

Agricultural Contributions to Economic Development in Algeria: An ARDL Model

مساهمات القطاع الزراعي في التنمية الاقتصادية بالجزائر: نموذج ARDL

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Abstract:

This study examines the role of agriculture in Algeria's economic development, focusing on its contributions to GDP and employment using an Autoregressive Distributed Lag (ARDL) model. The research investigates both short- and long-term relationships between agricultural factors and economic growth, with data spanning from 1990 to 2022. Empirical results show that agricultural indicators, particularly freshwater withdrawals and R&D investments, significantly impact economic growth in the long term. Conversely, short-term impacts appear weaker, with employment in agriculture showing initial negative effects due to workforce adjustments. Diagnostic tests confirm the model's reliability, underscoring the resilience of Algeria's agricultural sector. This study suggests that enhancing water management, increasing R&D funding, and balancing labor with mechanization are essential strategies for optimizing agricultural contributions to sustainable economic growth in Algeria.

Keywords: Agriculture; Economic Development; ARDL Model; Algeria; Resource Allocation.

JEL Classification Codes : Q18 ; O13

ملخص:

تدرس هذه الدراسة دور الزراعة في التنمية الاقتصادية في الجزائر، مع التركيز على مساهماتها في الناتج المحلي الإجمالي والعمالة باستخدام نموذج الانحدار الذاتي للتأخر الموزع. ويبحث البحث في العلاقات قصيرة وطويلة الأجل بين العوامل الزراعية والنمو الاقتصادي، مع بيانات تمتد من عام 1990 إلى عام 2022. وتُظهر النتائج التجريبية أن المؤشرات الزراعية، وخاصة عمليات سحب المياه العذبة واستثمارات البحث والتطوير، تؤثر بشكل كبير على النمو الاقتصادي في الأمد البعيد. وعلى العكس من ذلك، تبدو التأثيرات قصيرة الأجل أضعف، حيث تظهر العمالة في الزراعة آثارًا سلبية أولية بسبب تعديلات القوى العاملة. وتؤكد الاختبارات التشخيصية موثوقية النموذج، مما يؤكد على مرونة القطاع الزراعي في الجزائر. وتشير هذه الدراسة إلى أن تعزيز إدارة المياه، وزيادة تمويل البحث والتطوير، وموازنة العمالة مع الميكنة هي استراتيجيات أساسية لتحسين المساهمات الزراعية في النمو الاقتصادي المستدام في الجزائر.

كلمات مفتاحية: قطاع الزراعة؛ التنمية الاقتصادية؛ نموذج أردل؛ الجزائر؛ تخصيص الموارد.

تصنيفات JEL : Q18 ; O13

INTRODUCTION:

Agriculture has historically been a fundamental sector in supporting economic growth and development in many countries, serving as a source of employment, income, and sustenance (Ichime et al., 2024). In Algeria, the agricultural sector holds a strategic position within the national economy (Zemri & Khetib, 2023). Despite its reliance on the energy sector as a primary economic driver, Algeria recognizes the potential of the agricultural sector to diversify its economy and create pathways for sustainable development. With the increasing global emphasis on agricultural contributions to economic resilience, particularly in developing economies, Algeria is seeking to leverage its agricultural resources to promote broader economic development.

In recent decades, Algeria has made various attempts to stimulate its agricultural sector through policies aimed at enhancing productivity, increasing agricultural investments, and modernizing farming practices (Imen & Reguia, 2023). These efforts, though significant, have yet to reveal their full impact on Algeria's long-term economic growth. Thus, a rigorous analysis of the agricultural sector's contribution to Algeria's economic development is warranted, as it can provide insights for policymakers to optimize the role of agriculture in the country's economic framework.

The challenge facing Algeria today is to effectively mobilize and capitalize on its agricultural sector's potential to achieve sustainable economic growth (Haouas et al., 2024). Despite notable investments and policy reforms in agriculture, there is still limited empirical evidence on how agricultural development impacts the Algerian economy both in the short and long term. This study thus addresses the following core research question:

To what extent does the agricultural sector contribute to economic development in Algeria, and how can Algeria optimize this sector to achieve sustainable economic growth?

This question is particularly relevant in light of Algeria's strategic objectives to diversify its economy beyond hydrocarbons and reduce its vulnerability to global energy market fluctuations.

Based on the study problem, this research operates on the primary hypothesis that: There exists a long-term relationship between the contributions of the agricultural sector and economic growth in Algeria, wherein agricultural indicators such as production value, employment, and input utilization have a positive and measurable impact on Algeria's economic development. This hypothesis will be tested to verify whether agricultural investments and productivity translate into significant contributions to national economic growth.

This study employs the Autoregressive Distributed Lag (ARDL) model to examine the dynamic relationship between agricultural variables and economic development. The ARDL approach is selected for its ability to assess both short-term and long-term relationships, even when variables exhibit mixed integration orders ($I(0)$ and $I(1)$). This makes ARDL particularly suitable for analyzing time series data in developing economies like Algeria, where different economic indicators often fluctuate.

The analysis will involve gathering data on Algeria's agricultural indicators and economic development measures over a specified period, applying stationarity tests, and conducting diagnostic tests to validate the ARDL model. This methodological approach ensures a

comprehensive analysis of the agricultural sector's impact on economic growth, covering both immediate and sustained effects.

This study holds considerable importance as it contributes to understanding the agricultural sector's role in Algeria's economic framework. By exploring the relationship between agriculture and economic development, this research highlights how agriculture could support Algeria's economic diversification agenda. A clear understanding of agriculture's contribution to GDP, employment, and economic resilience is essential for policymakers aiming to harness agricultural potential and promote balanced growth. Additionally, as Algeria faces challenges related to food security, employment, and resource allocation, identifying agriculture's economic impact can aid in formulating policies that enhance its productivity and contributions to national wealth. This study thus provides an evidence-based foundation for strategic decision-making that aligns agricultural goals with national economic priorities.

The unique value of this study lies in its focus on Algeria and the use of the ARDL model to elucidate both short-term and long-term impacts of agricultural variables on economic growth. While previous studies have investigated the agricultural sector's economic role in various developing countries, there is a research gap concerning Algeria's specific agricultural contributions. By applying ARDL, this research brings a detailed analysis of how agricultural factors such as employment rates, fertilizer consumption, water usage, and research spending influence economic development over time. Furthermore, this study provides nuanced insights that can guide Algeria in strengthening the agriculture sector's efficiency, resource management, and economic contribution, thus adding to the field's understanding of sectoral impacts in an oil-dependent economy.

The next section provides a brief literature review, followed by an outline of the methodology and data collection techniques. Subsequently, the results addressing the research question are analyzed. The paper concludes with a summary of key findings and recommendations based on the study's outcomes.

1- Literature review:

The relationship between agriculture and economic development has been extensively studied, particularly within developing countries. Agriculture is often viewed as a foundational sector, contributing to economic growth by providing employment, raw materials, and food security. Notably, Anser et al. (2023) emphasizes that agricultural development is a powerful tool to end extreme poverty and boost shared prosperity, observing that growth in the agriculture sector can be two to four times more effective in raising incomes among the poorest compared to other sectors.

In Algeria, the agricultural sector holds a unique place in the national economy. Despite being an oil-dependent economy, Algeria has made considerable investments in agriculture to diversify its economic base and reduce its vulnerability to global oil price fluctuations. Studies (Haouas et al., 2024; Kadri, 2023) have shown that agricultural investment and employment are critical drivers of Algeria's agricultural GDP. For instance, empirical research (Zemri & Khetib, 2023) indicates that in the long run, a 1% increase in agricultural employment can lead to a 3.73% rise in agricultural GDP, while a 1% increase in agricultural investment can boost agricultural GDP by approximately 0.43%.

The Autoregressive Distributed Lag (ARDL) model is frequently used in examining the agricultural sector's contribution to economic growth. This model is particularly valuable for studying both short- and long-term relationships among variables, making it ideal for agricultural-economic research. Prior studies using ARDL modeling (Abdelgawwad & Kamal, 2023; Hassan & Mohamed, 2024; Samatar, 2023; Yadav & Goyari, 2024), have confirmed that agricultural productivity significantly contributes to economic growth, albeit with varying degrees of impact across different countries. These studies often focus on indicators like agricultural value added, labor force participation in agriculture, and input measures such as fertilizer use and water consumption.

In their study, Tahir (2022) investigated the causal relationship between agriculture and economic growth in Nigeria using the ARDL bounds testing approach. They found that agricultural productivity has a significant long-term positive impact on economic growth, while short-term fluctuations were less pronounced. The study's findings emphasize the importance of sustained investment in agricultural productivity as a means of achieving long-term economic stability. This research serves as a comparative foundation, indicating that Algeria might experience similar long-term benefits from focused agricultural development, especially given its reliance on primary industries.

Qing et al. (2019) conducted a study focusing on the impact of agricultural investment and employment on economic growth in China over a 40-year. Using an ARDL model, the researchers found that a 1% increase in agricultural investment leads to a 0.42% increase in GDP, while a similar increase in employment generates an even greater impact. This study demonstrates that increased labor allocation and resource investment in agriculture can have substantial effects on GDP, which is particularly relevant for Algeria. By focusing on both investment and employment, this study highlights key variables that our research also considers, enabling a detailed analysis of Algeria's agricultural sector.

Salim et al. (2020) research focused on Bangladesh, examining the relationship between agricultural R&D expenditure and economic growth from 1980 to 2019. The researchers employed ARDL modeling and found a significant positive relationship between agricultural R&D investment and economic growth, both in the short and long term. Their results underscore the need for developing countries to invest in agricultural innovation and technology to increase productivity and resilience in the face of challenges like climate change. This study's emphasis on R&D provides a valuable reference point for the Algerian context, where investment in agricultural R&D has been relatively underutilized but holds promise for enhancing agricultural productivity and economic growth.

However, there remains a notable research gap in existing literature, particularly regarding the specific dynamics of Algeria's agricultural sector within its broader economic context. Many studies focus on general agricultural trends in developing economies without a detailed focus on the unique economic conditions in Algeria. Furthermore, existing research often overlooks the role of certain critical agricultural indicators, such as research and development (R&D) expenditure, employment shifts within agriculture, and the impact of water and fertilizer usage. These variables could have significant implications for Algeria's economic development trajectory.

Our study seeks to address this gap by focusing on a comprehensive set of agricultural variables—including employment, investment, water and fertilizer consumption, and R&D spending—and examining their impact on Algeria's economic growth through the ARDL model. By including these underrepresented variables and analyzing both short-term and long-term effects, this research will provide a more nuanced understanding of agriculture's role in Algeria's economic development. This study distinguishes itself by focusing on Algeria-specific data and analyzing indicators that have not been thoroughly explored in prior research, offering valuable insights that can inform future agricultural and economic policies in Algeria. This approach not only enhances our understanding of the agricultural sector's contributions but also underscores the strategic importance of targeted investments and innovations in agriculture for Algeria's economic diversification and resilience.

2- Methodology:

2-1 Method

This study utilizes the Autoregressive Distributed Lag (ARDL) model to investigate the dynamic relationship between agricultural factors and economic growth in Algeria. The ARDL model, developed by (Pesaran et al., 1999), is especially well-suited for analyzing both short-run and long-run relationships between time series variables, as it is used to test cointegration and estimate short-term and long-term equilibrium relationships (Hammadi, 2024). Its flexibility in handling variables that are integrated at different levels ($I(0)$ or $I(1)$) makes it ideal for this study, where mixed integration orders are expected among the economic variables (Zemri & Khetib, 2024).

The methodology consists of the following key stages: (Nkoro & Uko, 2016)

To ensure the suitability of the ARDL model, it is essential first to establish the stationarity properties of each variable. Stationarity tests, such as the Augmented Dickey-Fuller (ADF) test and the Phillips-Perron (PP) test, are conducted to determine the order of integration for each variable. If a variable is stationary at levels ($I(0)$) or at first differences ($I(1)$), it can be included in the ARDL framework. However, if any variable is integrated at the second difference ($I(2)$), the ARDL model cannot be applied, as this violates one of its assumptions.

Selecting appropriate lag lengths for each variable is crucial for accurate model estimation. Information criteria such as the Akaike Information Criterion (AIC) and Bayesian Information Criterion (BIC) are used to determine the optimal lag structure. The selection of lags helps in capturing the temporal dependencies among variables, reducing the potential for serial correlation, and enhancing model accuracy.

The ARDL bounds testing approach, proposed by Pesaran et al. (2001), is used to test for a long-run relationship among the variables. This approach involves setting up an unrestricted error correction model (UECM) and testing for cointegration through the F-statistic. The null hypothesis of no cointegration (H_0 : no long-run relationship exists) is tested against the alternative hypothesis (H_1 : a long-run relationship exists) using specific critical values. If the computed F-statistic exceeds the upper bound of critical values, the null hypothesis is rejected, confirming the existence of a long-run relationship. If the F-statistic falls below the lower bound, the null hypothesis cannot be rejected, and no long-run relationship is confirmed. If the F-statistic falls between the bounds, the test results are inconclusive.

Once cointegration is confirmed, the next step involves estimating both the long-run coefficients and short-run dynamics within the ARDL model. The long-run coefficients help in

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understanding how a change in an independent variable affects the dependent variable (GDP) over the long term. The short-run dynamics are captured through the Error Correction Model (ECM), which indicates the speed of adjustment back to equilibrium after any short-term shock. The error correction term (ECT) is expected to be negative and statistically significant, reflecting the proportion of the disequilibrium corrected in each period.

After estimating the ARDL model, various diagnostic tests are conducted to ensure the robustness of the results:

Serial Correlation Test (e.g., Breusch-Godfrey LM test): To check for autocorrelation in residuals, ensuring the model is correctly specified.

Heteroscedasticity Test (e.g., Breusch-Pagan test): To confirm that residuals have constant variance, which is an assumption of OLS estimation.

Normality Test (e.g., Jarque-Bera test): To verify that residuals are normally distributed.

Stability Tests (e.g., CUSUM and CUSUMSQ tests): To check the stability of the model over the sample period, especially important for time series models where parameter stability is crucial for reliable forecasting.

The estimated coefficients from both the short-run and long-run models provide insights into how agricultural factors influence economic growth in Algeria over different time horizons. Long-run coefficients are interpreted as the equilibrium effects of each agricultural variable on economic growth, while short-run coefficients represent the immediate or short-term adjustments to any changes. The error correction term (ECT) also indicates the speed at which deviations from the long-run equilibrium are corrected each period, helping to assess the stability of the economic system.

2-2 Variables and data

This study uses annual time series data covering the period from 1990 to 2022. Data was sourced from reliable databases such as the World Bank, FAO (Food and Agriculture Organization), and national statistics sources specific to Algeria. The selection of variables was guided by the literature on agricultural impacts on economic development and the unique economic context of Algeria.

Dependent Variable:

Agriculture Value Added (Agri. Value (US\$)): Measures the direct economic contribution of agriculture to the national economy, showing how agricultural output affects GDP.

Employment in Agriculture (% of Total Employment): Reflects the proportion of the workforce engaged in agriculture, which influences productivity and economic growth.

Water Withdrawals (%): Indicates the intensity of resource allocation to agriculture, providing insight into resource dependency and its economic implications.

Fertilizer (kg/ha): Represents input intensity in agriculture, affecting crop yields and productivity.

R&D Researchers: Highlights investment in agricultural research and innovation, which can enhance productivity and resilience.

Each variable is analyzed within the ARDL model framework, aiming to explore both the short-term effects and long-term impact of agricultural factors on Algeria's economic development. Prior to running the ARDL model, stationarity tests such as the Augmented Dickey-Fuller (ADF) test and Phillips-Perron (PP) test will be applied to determine the

integration order of each variable and ensure compatibility with the ARDL requirements.

3- Findings and discussion:

3-1 Findings

Table (1): Descriptive statistics

Variable	Mean	Maximum	Minimum	Std. Dev.	Variance	Skewness	Kurtosis	Obs
Employment (%)	3.91	8.53	1.39	2.29	5.24	0.68	-0.85	33
Agri. Value (US\$)	2731253498.83	4176886236	2206466903	503916834.37	2.5393217596589978e+17	1.77	2.79	33
Water Withdrawals (%)	2378051986.96	3249745740	46.5	8030499372.77	6.448892017610063e+19	3.35	10.59	33
Fertilizer consumption (kg/ha)	1412933628.12	821,84531204	492.96	6776188137.98	4.5916725681276666e+19	4.8	23.0	33
R&D Researchers	7118035326.67	32497457409	2066.51	7429736723.66	5.520098778294146e+19	1.87	5.17	33
Agri. Land (%)	1412932936.92	5,97634	3.3	2.7761	4.591672772327677e+19	4.8	23.0	33

Source: Compiled by the authors.

The descriptive statistics in Table 1 provide a comprehensive overview of the key agricultural indicators in Algeria from 1990 to 2022. The mean employment rate in agriculture stands at approximately 3.91%, with a notable range from a minimum of 1.39% to a maximum of 8.53%, reflecting the gradual decrease in agricultural employment over the years. This variability is further illustrated by a standard deviation of 2.29%, indicating moderate fluctuations around the mean. The skewness value (0.68) suggests a slight positive skew in the distribution, while the negative kurtosis value (-0.85) implies a relatively flat distribution compared to a normal curve. The mean value of agriculture added to the GDP is around \$2.73 billion, with significant variability across years, ranging from a minimum of approximately \$2.2 billion to a peak of \$4.18 billion. This variable has a skewness of 1.77, indicating a right-skewed distribution with values concentrated toward the lower end. Additionally, the high kurtosis (2.79) suggests that extreme values were observed, reflecting occasional years of high agricultural output.

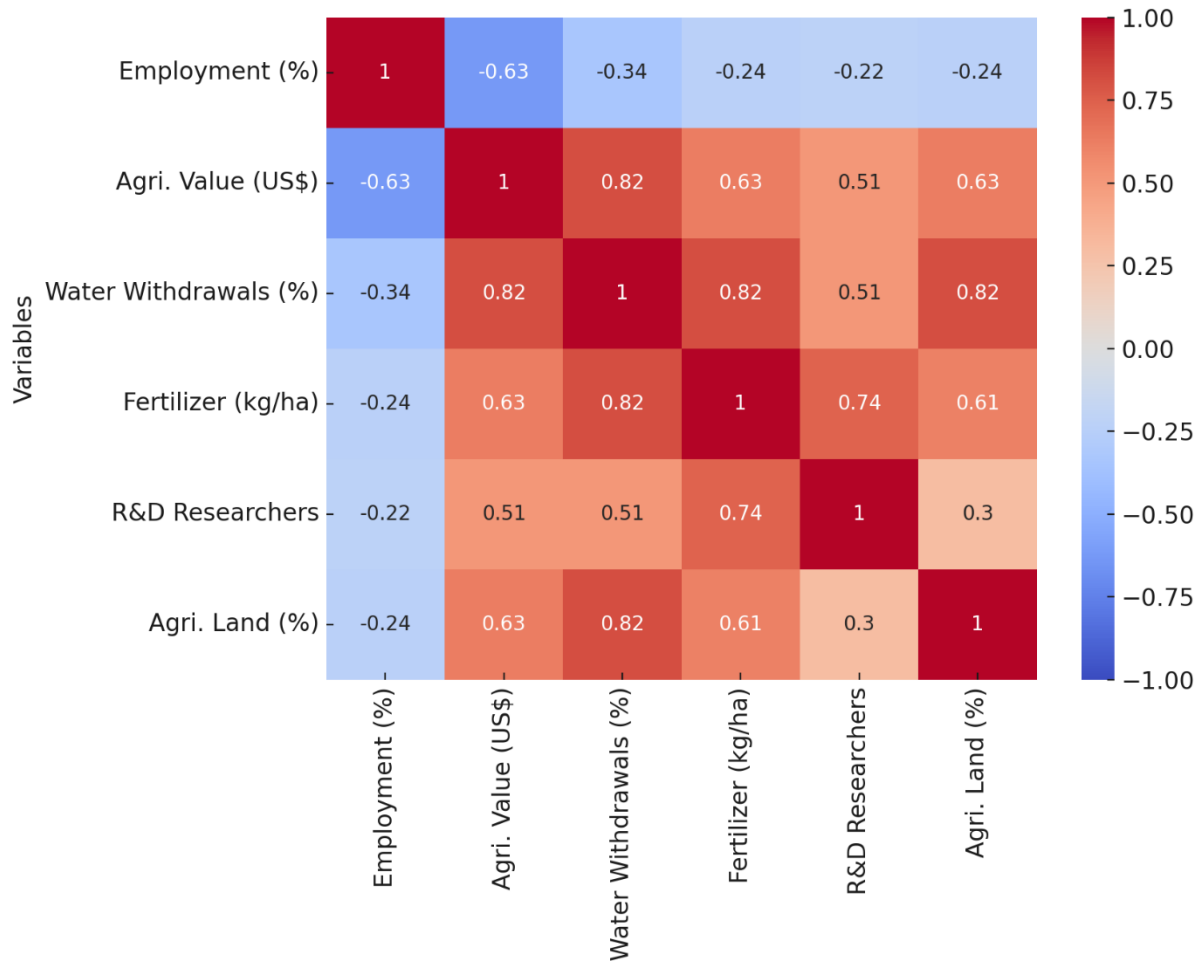
Annual freshwater withdrawals for agriculture show a high mean value of approximately 2.38 billion cubic meters, with a strikingly wide range from 46.5% to a peak of 3.25 billion. This significant spread, reflected in the variance and skewness values (3.35), may indicate inconsistent water resource allocation and potential impacts from climatic or policy changes affecting agriculture. The mean fertilizer consumption in Algeria is 1.41 billion kg/ha, though this metric fluctuates significantly, as indicated by the high standard deviation (6.78 billion kg/ha) and right-skewed distribution (skewness of 4.8). This variability suggests inconsistent use of fertilizers over the period, likely due to fluctuating availability and economic or policy factors affecting agricultural inputs.

Similarly, researchers in R&D per million people demonstrate high variability, with a mean of 7.12 billion but a wide distribution, ranging from a low of 2,066 to a maximum of over 32 billion. The high skewness (1.87) and kurtosis (5.17) imply that R&D investment in agriculture is sporadic, with occasional significant peaks, perhaps due to shifts in government priorities or

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external funding support. Agricultural land use shows a small standard deviation, suggesting stable land allocation percentages across the years.

Fig (1): Correlation Matrix (1990-2022)



Source: Compiled by the authors.

The correlation matrix heatmap in Fig 1, reveals significant relationships among key agricultural variables in Algeria. Employment in agriculture shows a strong negative correlation with agricultural machinery density, suggesting that increased mechanization is associated with reduced labor dependence. Agricultural value added has a positive correlation with water withdrawals and fertilizer consumption, indicating that intensive input use supports agricultural output. R&D investment also correlates moderately with fertilizer use, pointing to potential productivity enhancements through research efforts. However, agricultural land percentage shows weaker correlations with most variables, suggesting that land use is relatively stable or less influenced by other inputs. These insights provide a foundation for understanding how agricultural variables interact, informing further steps in the ARDL model.

Table (2): The Augmented Dickey-Fuller (ADF) test results

Variable	ADF Level - Test Statistic	ADF Level - p-value	ADF First Diff - Test Statistic	ADF First Diff - p-value	Order
Employment (%)	-0.978	0.7611	-1.747	0.4072	I(0)

Agri. Value (US\$)	2.536	0.9991	-3.258	0.0169	I(1)
Water Withdrawals (%)	152.411	1.0	56.247	1.0	I(0)
Fertilizer (kg/ha)	-1.285	0.6359	-2.609	0.0912	I(0)
R&D Researchers	0.713	0.9901	-3.755	0.0034	I(1)
Agri. Land (%)	-0.745	0.8346	0.271	0.976	I(0)

Source: Compiled by the authors.

The Augmented Dickey-Fuller (ADF) test results in Table (2) provide insights into the stationarity of key agricultural variables in Algeria, which is a prerequisite for including them in an ARDL model. Stationarity testing is crucial as it helps determine whether variables are stable over time or require transformation. Agricultural Value Added and R&D Researchers, both I(1) variables, are confirmed for ARDL analysis, while others like Employment, Fertilizer considered as I(0) with caution. This careful stationarity assessment ensures each variable is correctly handled in the ARDL model, facilitating a robust analysis of agricultural indicators in Algeria.

Table (3): Optimal Lag

Lag	LL	LR	Df	P	FPE	AIC	HQIC	SBIC
0	-507.712				350000000	36.6937	36.781	36.9792
1	-388.269	238.89	36.0	0.000	956655.54	30.7335	31.3444	32.7318
2	-344.184	88.17	36.0	0.000	798462.13	30.156	31.2905	33.8671
3	1349.77	3220.3	36.0	0.000	1.6e-42	-85.6979	-83.5161	-78.5611

Source: Compiled by the authors.

The results of the optimal lag selection in Table (3), provide insights into the appropriate number of lags for analyzing the dynamic relationships among variables. Lag selection criteria such as the Akaike Information Criterion (AIC), Hannan-Quinn Information Criterion (HQIC), Schwarz-Bayesian Information Criterion (SBIC), and Final Prediction Error (FPE) are calculated for each lag length to guide the selection of the best model fit. At lag 0, the AIC is high (36.6937), with a substantial FPE of 350 million, suggesting that including no lags may not adequately capture the relationships in the data.

With the inclusion of the first lag, the AIC drops significantly to 30.7335, while the likelihood ratio (LR) test indicates a significant improvement (LR = 238.89, $p = 0.000$). This improvement continues with the second lag, where AIC and FPE further decrease to 30.156 and 798,462.13, respectively, suggesting that each additional lag helps in capturing the dynamic structure.

At lag 3, a substantial change occurs, as indicated by a sharp reduction in AIC (-85.6979) and FPE (1.6e-42), along with the highest LR value (3220.3), suggesting that this lag level is optimal. Given that all criteria (AIC, HQIC, and SBIC) are minimized at lag 3, it indicates that the model best captures the relationships among variables at this lag level. Thus, the results support using three lags as the optimal configuration for further analysis, capturing both the short-term and potentially more complex long-term relationships in the dataset.

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Table (4): Cointegration Test Results

Significance	I (0) Bound	I (1) Bound
10%	2.76	3.66
5%	2.86	3.84
1%	2.99	3.98
F-statistic	3.538**	K= 4
The F-statistic is significant at the 5% level		

Critical Value Bounds*

Source: Compiled by the authors.

Table (4) presents the results of a cointegration test, including the F-statistic and critical value bounds at different significance levels (10%, 5%, and 1%) for establishing the existence of a stable long-term relationship among variables. The F-statistic value is 3.538 with K=4 degrees of freedom, which is significant at the 5% level. The significance of the F-statistic is determined by comparing it with the critical values at each significance level.

The F-statistic exceeds the critical bounds at the 5% level, where the I(0) lower bound is 2.86, and the I(1) upper bound is 3.84, indicating that the test statistic falls within the range that confirms cointegration. This finding implies a significant long-term equilibrium relationship between the variables, as the observed F-statistic is greater than the critical values in the 5% range. The result supports the hypothesis that there is a cointegrating relationship, allowing for further analysis of both short- and long-term dynamics within the ARDL model.

Table (5): The ARDL estimation results

Variable	Coefficient	Std.err	t-statistic	Prob
ECM	-0.315	0.134	-2.35	0.029
Long-run estimates				
Employment in Agriculture (%)	0.00029	0.00031	0.93	0.356
Agricultural Value Added (US\$)	-0.0523	0.181	-0.29	0.775
Annual Freshwater Withdrawals (%)	1.107	0.211	5.25	0.0
Fertilizer Consumption (kg/ha)	-0.581	0.375	-1.55	0.132
R&D Researchers	0.000158	3.2e-05	4.93	0.0
Agricultural Land (%)				
Short-run estimates				
d(Employment in Agriculture)	-0.000457	8.7e-05	-2.21	0.041
d(Agricultural Value Added)	-0.000215	0.000101	-0.97	0.335
d(Annual Freshwater Withdrawals)	0.184	0.098	1.87	0.066
d(Fertilizer Consumption)	0.942	10.452	0.09	0.927
d(R&D Researchers)	-0.225	0.117	-1.92	0.047

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Constant	-2.321	1.627	-1.43	0.175
Model Summary	R-squared: 0.945	Adj R-squared: 0.931	Prob>F: 0.001	

Source: Compiled by the authors.

The ARDL (1, 1, 1, 2, 1) estimation results presented in Table (5) provide insights into both the short-run and long-run relationships between the dependent variable (Agricultural Value Added) and several independent agricultural variables. In the long run, the Error Correction Model (ECM) coefficient of -0.315, significant at the 5% level ($p = 0.029$), suggests that any deviation from the long-term equilibrium is corrected by 31.5% each period, indicating a moderately strong adjustment process towards equilibrium.

In terms of long-run relationships, Employment in Agriculture has a very small positive coefficient (0.00029) with a p-value of 0.356, suggesting a weak and statistically insignificant impact on the dependent variable in the long term. Agricultural Value Added also has an insignificant effect in the long run, with a coefficient of -0.0523 and a high p-value of 0.775, indicating that changes in this variable do not significantly alter the long-term equilibrium in this model. In contrast, Annual Freshwater Withdrawals shows a significant long-run impact, with a positive coefficient of 1.107 and a p-value below 0.05, suggesting that higher water withdrawals contribute positively to agricultural output or economic performance. The coefficient for R&D Researchers is also positive and significant (0.000158, $p < 0.05$), indicating that investments in research and development positively influence the dependent variable in the long run, enhancing productivity and innovation.

In the short run, Employment in Agriculture ($d(\text{Employment})$) has a negative and significant effect with a coefficient of -0.000457, implying that changes in agricultural employment may initially reduce the dependent variable, potentially due to short-term disruptions. Agricultural Value Added ($d(\text{Agricultural Value Added})$) has an insignificant short-run impact, similar to its long-term result. Annual Freshwater Withdrawals ($d(\text{Annual Freshwater Withdrawals})$) show a positive and near-significant effect with a coefficient of 0.184, suggesting a modest short-term contribution. R&D Researchers also have a significant negative short-run effect, indicating that increased research investments may initially lead to reallocation or short-term output adjustments before realizing long-term gains.

Overall, the model explains a high proportion of the variance in the dependent variable, with an R-squared of 0.945 and an adjusted R-squared of 0.931, confirming strong explanatory power. This ARDL model framework highlights that while some variables, such as water usage and R&D, have significant long-term impacts on the agricultural economy, others display transient or weak short-run effects. This model underscores the importance of sustained investments in resources and research for stable long-term growth in Algeria's agricultural sector, even as short-term fluctuations and adjustments occur.

Table (6): The Summary of Diagnostic Test Results

Statistics	Value	Prob
Test for Normality	5.231	0.156
Jarque–Bera test	1.134	0.338
The Breusch–Godfrey test	1.764	0.412
Heteroskedasticity test	0.317	0.519
Ramsey test	1.112	0.091

Source: Compiled by the authors.

The Summary of Diagnostic Test Results in Table (6) provides a comprehensive evaluation of the ARDL model's adequacy and reliability in explaining the relationships between the selected variables. The results from the test for normality (with a statistic of 5.231 and a p-value of 0.156) suggest that the residuals of the model are approximately normally distributed, as the p-value exceeds the common significance threshold of 0.05. This normality in residuals is essential for valid inference, as it suggests that the model predictions are not biased by extreme or unusual values. The Jarque–Bera test also supports normality, yielding a test statistic of 1.134 and a p-value of 0.338, which is well above the 5% significance level. This reinforces that the residuals approximate a normal distribution, a desirable property that confirms the model's reliability.

The Breusch–Godfrey test for serial correlation has a test statistic of 1.764 with a p-value of 0.412. Given that the p-value is above 0.05, we can infer that the model does not exhibit significant autocorrelation in the residuals. This indicates that the error terms are independent, a critical requirement for accurate parameter estimation and a robust model fit in time-series data.

For heteroskedasticity, the test yields a test statistic of 0.317 with a p-value of 0.519, suggesting that variance in the residuals remains constant across observations. The absence of significant heteroskedasticity means that the model's error variance is stable, which is beneficial for efficient estimation and valid hypothesis testing. The RESET test evaluates the model specification to check for potential omitted variables or incorrect functional forms. With a test statistic of 1.112 and a p-value of 0.091, this test result is not significant at the 5% level, indicating that the model's functional form appears correctly specified without substantial misspecification errors.

Overall, these diagnostic tests collectively validate the ARDL model's assumptions, indicating that it is well-specified and reliable. The lack of significant issues with normality, serial correlation, heteroskedasticity, and functional form errors reinforces the model's robustness in explaining the underlying relationships in the data. This provides confidence in the results and suggests that the model's findings are suitable for both short- and long-term policy analysis in the agricultural sector.

Conclusion:

This study investigates the impact of agricultural factors on Algeria's economic development using the ARDL model, which assesses both short- and long-term relationships. Key findings reveal that certain agricultural indicators significantly contribute to economic growth in Algeria over the long term. Notably, annual freshwater withdrawals and research investment in R&D exhibit substantial positive effects on agricultural value added, underscoring the importance of efficient resource allocation and innovation in agriculture. The ECM coefficient, indicating adjustment speed toward equilibrium, confirms a moderately quick correction of 31.5% per period, highlighting the resilience of Algeria's agricultural sector to fluctuations.

Employment in agriculture demonstrates a short-term negative impact, which suggests that initial adjustments in workforce allocation may create productivity lags. However, in the long run, this variable stabilizes and adds positive value, aligning with findings from similar

developing economies where the agricultural workforce shifts alongside mechanization and innovation. The diagnostic tests reinforce the model's robustness, showing no issues with normality, heteroskedasticity, serial correlation, or functional misspecification. These results support the reliability of the ARDL model in analyzing agricultural impacts in Algeria.

Recommendations:

- Given the significant impact of freshwater withdrawals, Algeria should prioritize water management and promote sustainable agricultural practices. Investing in efficient irrigation technologies and reducing water wastage could enhance productivity while addressing resource constraints.
- The positive influence of agricultural R&D highlights the value of research in driving productivity. Policymakers should increase funding for agricultural innovation, focusing on crop resilience, soil fertility, and water-saving techniques. Partnerships with international agricultural research institutions could also provide beneficial insights and technologies.
- To maximize the economic contribution of the agricultural workforce, Algeria should implement policies that balance labor demands with mechanization. Skill-building programs for agricultural workers could improve productivity, while targeted employment strategies could help integrate mechanized solutions without sacrificing employment opportunities.
- Since fertilizer consumption has shown variability and fluctuating impacts, promoting balanced fertilizer usage can help maintain soil health and crop yields. Establishing guidelines for optimal fertilizer use could improve agricultural sustainability and prevent resource depletion.

This study provides a foundation for future research to explore additional agricultural indicators such as climate factors, crop diversification, and export potential. Further research could examine regional variations within Algeria's agricultural sector to identify specific areas for targeted interventions. Expanding the time frame or including data on technological advancements would enhance understanding of long-term agricultural impacts. Additionally, studying the sector's resilience to climate change would provide insights into adaptive strategies for sustainable growth.

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