Journal of contemporary economic research
Vol 09 , N°: 2 (2026), p 1-20
ISSN 2623-2602/ EISSN: 2716-8891

Wheat Production, Rainfall and Agricultural Value Added in Algeria: An ARDL Bounds-Testing Analysis for the Period (1990–2023)

ZIANE Meriem [1*], GAIDI Khemissi [2]

[1] LEZINRU, University of Mohamed El Bachir El Ibrahimi Bordj Bou Arreridj, Algeria, meriem.ziane@univ-bba.dz
[2] LEZINRU, University of Mohamed El Bachir El Ibrahimi Bordj Bou Arreridj, Algeria, khemissi.g@univ-bba.dz

Received: 8/2/2026 **Accepted**: 10/29/2026 **Published**: 11/4/2026

Abstract: This study examines the relationship between wheat production, annual rainfall and agricultural value added in Algeria using annual FAO data for 1990–2023. Agricultural value added (VAAGR) is the level of value added in current local currency, not a growth rate. The theoretical hypotheses are that wheat production (HT1) and annual rainfall (HT2) are each positively associated with agricultural value added. Augmented Dickey-Fuller tests indicate that the three log-transformed series are integrated of order one, so none is I(2). An autoregressive distributed lag (ARDL) model, ARDL(2,3,4), selected by the Akaike criterion and estimated over 1994–2023 (30 observations), is tested for a long-run level relationship with the bounds test of Pesaran, Shin and Smith (2001). The F-statistic (4.22) exceeds the upper bound at the 10% level but lies between the bounds at 5%, so the evidence of a long-run relationship is weak. The error-correction term is negative and significant (−0.079), implying slow adjustment (a half-life of about 8.5 years). The implied long-run elasticity of agricultural value added with respect to wheat production is 2.42 (p = 0.038 for the level coefficient), while the long-run rainfall elasticity (0.36) is not significant; HT1 therefore receives tentative support and HT2 none. Residual tests show no serial correlation, heteroskedasticity, ARCH effects or non-normality, and the CUSUM of squares plot stays within the 5% bounds. Because value added is measured in current prices, wheat is itself a component of agricultural output, and the sample is small, the results are conditional associations and not causal effects.

Keywords: Wheat Production, Agricultural Value Added, Rainfall, ARDL, Bounds Test, Algeria.
JEL Classification Codes : Q11 ; Q18 ; O13 ; C22

1. INTRODUCTION

* : *GAIDI Khemissi khemissi.g@univ-bba.dz* .

Wheat is the cornerstone of Algeria's food system, yet the country illustrates a striking paradox: despite being a long-standing producer, it ranks among the world's most import-dependent wheat consumers, reflecting deep structural weaknesses in its agricultural base (Chaabane & Benflis, 2025). National wheat production has followed a highly volatile path rather than a steady trend — from roughly 750,000 tons in 1990, up to 2.9 million tons in 1996, down to 760,000 tons by 2000, then swinging between a trough of 1.1 million tons in 2008 and a record peak of nearly 4 million tons in 2018. Productivity remains structurally weak, averaging only 14.83 quintals/hectare over 2000–2024, well below global (≈37 q/ha) and regional benchmarks (Ben Hadjer, 2024; Doubba, 2024).

This instability is closely tied to climate: since cultivation remains overwhelmingly rainfed, annual precipitation stands out as the dominant determinant of output and yield (Ben Hadjer, 2024; Chaabane & Benflis, 2025), while rising temperatures further depress productivity (Hadji et al., 2025). To counter these constraints, successive governments have supported the sector through reforms such as the PNDA/PNDAR and the PRAR, aiming to modernize farming and strengthen food security. Over the same period, agricultural value added (in current prices) has shown a continuous and accelerating rise, particularly after 2020, reflecting higher output, rising prices and the cumulative effect of these policies.

Despite this policy emphasis on wheat self-sufficiency, the extent to which wheat production specifically — rather than agricultural output more broadly — is statistically associated with the level of agricultural value added has not been econometrically established for Algeria over a long-time span. From this context, our study addresses the following central question:

To what extent is wheat production associated with agricultural value added in Algeria over the period 1990–2023?

Building on this question, we formulate the following main theoretical hypothesis:

HT: Wheat production is significantly associated with agricultural value added in Algeria over the period 1990–2023.

This central question can be broken down into two sub-questions, addressing the specific contribution of each explanatory variable retained in the empirical model:

SQ1: Is wheat production significantly associated with agricultural value added in Algeria?

SQ2: Is annual rainfall significantly associated with agricultural value added in Algeria?

Correspondingly, and consistent with the expectation — grounded in the literature cited in Section 2 — that both factors are positively associated with agricultural performance, two theoretical sub-hypotheses are formulated:

HT1: Wheat production is positively and significantly associated with agricultural value added in Algeria.

 ISSN 2623-2602/ EISSN: 2716-8891

HT2: Annual rainfall is positively and significantly associated with agricultural value added in Algeria.

The theoretical hypotheses above are distinguished from the statistical hypotheses of the tests. For each coefficient, the null hypothesis is H0: $\beta i = 0$ and the alternative implied by the theory is H1: $\beta i > 0$ (positive association). In practice, the t-tests reported in Section 4 are two-tailed (H1: $\beta i \neq 0$, 5% level), and the sign of each estimate is then compared separately with the expected positive sign. For the long-run relationship, the null hypothesis of the bounds test is that there is no level relationship between the variables (Section 3.2).

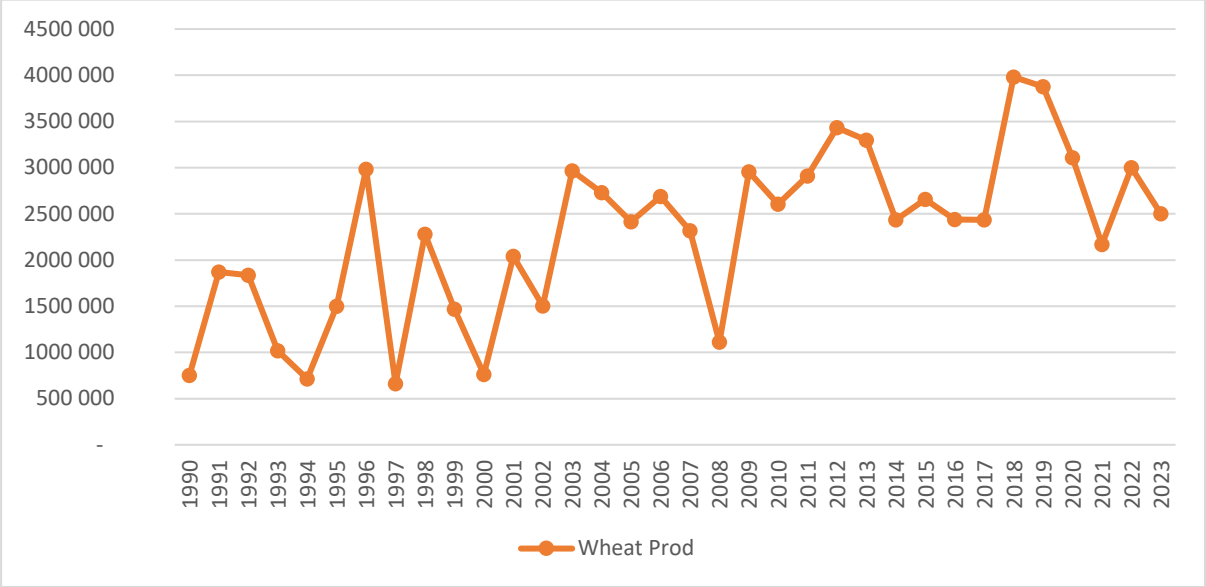
To test these hypotheses, this study uses annual time-series data obtained from the FAO database and an autoregressive distributed lag (ARDL) model with the bounds-testing approach of Pesaran, Shin and Smith (2001). Agricultural value added (VAAGR) is the dependent variable and wheat production (WHEAT) and annual rainfall (RAIN) are the explanatory variables; all transformed into natural logarithms to allow for an elasticity-based interpretation. The ARDL framework separates short-run dynamics from the long-run relationship and from the speed of adjustment, and it does not require the series to have the same order of integration, if none is integrated of order two. Because the model is a conditional framework, the estimated coefficients are interpreted as associations (elasticities) and not as causal effects.

2. WHEAT PRODUCTION AND AGRICULTURAL POLICY IN ALGERIA: AN OVERVIEW

2.1 Production Levels and Fluctuations

Algeria is classified as both a wheat producer and one of the world's most import-dependent wheat consumers, a paradox that reflects deep structural weaknesses in its agricultural base (Chaabane & Benflis, 2025). This means that Algeria has a deficit in wheat production, due to several factors that will be discussed below. National wheat production is unstable and highly volatile year over year: in 1990 it reached about 750,000 tons, rising to 2.9 million tons in 1996 due to favourable weather and rainfall, before falling back to 760,361 tons in 2000. Over the following two decades the trend rose overall, but with a trough of 1,111,033 tons in 2008 and a peak of 3,981,219 tons in 2018, only to fall back to around 1.8 million tons by 2021. This fluctuation is mainly explained by rainfall, the most influential factor in production, given Algeria's recurrent drought seasons.

Fig.1. Wheat production in Algeria, 1990–2023

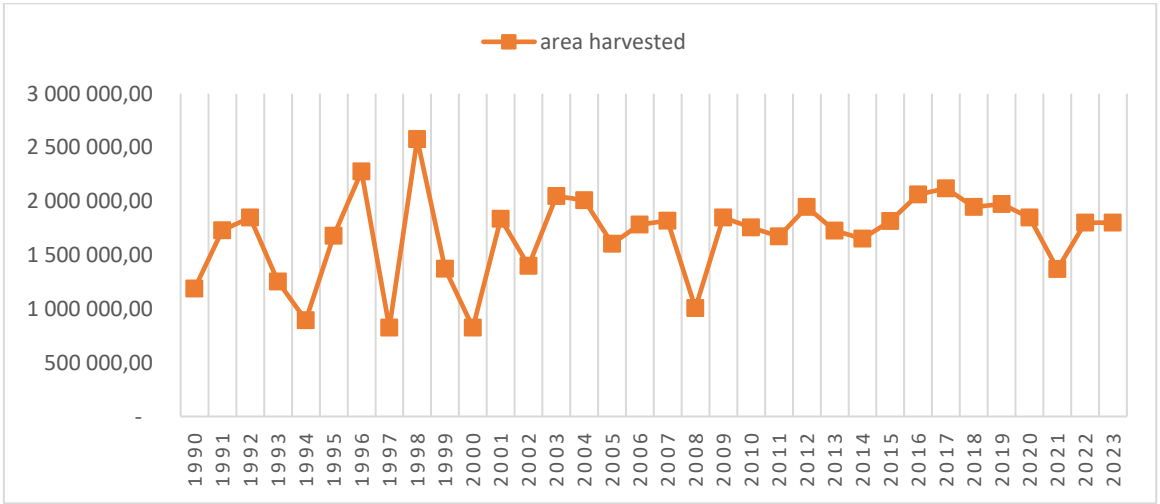


Source: Prepared by the authors based on FAO database.

2.2 Area Harvested with Wheat

The area harvested with wheat expanded over the study period, but not in a strictly linear fashion, providing a further indicator of instability. Between 1990 and 1999 the harvested area fluctuated considerably from one year to another — for instance from 0.825 million hectares to 2.577 million hectares the following year. During 2000–2020 the cultivated area for wheat averaged approximately 2 million hectares but was systematically underutilized: in years of poor rainfall, such as 2008, the harvested area fell to barely 1 million hectares, less than 35% of the total sown area (Ben Hadjer, 2024). A significant proportion of the land allocated to wheat cultivation therefore returns nothing, largely due to drought and insufficient irrigation systems.

Fig.2. Area harvested with wheat in Algeria, 1990–2023



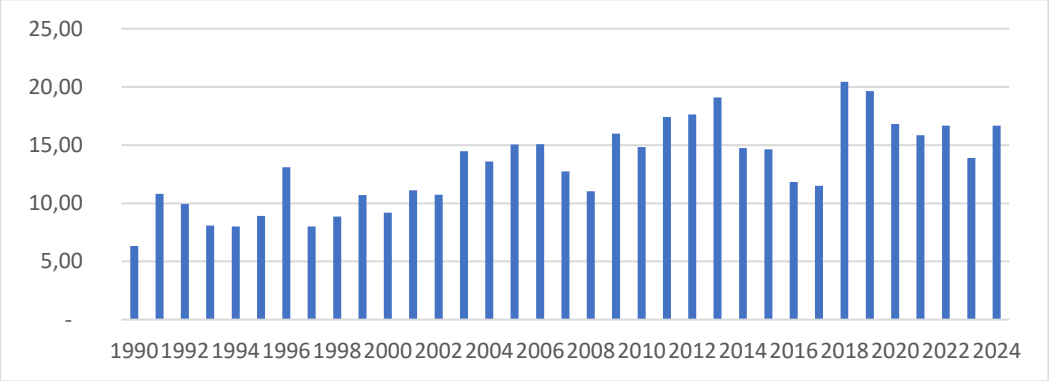
Source: Prepared by the authors based on FAO database.

 ISSN 2623-2602/ EISSN: 2716-8891

2.3 Productivity Gap

This pattern of irregular variation is a defining feature of Algerian wheat output. Average productivity (yield per hectare) remains well below regional and global benchmarks: it was estimated at only 14.83 quintals/hectare on average across 2000–2024, compared to a global average of approximately 37 quintals/hectare in 2024, and Egypt's 66 quintals/hectare in 2020 (Ben Hadjer, 2024; Doubba, 2024). Even Saudi Arabia, with its harsh arid conditions, records yields exceeding 60 quintals/hectare. Algeria's low productivity reflects not just climatic disadvantage but also structural weaknesses in input use, seed quality, and mechanization.

Fig.3. Wheat productivity in Algeria, 1990–2023



Source: Prepared by the authors based on FAO database.

2.4 The Role of Climate

Algeria's wheat production is rainfed, with irrigation covering only a small fraction of cereal land, which is why rainfall is the major factor impacting wheat yields. Ben Hadjer (2024) shows a clear positive correlation between annual precipitation and both total output and per-hectare yield, confirming what Chaabane and Benflis (2025) also find: that rainfall, alongside cultivated area and agricultural machinery, constitutes one of the statistically significant positive determinants of wheat production. Rainfall irregularity also helps explain production fluctuations; Hadji et al. (2025) employ an ARDL model on data from 2001 to 2021 and confirm a statistically significant long-run negative relationship between average temperature and wheat productivity — a 1% rise in average temperature corresponds to a 6.09% decline in wheat yield.

2.5 Policy and Institutional Factors

Since independence, public authorities reclaimed agricultural lands to allow Algerian farmers to work them through the agrarian revolution and self-management. New agricultural reforms were initiated from 2000 to 2014 through the implementation of several agricultural plans: the PNDA-PNDAR (National Agricultural-Rural Development Plan) and the PRAR (Agricultural and Rural Renewal), followed by the FELAHA plan and the governmental agricultural action plan applied between 2015 and

2024, which continues these governmental actions (Mimouni,2023). These plans are discussed below.

2.5.1 The National Agricultural Development Plan (PNDA/PNDAR)

Launched in 2000 for four years, the PNDA aimed to transform agriculture through market mechanisms and to stimulate private investment in farms. Built on economic and ecological principles, it sought to treat farming as an economic activity, create employment, and protect natural resources to ensure food security for household consumption. The plan focused on increasing production by expanding cultivated area, converting soils, reorganizing and intensifying production, and launching a 1.2-million-hectare reforestation program. In 2002 the PNDA became the PNDAR (National Agricultural and Rural Development Plan), broadening its scope to support rural development, private investment, improved agricultural services, local partnerships, multisectoral territorial integration, and sustainable resource management. These ideas were put into practice through the Integrated Rural Proximity Development Project (PPDRI). Authorities also passed the Agricultural Orientation Law to strengthen the legal framework, reinforce sector oversight, and promote youth integration into productive activities.

2.5.2 The Agricultural and Rural Renewal Policy (PRAR)

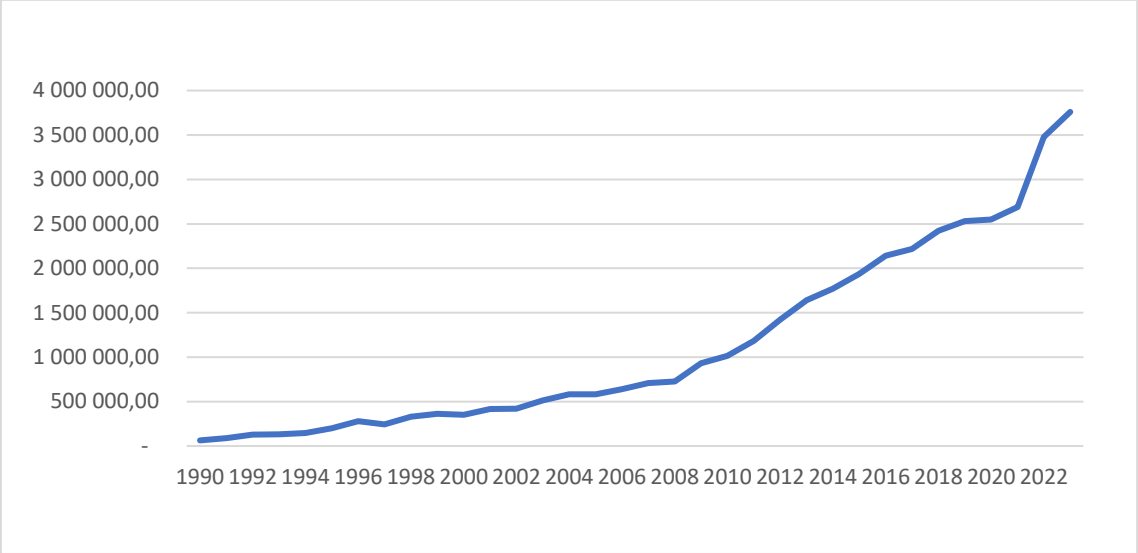
From 2010–2014, the PRAR policy reaffirmed the earlier goal of strengthening national food security sustainably and positioned agriculture as a driver of economic growth, with emphasis on intensifying production in key agri-food chains. this programs aimed to better manage and expand agricultural activity in rural areas, encouraging higher production for mass consumption while modernizing agricultural administration and training staff to improve governance. Support covered farmers from land access through product marketing, protecting their income. The policy rested on three complementary pillars — rural renewal, agricultural renewal, and PRCHAT (capacity-building and technical assistance) — backed by incentives that eased access to essential natural and financial resources for farmers.

2.6 Trends in Agricultural Value Added

Agricultural value added in Algeria (in current prices) shows a continuous and increasingly rapid rise over the study period, with moderate growth in the 1990s, a clear acceleration from the 2000s, and a particularly sharp increase after 2020. This may reflect both higher production volumes (through expanded irrigated areas, improved yields, and greater investment) and the impact of rising agricultural prices, which boost the monetary value of output. It also mirrors the effect of agricultural policies implemented since the 2000s to modernize agriculture, support private initiative, and strengthen food security, which have helped agriculture become a more important contributor to GDP and non-hydrocarbon growth. However, the trend alone does not reveal structural challenges — such as climatic vulnerability and regional productivity gaps — that still limit the sector's full potential.

 ISSN 2623-2602/ EISSN: 2716-8891

Fig.4. Agricultural value added in Algeria, 1990–2023



Source: Prepared by the authors based on FAO database.

3. METHODOLOGY

3.1 Data and Variables

This study investigates the relationship between wheat production, rainfall and agricultural value added in Algeria over the period 1990–2023, using annual time-series data (34 observations; 30 usable observations, 1994–2023, after the lags of the selected ARDL model). Three variables are used: agricultural value added (VAAGR), the dependent variable, and wheat production (WHEAT) and annual rainfall (RAIN), the explanatory variables. VAAGR indicates the level of agricultural value added, not a growth rate, despite the abbreviation. It is taken from the FAOSTAT Macro Indicators domain (element "Value Standard Local Currency", item "Value Added (Agriculture, Forestry and Fishing)") and is expressed in million units of local currency, that is, million Algerian dinars at current prices. The series is not deflated, so it reflects both quantity and price movements (see Section 4.8). All three variables are transformed into natural logarithms (LVAAGR, LWHEAT and LRAIN) to allow for an elasticity-based interpretation. The sample correlation between LWHEAT and LRAIN is 0.052 (VIF = $1/(1-r^2) \approx 1.003$), so the two regressors are not collinear in the statistical sense, although an economic link between rainfall and rainfed wheat output is expected. The data are summarised in Table A.

Table A. Variables, definitions and sources

Variable (symbol)	Definition and unit	Source	Transformation
Agricultural value added (VAAGR)	Value added of agriculture, forestry and fishing (FAOSTAT item 22016), million units of local currency (DZD), current prices	FAOSTAT, Macro Indicators domain (MK), element "Value Standard Local Currency" (6224), Algeria (M49 012); 05/02/2025	Natural logarithm (LVAAGR)
Wheat production (WHEAT)	Annual wheat production, in tons	FAOSTAT, Crops and livestock products (QCL), item code (CPC) 0111; 29/01/2025	Natural logarithm (LWHEAT)
Annual rainfall (RAIN)	Precipitation (Annual Mean mm)	Climate Change Knowledge Portal, Observed Timeseries of Annual Precipitation; 25/06/2026	Natural logarithm (LRAIN)

3.2 Model Specification

The relationship is estimated with an autoregressive distributed lag (ARDL) model and tested for a long-run level relationship with the bounds-testing procedure of Pesaran, Shin and Smith (2001). With LVAAGR as the dependent variable and lag orders (p, q, r), the ARDL model is:

$$LVAAGR_t = c + \Sigma_{i=1}^{p} \varphi_i \, LVAAGR_{t-i} + \Sigma_{j=0}^{q} \delta_j \, LWHEAT_{t-j} + \Sigma_{k=0}^{r} \pi_k \, LRAIN_{t-k} + \varepsilon_t$$

Its conditional error-correction form, used for the bounds test (see also Engle & Granger, 1987, for the error-correction representation), is:

$$\Delta LVAAGR_t = \alpha_0 + \rho \, LVAAGR_{t-1} + \theta_1 \, LWHEAT_{t-1} + \theta_2 \, LRAIN_{t-1} + \Sigma_{i=1}^{p-1} \psi_i \, \Delta LVAAGR_{t-i} + \Sigma_{j=0}^{q-1} \beta_j \, \Delta LWHEAT_{t-j} + \Sigma_{k=0}^{r-1} \gamma_k \, \Delta LRAIN_{t-k} + \varepsilon_t$$

where Δ is the first-difference operator, $LVAAGR_t$, $LWHEAT_t$ and $LRAIN_t$ are the natural logarithms of agricultural value added, wheat production and annual rainfall in year t, α_0 is the constant, ρ, θ_1 and θ_2 are the coefficients of the lagged levels, and ψ_i, β_j and γ_k capture the short-run dynamics. The long-run elasticities are $\kappa_1 = -\theta_1/\rho$ for wheat production and $\kappa_2 = -\theta_2/\rho$ for rainfall, with long-run constant $\kappa_0 = -\alpha_0/\rho$. The error-correction term is $ECT_{t-1} = LVAAGR_{t-1} - \kappa_0 - \kappa_1 \, LWHEAT_{t-1} - \kappa_2 \, LRAIN_{t-1}$, and equivalently the short-run part of the model can be written $\Delta LVAAGR_t = \rho \, ECT_{t-1} + \Sigma \, \psi_i \, \Delta LVAAGR_{t-i} + \Sigma \, \beta_j \, \Delta LWHEAT_{t-j} + \Sigma \, \gamma_k \, \Delta LRAIN_{t-k} + \varepsilon_t$, where ρ measures the speed of adjustment towards the long-run relationship.

The bounds test examines the null hypothesis of no level relationship, H0: $\rho = \theta_1 = \theta_2 = 0$, against the alternative that at least one of them is non-zero. The F-statistic is compared with a lower critical bound, valid if all series are I(0), and an upper bound, valid if all are I(1): a value above the upper bound rejects H0 (a long-run relationship exists), a value below the lower bound does not reject it, and a value between the bounds is inconclusive. The lag orders are selected with the Akaike information criterion (AIC) among all combinations of up to four lags for each variable, with a restricted constant and no deterministic trend (Case 2 of Pesaran et al., 2001). All variables are in natural

 ISSN 2623-2602/ EISSN: 2716-8891

logarithms, so the level coefficients are elasticities and the first differences approximate growth rates.

Conceptual framework. Agricultural value added is conceived as the output of a sectoral production function, $VAAGR_t = f(WHEAT_t, LAND_t, LABOR_t, CAPITAL_t, CLIMATE_t, POLICY_t)$, in which wheat production is one component of sectoral output and rainfall is a climatic input. The estimated model is a reduced-form specification that retains only WHEAT and RAIN; land, labour, capital, prices and policy variables are not included, so the coefficients are conditional on that omission. Moreover, because wheat is itself part of the output measured by agricultural value added, a positive association is partly mechanical and does not by itself identify a causal effect of wheat production on the rest of the sector. The estimated coefficients are therefore interpreted as conditional elasticities (associations).

3.3 Stationarity Tests

Before the ARDL model is estimated, the order of integration of LVAAGR, LWHEAT and LRAIN is examined with the Augmented Dickey-Fuller (ADF) test (Dickey & Fuller, 1979), applied to each series in levels and in first differences, with a constant and with a constant and a linear trend. The null hypothesis is that the series has a unit root; the p-values are the MacKinnon (1996) one-sided values reported by EViews. A common lag length of two augmentation terms is used for all series: the Schwarz criterion applied to LVAAGR selects two lags, whereas the Akaike and final-prediction-error criteria select five and the Hannan-Quinn criterion four. The bounds procedure requires that no series is integrated of order two, I(2); it does not require all series to have the same order of integration (Pesaran et al., 2001).

3.4 Diagnostic and Stability Tests

After estimation, the residuals of the selected ARDL model are examined with the following tests:

- **Serial correlation:** the Breusch-Godfrey LM test (Breusch, 1978; Godfrey, 1978) with two lags, which remains valid when lagged dependent variables are present, and the correlogram of the residuals with Q-statistic probabilities adjusted for the dynamic regressors. The null hypothesis is no serial correlation.
- **Heteroskedasticity:** the Breusch-Pagan-Godfrey test (Breusch & Pagan, 1979), whose null hypothesis is homoskedasticity, and the correlogram of the squared residuals as a check for autoregressive conditional heteroskedasticity (ARCH).
- **Normality:** the Jarque-Bera test (Jarque & Bera, 1987), whose null hypothesis is that the residuals are normally distributed.
- **Parameter stability:** the CUSUM of squares test (Brown, Durbin & Evans, 1975), computed on the least-squares form of the selected ARDL(2,3,4) equation (same regressors and sample). The model is regarded as stable if the cumulative sum stays within the 5% significance bounds.

Failure to reject a null hypothesis means only that there is insufficient statistical evidence against the corresponding assumption; with 30 observations these tests have limited power. Because the dynamics are modelled explicitly and the residuals show no autocorrelation, no HAC correction of the standard errors is applied. As EViews notes, the reported p-values do not account for the model-selection step.

4. RESULTS AND DISCUSSION

4.1 Unit Root Tests

Table 1 reports the ADF tests for the three series.

Table 1. ADF unit root tests (null hypothesis: the series has a unit root)

Series	Specification	ADF t-statistic	5% critical value	Prob.	Unit root at the 5% level
LVAAGR	Level, constant	−2.0445	−2.9604	0.2674	Not rejected
	Level, constant and trend	−2.2718	−3.5629	0.4359	Not rejected
	First difference, constant	−3.2241	−2.9640	0.0283	Rejected
	First difference, constant and trend	−3.2716	−3.5684	0.0904	Not rejected (rejected at 10%)
LWHEAT	Level, constant	−1.4710	−2.9604	0.5347	Not rejected
	Level, constant and trend	−3.2574	−3.5629	0.0923	Not rejected (rejected at 10%)
	First difference, constant	−4.8302	−2.9640	0.0005	Rejected
	First difference, constant and trend	−4.7493	−3.5684	0.0034	Rejected
LRAIN	Level, constant	−2.0157	−2.9604	0.2789	Not rejected
	Level, constant and trend	−2.2971	−3.5629	0.4231	Not rejected
	First difference, constant	−4.8676	−2.9640	0.0005	Rejected
	First difference, constant and trend	−5.1315	−3.5684	0.0013	Rejected

Source: Authors' calculations using EViews 14. Fixed lag length of 2; MacKinnon (1996) one-sided p-values. Level tests use 1993–2023 (31 observations) and first-difference tests 1994–2023 (30 observations).

In levels, the null hypothesis of a unit root is not rejected at the 5% level for any series in either specification (for LWHEAT with a trend, p = 0.092, so the null is rejected only at 10%). In first differences the null is rejected at the 5% level for all three series with a constant. With a constant and a trend, it is also rejected for LWHEAT and LRAIN, and for LVAAGR only at the 10% level (p = 0.090); the trend coefficient in that last test is not significant (p = 0.290), so the constant-only version is the relevant one. The three series are therefore treated as integrated of order one, I(1), and none is I(2), which is the condition required for the bounds test. ADF tests have low power in samples of this size and are sensitive to the lag length, and the Phillips-Perron and KPSS tests (Kwiatkowski et al., 1992) and unit root tests allowing for structural breaks (Zivot & Andrews, 1992)

 ISSN 2623-2602/ EISSN: 2716-8891

are not reported in this version (Section 4.8). The bounds procedure remains valid if one of the series turns out to be I(0).

4.2 ARDL Specification and Bounds Test

With a maximum of four lags for each variable, the AIC selected an ARDL(2,3,4) specification among 100 candidate models, estimated over 1994–2023 (30 observations) with a restricted constant and no trend (Case 2). The model contains 12 estimated parameters, including the constant, for 30 observations, so degrees of freedom are limited. Table 2 reports the bounds test.

Table 2. ARDL bounds test (null hypothesis: no levels relationship)

Critical bounds	F-statistic	10% level I(0) – I(1)	5% level I(0) – I(1)	1% level I(0) – I(1)
Finite sample (n = 30)	4.2237	2.915 – 3.695	3.538 – 4.428	5.155 – 6.265
Asymptotic	4.2237	2.630 – 3.350	3.100 – 3.870	4.130 – 5.000

Source: Authors' calculations using EViews 14. Case 2 (restricted constant); number of dynamic cointegrating variables k = 2; sample size 30. I(0) and I(1) are the stationary and non-stationary bounds.

The F-statistic (4.224) exceeds the upper bound at the 10% level (3.695), so the null hypothesis of no level relationship is rejected at that level. At the 5% level the statistic lies between the lower (3.538) and the upper (4.428) bound, so the test is inconclusive, and it is below the lower bound at 1% (5.155). Only the asymptotic bounds, which are not suited to 30 observations, would give a rejection at 5% (3.870). The evidence for a long-run level relationship is therefore weak, and the long-run estimates below are indicative. The significance of the error-correction coefficient in Table 3 cannot replace the bounds test, because the distribution of the t-ratio of the lagged dependent variable is non-standard under the null hypothesis (Pesaran et al., 2001).

4.3 Short-Run Dynamics and Error Correction

Table 3 reports the error-correction form of the ARDL(2,3,4) model, in which COINTEQ is the error-correction term.

Table 3. Error-correction form of the ARDL(2,3,4) model — dependent variable: D(LVAAGR)

Variable	Coefficient	Std. Error	t-Statistic	Prob.
COINTEQ	−0.0785	0.0177	−4.440	0.0002
D(LVAAGR(−1))	0.4792	0.1128	4.249	0.0004
D(LWHEAT)	0.2086	0.0235	8.890	0.0000
D(LWHEAT(−1))	−0.1448	0.0321	−4.516	0.0002
D(LWHEAT(−2))	−0.0581	0.0252	−2.307	0.0313
D(LRAIN)	−0.0125	0.0596	−0.209	0.8363
D(LRAIN(−1))	−0.0630	0.0683	−0.922	0.3669
D(LRAIN(−2))	−0.1665	0.0639	−2.606	0.0165
D(LRAIN(−3))	−0.1364	0.0559	−2.440	0.0236

Source: Authors' calculations using EViews 14. $R^2 = 0.872$; adjusted $R^2 = 0.824$; Durbin-Watson = 1.826; 30 observations (1994–2023).

The error-correction term is negative (−0.0785), as required for convergence towards the long-run relationship, but small: about 7.9% of a deviation from the long-run relationship is corrected each year. This implies a half-life of $\ln(0.5)/\ln(1 - 0.0785) \approx 8.5$ years and about 28 years to close 90% of a deviation, so adjustment is very slow relative to a sample of 30 years. Its p-value should not be read as a test of cointegration (Section 4.2).

In the short run, growth of agricultural value added is persistent: a growth rate of value added that is one percentage point higher last year is associated with a growth rate that is 0.48 percentage point higher this year. A 1% increase in wheat production is associated with a 0.21% increase in agricultural value added in the same year, but this is offset by negative coefficients on the first and second lags (−0.145 and −0.058), so the cumulative three-year association is about 0.006, close to zero. Because wheat is part of agricultural output, part of the same-year association is expected to be mechanical. For rainfall, the concurrent and first-lag changes are not significant, while the second and third lags are negative and significant (−0.166 and −0.136; cumulative association −0.378). Negative lagged coefficients on rainfall have no obvious economic explanation and, in a model with 12 parameters and 30 observations, may partly reflect over-fitting; they are reported as estimated associations and are not interpreted causally.

4.4 Long-Run Relationship

Table 4. Level coefficients of the conditional error-correction equation and implied long-run elasticities

Variable	Level coefficient	Std. Error	Prob. (level coefficient)	Implied long-run elasticity
LVAAGR(−1)	−0.0785	0.0327	0.0275	—
LWHEAT(−1)	0.1901	0.0850	0.0382	2.42
LRAIN(−1)	0.0285	0.1288	0.8274	0.36
Constant	−1.7802	0.7661	0.0321	−22.67

Source: Authors' calculations using EViews 14 (conditional error-correction regression). Implied long-run elasticity = −(level coefficient) ÷ (coefficient on LVAAGR(−1)), computed by the authors; the p-values refer to the level coefficients, not to the implied elasticities.

The implied long-run relationship is LVAAGR = −22.67 + 2.42 LWHEAT + 0.36 LRAIN. The implied long-run elasticity of agricultural value added with respect to wheat production is about 2.42, and the level coefficient is significant at 5% (p = 0.038). This result is fragile: the bounds test gives only weak evidence of a level relationship, the p-values do not account for model selection, and an elasticity above one should not be read as evidence of multiplier effects. It may reflect common trends (the equation contains no trend although LVAAGR and LWHEAT both rise over the period), price effects (value added is in current prices), the mechanical link between wheat and agricultural output, simultaneity or omitted variables. The implied long-run rainfall elasticity (0.36) is not statistically significant (p = 0.83). The ARDL results therefore

 ISSN 2623-2602/ EISSN: 2716-8891

provide no evidence that annual rainfall is associated with agricultural value added in the long run, nor that more rainfall reduces it.

4.5 Diagnostic and Stability Tests

Table 5 summarises the residual diagnostics of the ARDL(2,3,4) model.

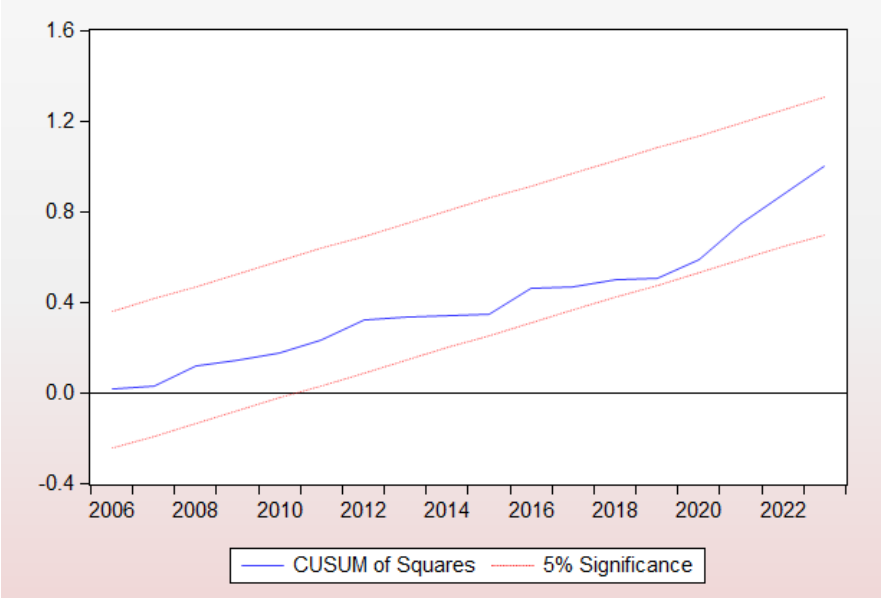
Table 5. Residual diagnostic and stability tests

Test	Statistic	p-value	Conclusion
Breusch-Godfrey LM (2 lags)	F(2,16) = 0.087; Obs*R^2 = 0.323	0.917; 0.851	H0 of no serial correlation not rejected
Breusch-Pagan-Godfrey	F(11,18) = 0.788; Obs*R^2 = 9.755	0.649; 0.553	H0 of homoskedasticity not rejected
Jarque-Bera (normality)	JB = 0.455	0.797	H0 of normality not rejected
Q-statistics, residuals (lags 1–16)	0.105 – 9.764	0.631 – 0.969	No serial correlation detected
Q-statistics, squared residuals (lags 1–16)	0.000 – 18.586	0.233 – 0.989	No ARCH effects detected
CUSUM of squares (2006–2023)	Plot within the 5% bounds	—	No instability detected

Source: Authors' calculations using EViews 14. Q-statistic probabilities for residuals are adjusted for the two dynamic regressors; EViews notes that correlogram probabilities may not be valid for this equation specification.

None of the tests rejects its null hypothesis: there is no evidence of residual serial correlation, heteroskedasticity, ARCH effects or non-normality (skewness 0.13; kurtosis 2.46). With 30 observations these tests have limited power, so they indicate only that no problem was detected, not that the specification is correct. Figure 5 shows the CUSUM of squares plot. The cumulative sum stays within the 5% bounds throughout 2006–2023, so no parameter instability is detected. It comes close to the lower bound around 2014–2016 and in 2020 and rises faster after 2019, which suggests somewhat larger residual variance in the most recent years, but without crossing the bounds. The plain CUSUM test and break tests at specific dates are not reported (Section 4.8).

Fig.5. CUSUM of squares test for the ARDL(2,3,4) model



Source: Authors' calculations using EViews 14 (least-squares form of the ARDL(2,3,4) equation, 5% significance bounds).

4.6 Summary of the Results

HT1 (wheat production) is tentatively supported: the long-run association is positive (elasticity 2.42; p = 0.038 for the level coefficient), but the bounds test gives only weak evidence of a level relationship, the short-run same-year association (0.209) is reversed within two years, and the size of the long-run elasticity cannot be given a causal or multiplier interpretation. HT2 (rainfall) is not supported: the long-run elasticity is 0.36 (p = 0.83), and the negative lagged short-run coefficients are not given a causal reading. The main hypothesis (HT) is therefore supported only weakly and conditionally.

4.7 Discussion

The results indicate a weak long-run relationship between wheat production and agricultural value added in Algeria over 1990–2023. The bounds test rejects the null hypothesis of no level relationship at the 10% level only and is inconclusive at 5%, and the error-correction term (−0.0785) implies that deviations from the long-run relationship are corrected very slowly, with a half-life of about 8.5 years. Conditional on this weak evidence, the implied long-run elasticity of agricultural value added with respect to wheat production is positive and large (2.42). An elasticity above unity is compatible with a more-than-proportional co-movement of wheat production and agricultural value added, which may be consistent with the central place of wheat in Algeria's agricultural sector. It cannot, however, be taken as evidence of multiplier effects in the value chain: wheat is a component of the output measured by agricultural value added, value added is measured in current prices so that price and inflation trends enter the relationship, no deterministic trend is included, and the omitted variables listed in Section 4.8 may move with both series.

The short-run results show that the association is concentrated in the same year (0.209) and is largely reversed in the following two years (−0.145 and −0.058), so the

 ISSN 2623-2602/ EISSN: 2716-8891

cumulative three-year association is close to zero. This pattern is more consistent with transitory co-movement, including the mechanical component, than with a lasting effect of wheat production on the rest of the sector, but the present model cannot separate these explanations. The persistence of agricultural value added itself (0.479) shows that past growth carries over strongly into current growth.

For rainfall, the long-run elasticity (0.36) is statistically indistinguishable from zero, so HT2 is not supported. The negative and significant coefficients on the second and third lags of rainfall in the short-run equation should not be read as evidence that rainfall reduces agricultural value added. They have no clear economic explanation, may be a by-product of estimating 12 parameters on 30 observations, and are conditional on wheat production, which itself depends on rainfall, so that the rainfall coefficients may capture a residual or indirect component. Total annual rainfall also does not capture timing, intensity or seasonal distribution; seasonal rainfall, deviations from the historical mean, drought indices and temperature are natural directions for further work.

A positive long-run association between wheat output and agricultural value added is not inconsistent with Algeria's policy emphasis on wheat self-sufficiency as a lever for rural development and food security. Wheat occupies a substantial share of cultivated land and benefits from state support (subsidised inputs, guaranteed purchase prices and irrigation programmes), so fluctuations in wheat output may be transmitted to related activities such as milling and animal feed. The present analysis, however, does not test these channels and does not show that wheat-support policies raise agricultural value added.

The diagnostics offer limited reassurance. No serial correlation, heteroskedasticity, ARCH effects or non-normality is detected in the residuals of the dynamic specification, and the CUSUM of squares plot remains within the 5% bounds. These tests have limited power with 30 observations, and none of them addresses omitted variables, reverse causality or the price basis of the dependent variable. The adjusted R^2 of the error-correction regression (0.824) refers to the variation of the growth of agricultural value added and is not a measure of the explanatory power of wheat production; other determinants, such as irrigated land area, fertilizer use, mechanization, prices and macroeconomic conditions, are omitted and warrant further investigation.

4.8 Limitations of the Study

- **Weak evidence of cointegration:** the bounds test rejects the null hypothesis of no level relationship at the 10% level only and is inconclusive at 5%, so the long-run estimates are indicative.
- **Small sample and model complexity:** the selected ARDL(2,3,4) model has 12 parameters for 30 observations. The p-values do not account for the model-selection step, the unit root and bounds tests have limited power, and only the AIC with a maximum of four lags was used; results may be sensitive to other lag choices (for example SIC or HQ, or a maximum lag of two).

- **Price basis of value added:** agricultural value added is measured in current prices and is not deflated, so the estimated association partly reflects price and inflation trends and not only real output. Re-estimating the model with value added in constant prices is the main extension required.
- **Deterministic trend:** only a restricted constant (Case 2) was estimated. Because LVAAGR and LWHEAT both trend upward, common trends may inflate the long-run elasticity (Granger & Newbold, 1974); a specification with a trend should be examined.
- **Omitted variables:** harvested and irrigated area, fertilizer consumption, mechanization, agricultural investment, input and output prices, government support, temperature or drought indices, and policy variables are not included, which may bias the coefficients of the included variables.
- **Mechanical relationship, endogeneity and causal interpretation:** wheat is part of the output measured by agricultural value added, and production and value added may be jointly determined by weather, prices and policy. The ARDL framework models dynamics but does not identify causal effects, so the results are conditional associations.
- **Rainfall measurement:** total annual rainfall does not capture timing, intensity or regional distribution, and non-linear effects (a quadratic term) and an interaction between wheat production and rainfall were not tested, so the interpretation of the rainfall coefficients is tentative.
- **Structural change and stability:** stability was checked only with the CUSUM of squares test on the least-squares form of the model. Unit root tests allowing for breaks (Zivot & Andrews, 1992), the Phillips-Perron and KPSS tests, the plain CUSUM test, Chow or Quandt-Andrews tests, and policy dummies (PNDA/PNDAR, PRAR, drought episodes, COVID-19) are not reported in this version.
- **Serial correlation test order:** the Breusch-Godfrey test is reported for two lags only; other orders should be examined.

5. CONCLUSION

This study set out to test the main theoretical hypothesis (HT) that wheat production is significantly associated with agricultural value added in Algeria over the period 1990–2023, through two sub-hypotheses: that wheat production (HT1) and annual rainfall (HT2) are each positively and significantly associated with agricultural value added. Using annual FAO data, ADF tests showing that LVAAGR, LWHEAT and LRAIN are integrated of order one, and an ARDL(2,3,4) model estimated over 1994–2023 with the bounds-testing approach, the analysis supports HT only weakly and conditionally. This is a conditional association and not an established causal effect.

Regarding the two sub-hypotheses, the results are mixed. The bounds test rejects the null hypothesis of no level relationship at the 10% level only (F = 4.22) and is

 ISSN 2623-2602/ EISSN: 2716-8891

inconclusive at 5%. Conditional on that weak evidence, HT1 is tentatively supported: the implied long-run elasticity of agricultural value added with respect to wheat production is 2.42 (p = 0.038 for the level coefficient), while the short-run association is positive in the same year (0.209) and reversed within two years. HT2 is not supported: the long-run rainfall elasticity (0.36) is not significant (p = 0.83), and the negative lagged short-run coefficients should not be read as evidence that rainfall reduces agricultural value added.

The error-correction term is negative and significant (−0.0785) but small, implying a half-life of about 8.5 years, so adjustment towards the long-run relationship is very slow. Residual tests detect no serial correlation, heteroskedasticity, ARCH effects or non-normality, and the CUSUM of squares plot stays within the 5% bounds. These checks have limited power with 30 observations, and they do not address omitted variables, reverse causality or the fact that value added is measured in current prices. The results are therefore not presented as robust or causal.

From an economic standpoint, the positive long-run association is compatible with the prominent position of wheat in Algeria's agricultural sector, but because wheat is a component of agricultural output and the elasticity exceeds one, it does not by itself demonstrate multiplier effects in the value chain. The next steps are to re-estimate the model with agricultural value added in constant prices, to examine specifications with a deterministic trend, to add control variables (harvested and irrigated area, fertilizer use, mechanization, prices and policy dummies), to use seasonal rainfall or drought indicators, and to test for structural breaks and the robustness of the lag choice.

6. Recommendations

The findings of this study are conditional associations estimated on a small sample, so the recommendations below are offered as prudent policy orientations and not as effects established by the model. They rely on the empirical results together with the structural features of the sector documented in Section 2.

1. Sustain production-focused support for the wheat sector and evaluate its results. The long-run association between wheat production and agricultural value added is positive (implied elasticity 2.42), although the evidence of a long-run relationship is weak and the estimate cannot be read as a causal or multiplier effect. Continued public support — through input subsidies, mechanization programs and guaranteed purchase prices — remains consistent with the national food-security objective, provided that it is accompanied by a systematic evaluation of its outcomes.

2. Reduce dependency on rainfed cultivation through irrigation expansion. Wheat output in Algeria is highly volatile and overwhelmingly rainfed (Section 2). The ARDL results do not detect a statistically significant long-run association between annual rainfall and agricultural value added (elasticity 0.36; p = 0.83), but this should not be read as evidence that rainfall is unimportant: total annual rainfall does not capture the

timing, intensity or regional distribution of precipitation (Section 4.8). Expanding irrigation infrastructure, particularly in wheat-growing regions heavily reliant on rainfall, would reduce exposure to climatic variability and help stabilize year-to-year output.

3. Strengthen water management and rainfall monitoring. Because annual totals hide seasonal and regional patterns, investment in water-retention and drainage infrastructure and in drought monitoring, together with rainfall data collected at regional and seasonal level, would both protect crops and allow future studies to measure the role of climate more precisely.

4. Close the productivity gap through improved inputs and extension services. With average yields of 14.83 quintals/hectare against a global average near 37 quintals/hectare, targeted investment in seed quality, fertilizer access, and farmer training could raise productivity independently of the area cultivated.

5. Promote drought-resistant and climate-adapted wheat varieties. Given the sector's demonstrated climate sensitivity, adopting varieties bred for lower water requirements and heat tolerance would reduce the volatility documented in Section 2.

6. Reinforce monitoring and evaluation of existing agricultural programs. Continuity in initiatives such as the PNDA/PNDAR and PRAR should be paired with wheat-specific performance indicators, allowing policymakers to isolate the sector's response to public investment from broader agricultural trends. Value added should also be tracked in constant prices so that quantity and price effects can be separated.

7. Support further research using extended dynamic models. Future studies should re-estimate the ARDL model with value added in constant prices, with a deterministic trend and with control variables (prices, cultivated area, fertilizer use, mechanization and policy dummies), and should test for structural breaks, reverse causality and non-linear rainfall effects, for instance within VECM or Granger-causality frameworks, in order to provide more precise guidance for the timing and sequencing of policy interventions.

7. Bibliography List

1. Hadji, F., Rimi, O., Mahdid, F.Z., Chemani, W., & Sadok, A. (2025). Analyzing wheat productivity dynamics in Algeria under climate change: An econometric approach. Advances in Consumer Research, 2(1), 62–70.
2. Chaabane, G., & Benflis, L. (2025). Factors affecting wheat production in Algeria: An econometric study for the period 1990–2019. Journal of Economic Papers, 16(1), 68–85.
3. Doubba, S. (2024). Analysis of the development of wheat production and its contribution to meeting the requirements of food security in Algeria during the period 2000–2021. Journal of Economics and Human Development, 15(2), 7–21.
4. Jaffri, D., & Ajjal, A. (2018). Demand for wheat commodity in Algeria: A standard analytical study for the period 1990–2015. Journal of Economic, Management and Commercial Sciences, 11(1), 124–141.

 ISSN 2623-2602/ EISSN: 2716-8891

5. Tahrat, A., & Bechikr, A. (2019). Analytical and econometric study on determinants of the demand for wheat in Algeria (1985–2016). Journal of Finance and Markets, 6(1), 421–440.
6. Ben Hadjer, M. (2024). Agricultural development policies and their impact on Algeria's self-sufficiency in wheat during the period 2000–2020. Dirassat & Abhath: Arabic Journal of Human and Social Sciences, 16(3), 724–740.
7. Mimouni, C. (2023). Agricultural development plans in Algeria: State of play and their impact on agricultural production from 2000 to 2019. Finance & Markets Journal, 10(2), 121–142.
8. Breusch, T. S. (1978). Testing for autocorrelation in dynamic linear models. Australian Economic Papers, 17(31), 334–355. https://doi.org/10.1111/j.1467-8454.1978.tb00635.x
9. Breusch, T. S., & Pagan, A. R. (1979). A simple test for heteroscedasticity and random coefficient variation. Econometrica, 47(5), 1287–1294. https://doi.org/10.2307/1911963
10. Brown, R. L., Durbin, J., & Evans, J. M. (1975). Techniques for testing the constancy of regression relationships over time. Journal of the Royal Statistical Society: Series B, 37(2), 149–163. https://doi.org/10.1111/j.2517-6161.1975.tb01532.x
11. Dickey, D. A., & Fuller, W. A. (1979). Distribution of the estimators for autoregressive time series with a unit root. Journal of the American Statistical Association, 74(366a), 427–431. https://doi.org/10.1080/01621459.1979.10482531
12. Engle, R. F., & Granger, C. W. J. (1987). Co-integration and error correction: Representation, estimation, and testing. Econometrica, 55(2), 251–276. https://doi.org/10.2307/1913236
13. Godfrey, L. G. (1978). Testing against general autoregressive and moving average error models when the regressors include lagged dependent variables. Econometrica, 46(6), 1293–1301. https://doi.org/10.2307/1913829
14. Granger, C. W. J., & Newbold, P. (1974). Spurious regressions in econometrics. Journal of Econometrics, 2(2), 111–120. https://doi.org/10.1016/0304-4076(74)90034-7
15. Jarque, C. M., & Bera, A. K. (1987). A test for normality of observations and regression residuals. International Statistical Review, 55(2), 163–172. https://doi.org/10.2307/1403192
16. Kwiatkowski, D., Phillips, P. C. B., Schmidt, P., & Shin, Y. (1992). Testing the null hypothesis of stationarity against the alternative of a unit root. Journal of Econometrics, 54(1–3), 159–178. https://doi.org/10.1016/0304-4076(92)90104-Y
17. MacKinnon, J. G. (1996). Numerical distribution functions for unit root and cointegration tests. Journal of Applied Econometrics, 11(6), 601–618. https://doi.org/10.1002/(SICI)1099-1255(199611)11:6<601::AID-JAE417>3.0.CO;2-T
18. Pesaran, M. H., Shin, Y., & Smith, R. J. (2001). Bounds testing approaches to the analysis of level relationships. Journal of Applied Econometrics, 16(3), 289–326. https://doi.org/10.1002/jae.616

19. Zivot, E., & Andrews, D. W. K. (1992). Further evidence on the great crash, the oil-price shock, and the unit-root hypothesis. Journal of Business & Economic Statistics, 10(3), 251–270. https://doi.org/10.1080/07350015.1992.10509904