The low standard deviation suggests a consistent and uniform progression, highlighting sustained efforts to improve irrigated land.

Through this graphical visualization, we assume the non-stationarity of our variables in terms of the mean.

Fig. 4: Evolution of Irrigated Land (1990–2022)

Source: Elaborated by the author based on AOAD data.

4.2 Stationarity Test (ADF)

Before conducting the cointegration test, it is necessary to perform a unit root test to determine whether the time series are stationary. A time series whose mean and/or variance changes over time is considered non-stationary. If non-stationarity is not addressed, it can lead to spurious regressions, producing misleading statistical inferences.

Several tests can be used to assess stationarity (i.e., the presence of a unit root), including:

The Augmented Dickey-Fuller (ADF) test, The Phillips-Perron (PP) test, and The Kwiatkowski-Phillips-Schmidt-Shin (KPSS) test.

The ADF test is particularly useful in cases of autocorrelated errors, while the PP test is more appropriate when heteroskedasticity is present (Bourbonnais, 2007).

In this study, we apply the Augmented Dickey-Fuller unit root test. The results are presented in Table 2 below:

Table 2: ADF Unit Root Test Results

At Level					
		GADP	GFCF	IRLA	ALAB
With Constant	t-Statistic	3.8223	1.7284	-0.3449	-1.0881
	Prob.	1.0000	0.9995	0.9070	0.7078
		n0	n0	n0	n0
With Constant & Trend	t-Statistic	-0.4601	-0.7300	-4.5466	-0.8620
	Prob.	0.9800	0.9619	0.0063	0.9480
		n0	n0	***	n0
Without Constant & Trend	t-Statistic	-0.7842	3.0243	2.9341	-3.2846
	Prob.	0.3673	0.9989	0.9987	0.0018
		n0	n0	n0	***
At First Difference					
		d(GADP)	d(GFCF)	d(IRL)	d(LAB)
With Constant	t-Statistic	-1.6459	-4.1389	-5.4477	-6.4162
	Prob.	0.4471	0.0030	0.0001	0.0000
		n0	***	***	***
With Constant & Trend	t-Statistic	-7.7393	-4.7168	-5.3514	-6.0662
	Prob.	0.0000	0.0035	0.0007	0.0001
		***	***	***	***
Without Constant & Trend	t-Statistic	-0.0576	-3.4425	-2.2018	-5.1259
	Prob.	0.6549	0.0012	0.0288	0.0000
		n0	***	**	***

Source: Elaborated by the author using EViews 12.

Based on the results shown in Table 2, the Irrigated Land (IRLA) and Agricultural Labour (ALAB) series are stationary at level (I(0)). In contrast, the Gross Domestic Agricultural Production (GADP) and Gross Fixed Capital Formation (GFCF) series are integrated at order 1 (I(1)), meaning they become stationary after first differencing. Since the series are integrated at different orders, the bounds cointegration test is deemed appropriate.

4.3 Cointegration Test by Pesaran et al. (2001)

As previously highlighted, because the variables are integrated at different orders, and none of them is I(2) (as ARDL modeling is not

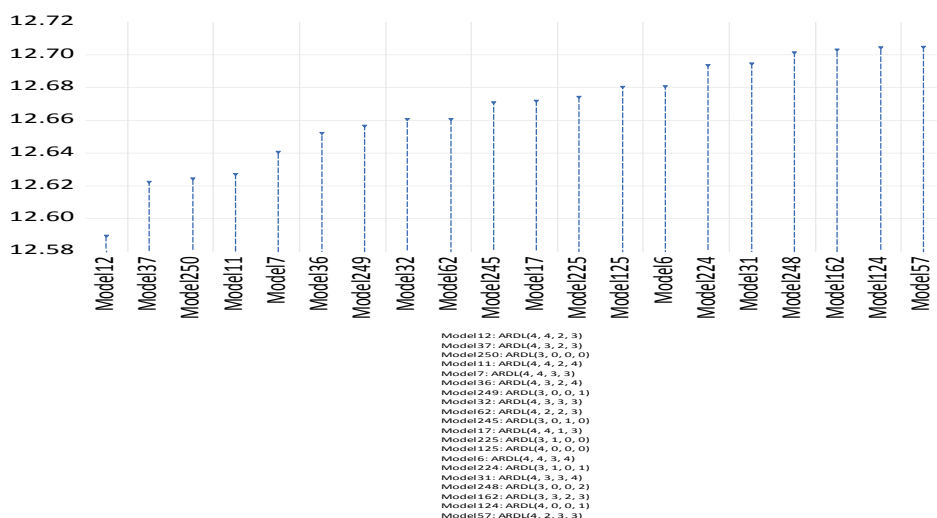
valid for series that are stationary at the second difference), the bounds test by Pesaran et al. (2001) is the most suitable approach.

4.3.1 Optimal ARDL Model Selection and Estimation

Before applying the cointegration test, we must first select the most optimal ARDL model and then proceed with its estimation.

To identify the optimal ARDL model, which provides statistically significant results with the fewest parameters, we use the Akaike Information Criterion (AIC). Figure 5 below illustrates the top 20 models ranked according to the AIC criterion:

Fig. 5: Akaike Information Criterion (Top 20 Models)



Source: Elaborated by the author using EViews 12.

Based on the Akaike Information Criterion (AIC) and Figure 5, the ARDL (4,4,2,3) model is identified as the most optimal among the tested models, as it yields the smallest AIC value.

Table 3 presents the estimation results of the selected optimal ARDL (4,4,2,3) model.

Table 3: Optimal ARDL model estimation

Variable	Coefficient	Std. Error	t-Statistic	Prob.
GADP(-1)	-0.472886	0.332074	-1.424038	0.1799
GADP(-2)	-1.244676	0.553835	-2.247379	0.0442
GADP(-3)	-0.780915	0.710982	-1.098361	0.2987
GADP(-4)	2.658247	1.436325	1.850728	0.0938
GFCF	0.017402	0.004798	3.626910	0.0035
GFCF(-1)	-0.002203	0.007173	-0.307119	0.7639
GFCF(-2)	0.007101	0.007073	0.973692	0.3482
GFCF(-3)	0.008360	0.005445	1.535423	0.1514
GFCF(-4)	-0.006537	0.005763	-1.133754	0.2765
IRLA	-0.824805	0.525551	-1.569412	0.1373
IRLA(-1)	0.436174	0.570250	0.764883	0.4951
IRLA(-2)	0.630388	0.450231	1.400634	0.1879
ALAB	3.76E-05	0.000102	0.308924	0.7677
ALAB(-1)	0.000133	0.000116	1.142326	0.2735
ALAB(-2)	0.000095	0.000102	0.931697	0.3388
ALAB(-3)	0.000241	0.000132	1.830138	0.0922
C	-406.5331	155.9643	-2.606578	0.0289
Statistic		Value	Statistic	Value
R-squared		0.994155	Mean dependent var	1200.654
Adjusted R-squared		0.986362	S.D. dependent var	970.8066
S.E. of regression		113.3715	Akaike info criterion	12.58942
Sum squared resid		154237.2	Schwarz criterion	13.39076
Log likelihood		-165.5440	Hannan-Quinn criter.	12.84027
F-statistic		127.5704	Durbin-Watson stat	2.020288
Prob(F-statistic)		0.000000		

Source: Author's estimation using Eviews 12.

4.3.2 Diagnostic Tests

At this stage, we assess the validity of the estimated model using a series of diagnostic tests, including: The Breusch-Godfrey test for autocorrelation, The Breusch-Pagan-Godfrey test for heteroskedasticity, The Jarque-Bera test for normality of residuals, and The CUSUM test for model stability.

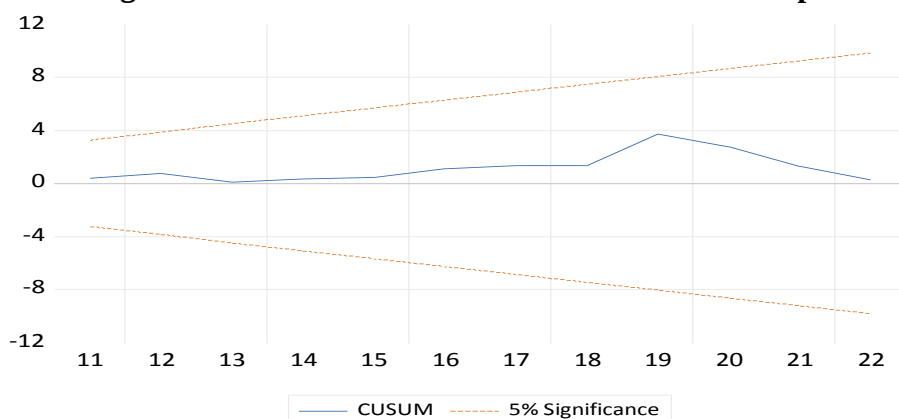
Table 4: Model Validity Tests

Hypothesis	Tests	Test statistic	Value	Prob
Autocorrelation	Breusch-Godfrey	F Statistic	- 0.2749	0.7652
Heteroscedasticity	Breusch-Pagan-Godfrey	F Statistic	- 0.5387	0.8767
Normality	Jarque-Bera	JB Statistic	1.6881	0.4299

Source: Author's elaboration based on the appendices.

The ARDL (4,4,2,3) model provides a statistically satisfactory specification, explaining 99.41% of the observed variability in GADP in Algeria between 1990 and 2022. At a 5% significance level, the null hypothesis is accepted for all robustness tests, confirming that the residuals satisfy the model's validity conditions—namely normality, homoscedasticity, and absence of autocorrelation.

Even when a cointegration relationship exists, results may be unreliable if the model's parameters are unstable over time. The CUSUM test, which analyses the cumulative sum of recursive residuals, is particularly relevant for evaluating model stability.

Fig. 6: Cumulative Sum of Recursive Residuals Graph

Source: Author's estimation using EViews 12.

The CUSUM test results indicate that the estimated model is stable, as the curve remains within the critical bounds (dotted corridor). This confirms that the coefficients remain stable over time.

4.3.3 Cointegration Bounds Test

Following the methodology proposed by Pesaran et al. (2001), we test the null hypothesis of no cointegration among the variables against the alternative hypothesis that a long-term relationship exists.

The testing procedure involves comparing the computed bounds values with the Fisher statistic:

- If the Fisher value exceeds the upper bound, we reject the null hypothesis, confirming cointegration.
- If the Fisher value falls below the lower bound, we fail to reject the null hypothesis, indicating no cointegration.

Table 5: ARDL Bounds Test Results

Test Statistic	Value	Significance Level	I(0)	I(1)
Asymptotic: n=1000				
F-statistic	27.08740	10%	2.37	3.2
K	3	5%	2.79	3.67
		2.5%	3.15	4.08
		1%	3.65	4.66
Actual Sample Size	28	Finite Sample: n=35		
		10%	2.618	3.532
		5%	3.164	4.194
		1%	4.428	5.816
		Finite Sample: n=30		
		10%	2.676	3.586
		5%	3.272	4.306
		1%	4.614	5.966

Source: Author's estimation using EViews 12.

The bounds cointegration test results confirm the existence of a cointegration relationship among the variables, as the F-statistic value (27.0874) exceeds the upper bound at the 5% critical threshold. This finding supports the estimation of long-term effects among the studied variables.

4.4 Empirical Results and Interpretation

4.4.1. Short-Run Coefficients and Dynamics

Table 6 presents the Error Correction Model (ECM) results, which examine short-term relationships among the variables and adjustments toward long-term equilibrium.

Table 6: Error Correction Model Estimation

Variable	Coefficient	Std. Error	t-Statistic	Prob.	
D(GADP(-1))	-0.632657	0.143430	-4.410898	0.0008	
D(GADP(-2))	-1.877333	0.376781	-4.982562	0.0003	
D(GADP(-3))	-2.658247	0.741963	-3.582721	0.0038	
D(GFCF)	0.017402	0.004798	3.626910	0.0035	
D(GFCF(-1))	-0.008923	0.004559	-1.957319	0.0740	
D(GFCF(-2))	-0.001822	0.003196	-0.570227	0.5790	
D(GFCF(-3))	0.006537	0.003529	1.852356	0.0883	
D(IRLA)	-0.824805	0.394999	-2.088118	0.0582	
D(IRLA(-1))	-0.630388	0.362186	-1.740509	0.1083	
D(ALAB)	3.76E-05	8.04E-05	0.467928	0.6428	
D(ALAB(-1))	-0.000395	0.000122	-3.228136	0.0238	
D(ALAB(-2))	-0.000241	9.95E-05	-2.424910	0.0320	
CointEq(-1)	-0.840229	0.172084	-4.882665	0.0004	
Statistic		Value	Statistic		Value
R-squared		0.830176	Mean dependent var		110.2300
Adjusted R-squared		0.702808	S.D. dependent var		180.1132
S.E. of regression		98.12861	Akaike info criterion		12.31398
Sum squared resid		154237.2	Schwarz criterion		12.50534
Log likelihood		-165.5440	Hannan-Quinn criter.		12.50534
Durbin-Watson stat		2.020288			

Source: Author's estimation using EViews 12.

The error correction coefficient is negative and statistically significant, validating the adjustment toward long-term equilibrium. Specifically, 84.02% of deviations from long-term equilibrium are corrected each period, suggesting a rapid convergence toward equilibrium.

Current variations in Gross Fixed Capital Formation (GFCF) have a significant and positive impact on Gross Domestic Agricultural Production (GADP), indicating that investment in fixed capital immediately stimulates agricultural production. However, lagged variations of GFCF are not significant in the short term.

Contemporary and one-period lagged variations in Agricultural Labor (ALAB) are insignificant. However, the two-period lagged variation of ALAB significantly negatively affects GADP, possibly reflecting structural adjustments in labor utilization.

Variations in Irrigated Land (IRLA) do not significantly impact GADP in the short run. However, while short-term effects are negligible, the irrigated land may play a crucial role in the long term, warranting further analysis over an extended time horizon.

4.4.2. Long-Run Coefficients

Table 7 presents the long-run estimation results, showing that all explanatory variables are statistically significant at the 5% level.

Table 7: Long-Run Coefficients Estimation Results

Variable	Coefficient	Std. Error	t-Statistic	Prob.
GFCF	10.06139	3.285507	3.125552	0.0074
IRLA	894.0791	228.3465	3.915449	0.0016
ALAB	0.654605	0.275923	2.372417	0.0352
C	- 474952.09121 1	169318.34641 5	- 2.805083	0.0159
EC = GADP - (10.0614*GFCF + 894.0791*IRLA + 0.6546*ALAB - 474952.0912)				

Source: Author's estimation using EViews 12.

Investment (GFCF) has a positive and significant impact on agricultural production (GADP) in Algeria, reinforcing its role as a key driver of production growth. In the long run, an increase in GFCF by one million dinars leads to a 10.06 million dinar rise in GADP, confirming that fixed capital investments enhance agricultural efficiency and modernization.

Agricultural Labor (ALAB) also significantly contributes to long-term production growth. A one-unit increase in agricultural labor results in a 0.65 million dinar increase in GADP. Although its numerical impact is smaller compared to GFCF and IRLA, its significance highlights the continued importance of human capital in agriculture, particularly in labor-intensive farming systems.

Irrigated Land (IRLA), unlike in the short term, has a major long-term impact on GADP. An increase of 1,000 hectares in IRLA leads to an 894.08 million dinar increase in GADP, confirming that irrigation is a critical factor for agricultural productivity. By enabling higher yields and reducing dependence on climatic conditions, irrigation plays a pivotal role in enhancing long-term agricultural output.

The negative constant term suggests the presence of structural constraints that could limit agricultural growth unless appropriate policy measures are implemented.

5. Conclusion

This research provides empirical evidence of the critical role of investment in driving the growth of the Algerian agricultural sector. The findings indicate that investment in fixed capital, agricultural labour, and irrigation infrastructure significantly contributes to long-term agricultural productivity. While short-term effects vary, the long-run analysis confirms that an increase of one million dinars in investment leads to a 10.06 million dinar increase in agricultural production. Similarly, irrigated land expansion and labour availability positively influence agricultural output, highlighting the importance of effective resource management.

However, climatic variability, inefficient resource allocation, and reliance on food imports continue to constrain sectoral growth. Policymakers should prioritize strategic investments in sustainable irrigation systems, mechanization, and human capital development to enhance agricultural resilience and reduce food dependency. Future research could explore the impact of technological advancements and climate change adaptation strategies on Algeria's agricultural performance.

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7. Appendices

Autocorrelation test: Breusch-Godfrey

Breusch-Godfrey Serial Correlation LM Test:
Null hypothesis: No serial correlation at up to 2 lags

F-statistic	0.274916	Prob. F(2,10)	0.7652
Obs*R-squared	1.511411	Prob. Chi-Square(2)	0.4697

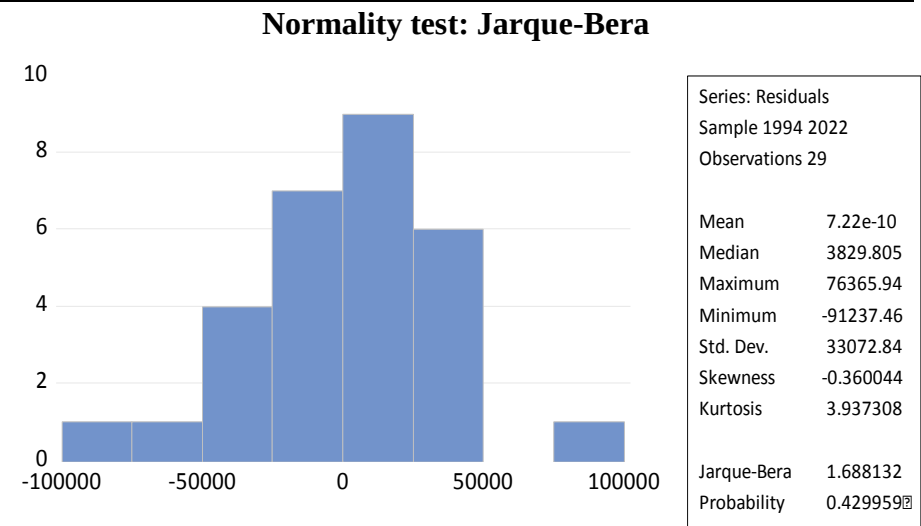
Source: Author’s estimation using EViews 12.

Heteroscedasticity test: Breusch-Pagan-Godfrey

Heteroskedasticity Test: Breusch-Pagan-Godfrey
Null hypothesis: Homoskedasticity

F-statistic	0.538771	Prob. F(16,12)	0.8767
Obs*R-squared	12.12346	Prob. Chi-Square(16)	0.7354
Scaled explained SS	3.912495	Prob. Chi-Square(16)	0.9990

Source: Author’s estimation using EViews 12.



Source: Author’s estimation using EViews 12.