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Analyzing Wheat Productivity Dynamics in Algeria Under Climate Change an Econometric Approach

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Abstract

This study investigates the dynamics of wheat productivity in Algeria under the pressure of climate change, utilizing quantitative data from 2001 to 2021. The research employs an Autoregressive Distributed Lag (ARDL) model to assess the impact of climatic factors (temperature), agricultural inputs (tractors, harvesters, nitrogen consumption), and their interrelationships on wheat yield. The analysis reveals a significant long-run equilibrium relationship between these variables and wheat productivity. Key findings indicate that increased temperature negatively affects wheat productivity, while the use of harvesters and tractors have positive impact on wheat production. Also, the use of Nitrogen consumption has a positive impact on wheat productivity. The model exhibits satisfactory explanatory power (R-squared = 0.875) and passes various diagnostic tests, confirming its robustness. The results highlight the vulnerability of Algerian wheat production to climate change and underscore the importance of technological advancements and optimized input management for ensuring food security. This research emphasizes the need for targeted agricultural policies aimed at mitigating climate change impacts and promoting sustainable wheat production practices in Algeria.

Keywords: Climate change, wheat productivity, rainfall, cultivated area, Algeria

1. INTRODUCTION

The world is witnessing numerous changes, the most significant of which are climate changes. These changes have impacted all countries without exception, affecting various aspects, including agricultural production. Algeria is not immune to these changes. Despite prioritizing major sectors, particularly agriculture, since its independence, Algeria's agricultural production still faces numerous challenges. Consequently, agricultural imports, especially wheat, have reached record highs in recent years. Simultaneously, agricultural exports, particularly wheat exports, remain weak due to various factors, primarily low production levels. This low production is primarily attributed to climate change, including reduced precipitation and increased temperatures, alongside economic, political, and organizational factors.

1.1 Problem Statement:

Algeria suffers from climate change, which has significantly impacted wheat production and productivity. This issue has several negative economic consequences, including dependence on external sources to meet wheat needs, which are subject to significant price fluctuations. These impacts necessitate the implementation of an agricultural development policy in Algeria to enable adaptation to climate change.

1.2 Research Objectives:

The study aims to achieve several objectives, including:
Diagnosing the current state of wheat production in Algeria.

Assessing the impact of climate change, particularly precipitation and temperature, on wheat productivity in Algeria.

Highlighting the economic and social impacts resulting from changes in wheat productivity in Algeria.
Proposing solutions to address this challenge.

1.3 Methodology:

The study will employ a mixed-methods approach, combining quantitative and qualitative data collection and analysis techniques. The quantitative data will be obtained from secondary sources, including official statistics from the Algerian Ministry of Agriculture and statistics from Arab Organization for Agricultural Development, , Khartoum, Various Volumes.

1.4 Data Analysis:

Quantitative data will be analyzed using statistical methods, including descriptive statistics, correlation analysis, and regression analysis. Qualitative data will be analyzed using thematic analysis to identify recurring patterns and themes.

2. Literature reviews:

Study of Asmaa Bahloul, Mervat Ashour, and Mohy El-Deen El-Bejawy (2019) aimed to measure the economic impacts of climate change on the wheat crop in the regions and governorates of the Arab Republic of Egypt. The research method was to use the Ricardo model to assess the economic impacts of climate change on the net yield of crops. The main results were as follows: there are negative effects of the increase in the temperature of the minimum and the relative and relative humidity (except for the high humidity of about 5%, the positive effect on the net yield of the yield of wheat), while the effects were positive and increasing the decrease of the minimum and relative temperatures and relative humidity.

Study of Bouarab rabih, and Fethallah Messaouda (2022) aims to measure and analyze the impact of climate change on Algerian agricultural production as an important factor affecting the sector in general. For this purpose, a production function model was used to estimate the production elasticities and measure the marginal effects of climate change during the period (1980-2020). Results showed that an increase in temperature during the spring and summer seasons by 1% leads to a decrease in agricultural production by 0.48% and 0.34%, respectively. Precipitation in summer and winter displays a negative impact, where an increase in precipitation during these two seasons by 1% leads to a decrease in agricultural production by 0.05%.

Study of Hamdane Zineb, Nezai Azzeddine, and Abdallah Noureddine (2022): This study measured the effect of the explanatory factors represented by climatic factors, the amount of financing, and the provision of rural housing on the technical inefficiency of wheat production for the municipalities of Saida Province using the method of stochastic frontier analysis during the period 2015/2020. The results of the study showed that the evaluation of the frontier production function according to the method Maximum Likelihood was according to the random model, and that the elasticity of each of the cultivated land, irrigated land, fertilized land, and mechanization reached (0.62, 0.28, 0.98, 0.5), respectively.

Study of Hosam Eldin Sedik Ali (2023) aims to determine the extent to which productivity changes due to climate change and to identify the extent to which the actual reality matches with the economic theory, which emphasizes that climate change leads to agricultural productivity change. Statistical tests were carried out to ensure the existence of a long-term equilibrium relationship between the impact of climate changes on wheat productivity in Egypt using the Autoregressive Distributed Lagged Methodology (ARDL), as it was found that there is an inverse relationship between the climate changes and the wheat productivity, which is a relationship consistent with economic logic as shown the existence of a long-term equilibrium relationship between climate change and wheat productivity in Egypt.
Nouraddine Hormuz, Adham jalb, and Osama Ramadan Kadban (2015): The research aims to study the effects of the climatic elements, rain, dry heat and drought on wheat and barley production. This study reached that: There is a very strong and statistically significant between the irrigated wheat production and rainfall, dry heat and drought index, witch was the most influential, effed followed by precipitation drought index, and by dry heat And There is no statistically significant relationship between rain-Fed wheat production and rainfall dry heat or drought index. And There is no statistically significant relationship between the production of rain-Fed barleyand rainfall and dry heat or drought index.

3. The Current State of Wheat Productivity in Algeria:

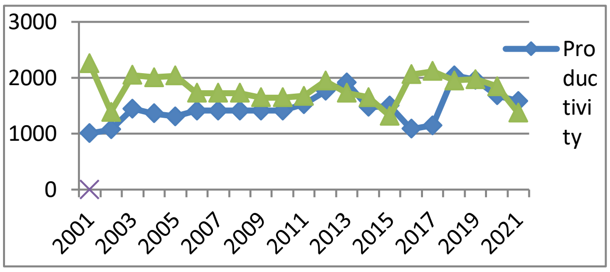
Algeria is among the grain-producing countries, particularly wheat, yet it remains one of the largest wheat importers globally. Algerian wheat is considered one of the finest products worldwide, and both hard and soft wheat varieties are among the most important cereal crops. Algeria is renowned for producing a wide array of wheat types, including Balioni, Hedba, Mohamed Bashir, and Boussalem wheat.

3.1 Evolution of Agricultural Area, Wheat Productivity in Algeria 2001-2021:

Cereals represent a cornerstone of Algeria's agricultural production and consumption patterns, with wheat and its derivatives holding particular prominence. Wheat serves as the staple food for most Algerians, and the area dedicated to cereal cultivation occupies approximately 74% of the total arable land. During the period from 2006 to 2010, the area allocated to wheat cultivation averaged around 2,012,810 hectares, while in 2021, this area reached 1,368,700 hectares.

Wheat production has witnessed significant fluctuations in terms of quantity, directly influenced by climatic factors, particularly rainfall. Similarly, wheat productivity has also experienced substantial imbalances and oscillations from year to year. Productivity reached its lowest levels in 2008 and 2017, with 1270 kg/hectare and 1150.17 kg/hectare, respectively. In contrast, 2018 recorded the highest productivity at 2043.32 kg/hectare, while 2021 reached 1584.27 kg/hectare. Figure 1 illustrates this trend.

Figure 1: Evolution of Agricultural Area Production, Wheat Productivity in Algeria 2001-2021



Source: Arab Organization for Agricultural Development (AOAD), Annual Agricultural Statistics, Khartoum, Sudan, Vols. 28-39, Various Years

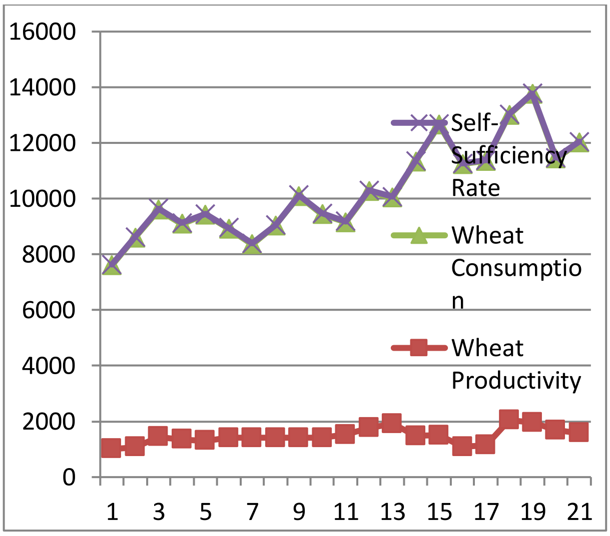
From the results of the figure.1, we note:
Decline in the cultivated area for wheat during specific years, particularly 2008, 2011, and 2014. For instance, after averaging 1,724.24 thousand hectares during the period from 2006 to 2010, the cultivated area experienced a significant drop to 1,006.57 thousand hectares in 2008. This decline can be attributed to the scarcity of rainfall during that year. Conversely, the cultivated area witnessed an upward trend from 2015 to 2019. This improvement stems from favourable climatic conditions and the positive impact of implementing the National Agricultural Development Plans.

Wheat productivity has also exhibited fluctuations. Except for 2018 and 2019, when wheat productivity reached 2,043.32 kg/ha and 1,962.99 kg/ha, respectively, there has been no significant and noticeable increase in productivity. Compared to other Arab countries, wheat productivity in Algeria remains relatively low. For instance, wheat productivity in Saudi Arabia stands at 6,068.26 kg/ha, while in Egypt, it reached 6,378.85 kg/ha in 2019. The primary reasons for Algeria's low wheat productivity include reduced rainfall, recurrent droughts, and the improper use of fertilizers. Aside from the limited availability of fertilizers due to market shortages and rising prices, their application often fails to adhere to scientific standards, both in terms of quantity and type. This inadequate fertilizer use hinders production improvement and productivity gains, especially when coupled with the use of unsuitable seeds that are not selected based on soil characteristics, climate conditions, and crop requirements.

3.2 Wheat Consumption and Self-Sufficiency Rate in Algeria from 2001 to 2021:

Algeria ranks among the world's highest wheat-consuming countries, with an annual consumption volume of approximately 10.8 million tons. Due to the insufficiency of domestic production to meet this substantial demand, Algeria has become heavily reliant on wheat imports. Figure 2 illustrates the trends in wheat production, availability for consumption, and the self-sufficiency rate during the period from 2001 to 2021.

Figure 2: Wheat productivity, Available for Consumption, and Self-Sufficiency 2001- 2021



Source: Arab Organization for Agricultural Development (AOAD), Annual Agricultural Statistics, Khartoum, Sudan, Vols. 28-39, Various Years

From the results of Figure 2, we note that wheat consumption in Algeria experienced a significant upward trend from 2001 to 2021. From 2009 to 2013, annual wheat consumption averaged 8,907.8 thousand tons. This figure rose to 22,799.3 thousand tons in 2018. This increase can be attributed to several factors, including:
Algeria's population grew steadily from 36.6 million in 2003 to 44 million in 2021, leading to a corresponding increase in overall food demand, including wheat.

The adoption of Western-style diets, characterized by higher consumption of wheat-based products, has contributed to the rising demand for wheat.

Government subsidies on wheat products have made them more affordable, further stimulating consumption.

4. A Quantitative Analysis of the Impacts of Climate Change on Wheat Productivity in Algeria:

Descriptive Study of Model Variables:

Table 1: Model Variables

Symbol	Variable Name	Data Source	Expected Sign
prod	Wheat Productivity (tonnes/hectare)		
temp	Temperature (°C)		+
Trac	Tractors		+
Harv	Harvesters		+
Nitro	Nitrogen consumption 1000 tons of microgen		+

Table 2: Descriptive Statistics of study variables

	PROD	TEMP	TRAC	HARV	NITRO
Mean	1473.495	23.74524	104035.9	10493.19	950.59
Median	1414	23.78	104716	10831	763.27
Maximum	2043.32	24.09	113125	11728	6730
Minimum	1005	23.43	83638	8222	60.69
Std. Dev.	282.2213	0.175745	7332.075	1106.415	1410.162
Skewness	0.350094	-0.090529	-1.03617	-0.738141	3.482121
Kurtosis	2.62355	2.274564	4.04249	2.392089	14.88069
Jarque-Bera	0.55298	0.48916	4.708706	2.230346	165.945
Probability	0.758441	0.783033	0.094955	0.327859	0
Sum	30943.39	498.65	2184754	220357	19962.39
Sum Sq. Dev.	1592977	0.617724	1080000000	24483067	39771117
Observations	21	21	21	21	21

Source: outputs Eviews

From the results of the table above, we note:

The average wheat productivity is about 1473.5 kg/hectare. It ranges between 1005 and 2043.32 kg/hectare, meaning that there is a noticeable variation in wheat productivity, indicating differences in efficiency or agricultural conditions during the study period.

The average temperature is 23.74524 with a standard deviation of 0.175745, meaning that the temperature is largely stable during the study period with very little difference between the minimum and maximum.

The average number of tractors is 104035 with a standard deviation of 7332, meaning that the number of tractors varies greatly, reflecting a difference in the availability of agricultural equipment between the study years.

The average number of harvesters was estimated at 10493 and the standard deviation was 1106, indicating that the number of harvesters varies greatly, reflecting a variation in the resources available for agricultural production during the study period.

The average nitrogen consumption was estimated at 950.59 with a variation ranging between 60.69 and 6730 with a standard deviation of 1410.162, indicating that it has many extreme values and does not fit a normal distribution. This suggests that nitrogen levels have high variability, with a few significantly higher values that may be outliers.

Table 3: Matrix of correlations

Correlation	PROD	TEMP	TRAC	HARV	NITRO
PROD	1	-0.392194	0.432813	0.588521	-0.360154
TEMP	-0.392194	1	0.206438	0.046887	-0.076008
TRAC	0.432813	0.206438	1	0.376328	-0.23748
HARV	0.588521	0.046887	0.376328	1	-0.441019
NITRO	-0.360154	-0.076008	-0.23748	-0.441019	1

Source: outputs Eviews

From the results of the table above, we note: A positive correlation, ranging from moderate to weak, was established between the dependent variable, production (PROD), and each of the independent variables: harvest (HARV), and tracking (TRAC). Conversely, a moderate negative correlation was detected between production (PROD) and temperature (TEMP). The correlation coefficients among the independent variables varied from -0.33624 to 0.376328, suggesting the absence of multicollinearity.

Testing the stationarity of variables:

Table 04: Unit root test using the Advanced Dickey-Fuller (ADF)

Model Variables		LPROD	LTEMP	LTRAC	LHARV	LNITRO
At Level						
With Constant	t-Statistic	-3.589	-3.6441	-2.3674	-1.7459	-3.6405
	Prob.	0.0165	0.0141	0.1626	0.3945	0.0143
With Constant & Trend	t-Statistic	-3.4062	-3.6922	-8.5047	-1.8735	-3.689
	Prob.	0.0837	0.052	0.000	0.6304	0.0473

Without Constant & Trend	t-Statistic	0.4788	0.0789	1.0383	0.7024	0.0655
	Prob.	0.8094	0.6965	0.9143	0.8589	0.6922
At First Difference						
With Constant	t-Statistic	-4.3515	-5.3236	-11.1101	-5.4972	-5.3205
	Prob.	0.0044	0.0004	0.000	0.0003	0.0004
With Constant & Trend	t-Statistic	-3.2184	-5.1929	-12.7521	-5.534	-5.1897
	Prob.	0.1181	0.0028	0.000	0.0015	0.0028
Without Constant & Trend	t-Statistic	-4.2521	-5.4751	-6.4639	-5.3183	-5.472
	Prob.	0.0003	0.000	0.000	0.000	0.000

Source: outputs Eviews

From the table results we notice that:

LPROD, LNITRO and LTEMP are stationary at the level with the constant only, they are integrated of degree zero I(0).

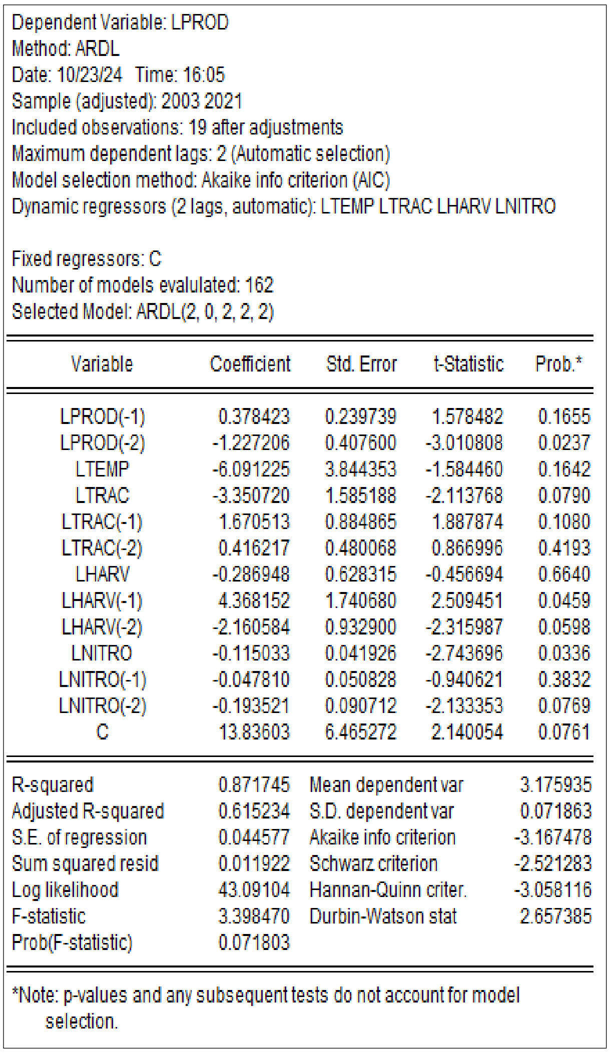
LHARV and LTRAC are not stationary at the level, but they are stationary at the first difference, which means that the data become stationary after taking the first difference, they are integrated of degree one I(1).

Then the cointegration test can be performed using the autoregressive distributed lag method (ARDL).

Model Estimation:

A stepwise regression approach was employed to select the model variables. Independent variables were entered sequentially, and their contribution to the model's significance was evaluated. The presence of both long-run equilibrium and short-run adjustment mechanisms (error correction mechanism) was examined. The Schwarz Bayesian Criterion (SBC) was used to determine the optimal lag lengths. The following table presents the estimation results of the ARDL model with lags (2,0,0,0,2)

Table 05: Results of estimating the (ARDL) model with slowing (2,0,2,2,2)



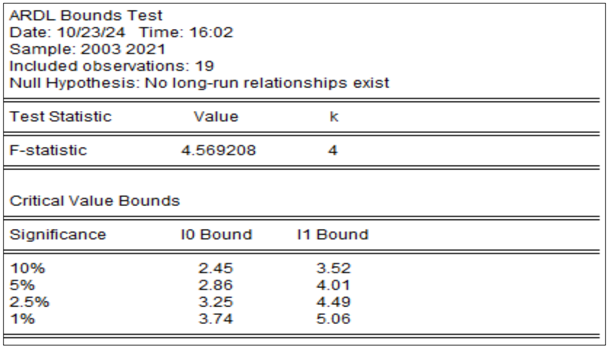
```
Dependent Variable: LPROD
Method: ARDL
Date: 10/23/24   Time: 16:05
Sample (adjusted): 2003 2021
Included observations: 19 after adjustments
Maximum dependent lags: 2 (Automatic selection)
Model selection method: Akaike info criterion (AIC)
Dynamic regressors (2 lags, automatic): LTEMP LTRAC LHARV LNITRO

Fixed regressors: C
Number of models evalulated: 162
Selected Model: ARDL(2, 0, 2, 2, 2)

        Variable       Coefficient    Std. Error    t-Statistic    Prob.*

        LPROD(-1)       0.378423      0.239739      1.578482      0.1655
        LPROD(-2)      -1.227206      0.407600     -3.010808      0.0237
          LTEMP        -6.091225      3.844353     -1.584460      0.1642
          LTRAC        -3.350720      1.585188     -2.113768      0.0790
        LTRAC(-1)       1.670513      0.884865      1.887874      0.1080
        LTRAC(-2)       0.416217      0.480068      0.866996      0.4193
          LHARV        -0.286948      0.628315     -0.456694      0.6640
        LHARV(-1)       4.368152      1.740680      2.509451      0.0459
        LHARV(-2)      -2.160584      0.932900     -2.315987      0.0598
          LNITRO       -0.115033      0.041926     -2.743696      0.0336
        LNITRO(-1)     -0.047810      0.050828     -0.940621      0.3832
        LNITRO(-2)     -0.193521      0.090712     -2.133353      0.0769
            C          13.83603       6.465272      2.140054      0.0761

R-squared             0.871745    Mean dependent var       3.175935
Adjusted R-squared    0.615234    S.D. dependent var       0.071863
S.E. of regression    0.044577    Akaike info criterion   -3.167478
Sum squared resid     0.011922    Schwarz criterion       -2.521283
Log likelihood        43.09104    Hannan-Quinn criter.    -3.058116
F-statistic           3.398470    Durbin-Watson stat       2.657385
Prob(F-statistic)     0.071803

*Note: p-values and any subsequent tests do not account for model
     selection.
```

Source: outputs Eviews

Limits Methodology Test:

The results of the limits test indicate that the calculated Fisher statistic F-statistic = 4.5962, which is greater than the critical value of the upper limit at a significance level of 5%, which makes us reject the null hypothesis stating: "There is no long-term equilibrium relationship" and accept the alternative hypothesis stating: "There is a long-term equilibrium relationship" between the model variables.

Table 06: Testing the boundary approach for the existence of a long-term relationship

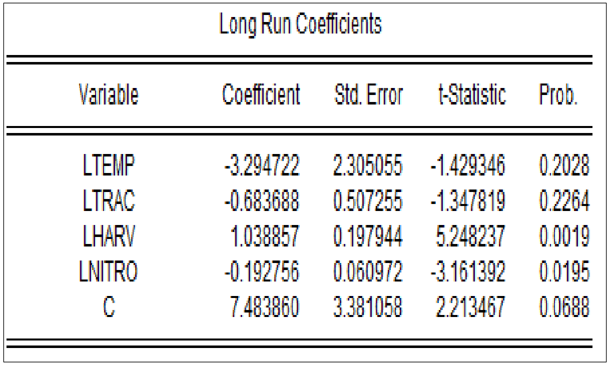


```
ARDL Bounds Test
Date: 10/23/24   Time: 16:02
Sample: 2003 2021
Included observations: 19
Null Hypothesis: No long-run relationships exist

Test Statistic            Value           k

F-statistic             4.569208          4


Critical Value Bounds

Significance            I0 Bound       I1 Bound

10%                       2.45           3.52
5%                        2.86           4.01
2.5%                      3.25           4.49
1%                        3.74           5.06
```

Source: outputs Eviews

Estimation of Long-Run Model Parameters:
After confirming the existence of a long-run equilibrium relationship among the independent variables and wheat productivity, we will proceed to estimate the long-run relationship using the ARDL model. This stage involves estimating the long-run parameters, as shown in the following table.

Table 7: Long-Run Model Parameter Estimates



Long Run Coefficients

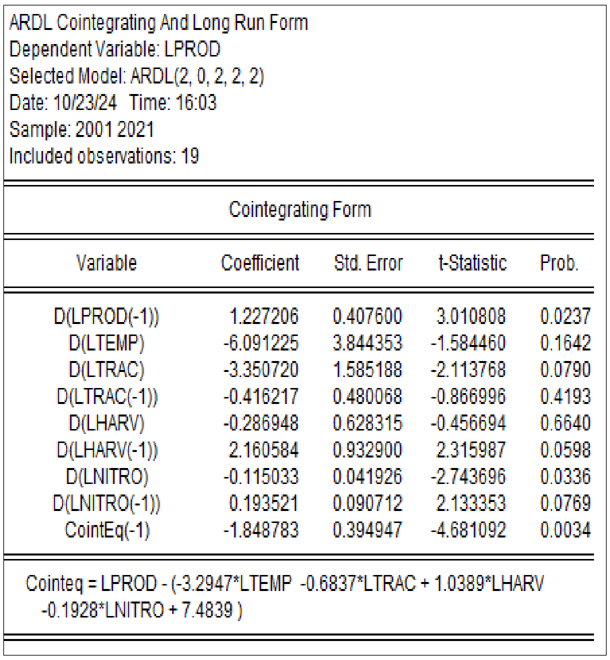
Variable	Coefficient	Std. Error	t-Statistic	Prob.
LTEMP	-3.294722	2.305055	-1.429346	0.2028
LTRAC	-0.683688	0.507255	-1.347819	0.2264
LHARV	1.038857	0.197944	5.248237	0.0019
LNITRO	-0.192756	0.060972	-3.161392	0.0195
C	7.483860	3.381058	2.213467	0.0688

Source: outputs Eviews

Estimating the error correction limit model and short-run parameters:

As for the error correction limit (ECM) parameter (-1), which measures the speed of return to equilibrium, its value (-1.848) came with a negative and significant sign at the 5% level, which confirms the existence of an error correction mechanism in the model. The following table shows the results of estimating the limit model. Error correction and short-run parameter

Table 8: Estimates of Error Correction Model and Short-Run Coefficients.



ARDL Cointegrating And Long Run Form
Dependent Variable: LPROD
Selected Model: ARDL(2, 0, 2, 2, 2)
Date: 10/23/24 Time: 16:03
Sample: 2001 2021
Included observations: 19

Cointegrating Form

Variable	Coefficient	Std. Error	t-Statistic	Prob.
D(LPROD(-1))	1.227206	0.407600	3.010808	0.0237
D(LTEMP)	-6.091225	3.844353	-1.584460	0.1642
D(LTRAC)	-3.350720	1.585188	-2.113768	0.0790
D(LTRAC(-1))	-0.416217	0.480068	-0.866996	0.4193
D(LHARV)	-0.286948	0.628315	-0.456694	0.6640
D(LHARV(-1))	2.160584	0.932900	2.315987	0.0598
D(LNITRO)	-0.115033	0.041926	-2.743696	0.0336
D(LNITRO(-1))	0.193521	0.090712	2.133353	0.0769
CointEq(-1)	-1.848783	0.394947	-4.681092	0.0034

Cointeq = LPROD - (-3.2947*LTEMP -0.6837*LTRAC + 1.0389*LHARV -0.1928*LNITRO + 7.4839)

Source: outputs Eviews

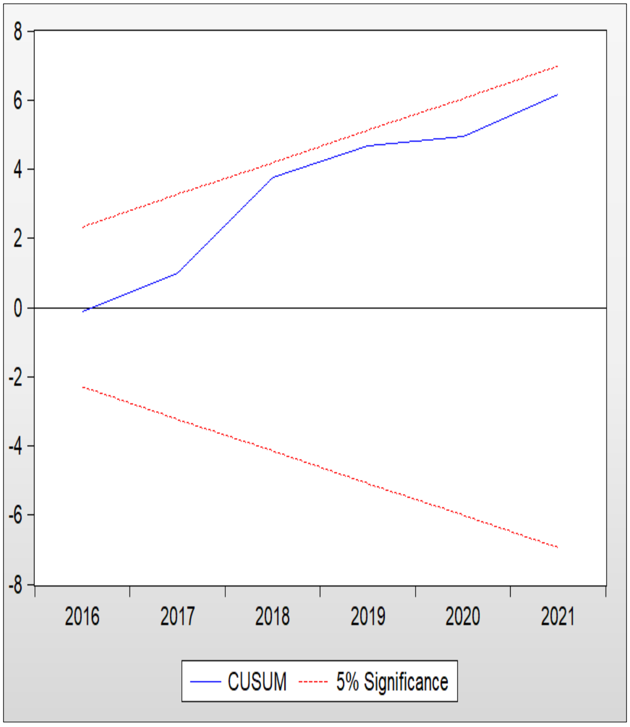
As for the error correction limit model, we note that the results were very similar to the results in the long run, meaning that the relationship between the independent variables and the dependent variable in terms of significance as well as in terms of its type in the short run, is largely consistent with its relationship in the long run.

Model Stability Test: Error Correction Mechanism (ECM) Test:
To ensure that the data used in this study is free from any structural breaks, it is necessary to employ suitable tests such as: the Cumulative Sum of Recursive Residuals (CUSUM) test, and the Cumulative Sum of Squares of Recursive Residuals (CUSUMSQ) test.

These tests are considered among the most important in this field, as they reveal two significant aspects: the detection of any structural changes in the data and the stability; and consistency of long-run and short-run parameters.

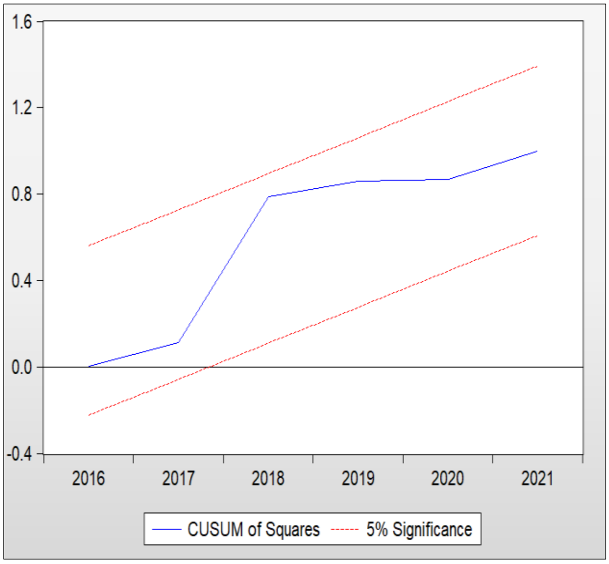
Numerous studies have shown that such tests are commonly associated with the ARDL methodology. The structural stability of the estimated coefficients of the error correction model for the autoregressive distributed lag model is verified if the CUSUM and CUSUMSQ statistics , fall within the critical bounds at the 5% level of significance. In light of these studies, we applied the CUSUM and CUSUMSQ tests proposed by Brown, Durbin, and Evans (1975).

Figure No. (03): Cumulative sum of recurring residuals (CUSUM) test



Source: outputs Eviews

Figure No. (04): Cumulative sum of squares test (CUSUM of Squares)

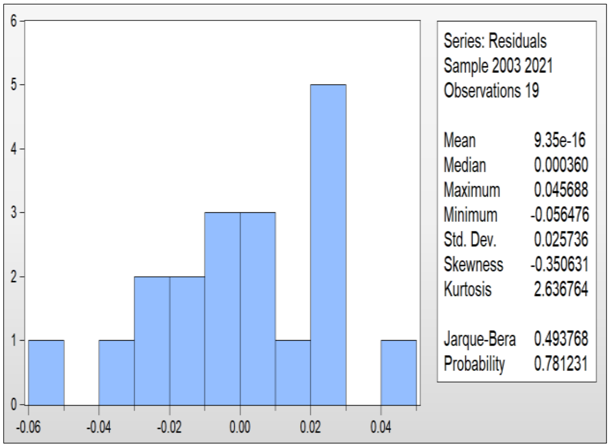


Source: outputs Eviews

Model diagnostic tests:

Normal distribution test: To test the normal distribution of the estimated model residuals, we use the (Jarque-Bera test) to assume the null (normal distribution of residuals:

Figure No. (05): Normal distribution test of residuals



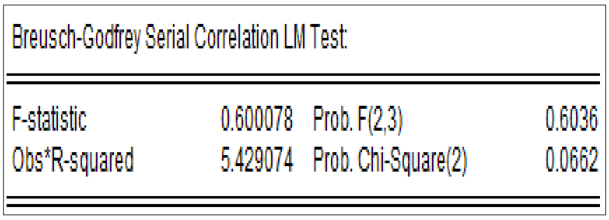
```
Series: Residuals
Sample 2003 2021
Observations 19

Mean         9.35e-16
Median       0.000360
Maximum      0.045688
Minimum     -0.056476
Std. Dev.    0.025736
Skewness    -0.350631
Kurtosis     2.636764

Jarque-Bera  0.493768
Probability  0.781231
```

Source: outputs Eviews

The test results, as shown in Figure (3), confirmed that the model residuals follow the normal distribution, as the probability values (P-Values) for the Jarque-Bera test reached 0.493, which is greater than the 5% significance level.

Residual Autocorrelation Test: The estimated model cannot be relied upon if its residuals exhibit autocorrelation. because autocorrelation can adversely affect the accuracy of the estimated parameter values and lead to misleading inferences regarding significance tests. Therefore, it is essential to ensure that the estimated model is free from this problem. The Breusch-Godfrey Serial Correlation LM test is used to test the null hypothesis of no serial correlation among the residuals.

Table No. (9): Test of autocorrelation between residuals



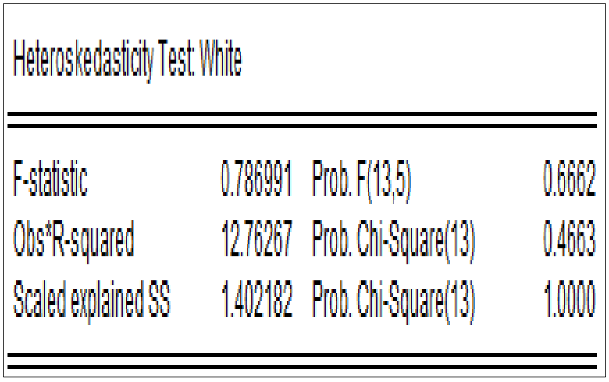
```
Breusch-Godfrey Serial Correlation LM Test:

F-statistic      0.600078   Prob. F(2,3)          0.6036
Obs*R-squared    5.429074   Prob. Chi-Square(2)   0.0662
```

Source: outputs Eviews

The test results, as shown in the table above, confirmed that the residuals of the estimated model are free of this problem, as the probability values (P-Values) for the F statistic reached 0.60, which is greater than the 5% significance level, which confirms that the null hypothesis can be accepted that the estimated model is free of the problem of autocorrelation between its residuals.

Heteroscedasticity test: One of the characteristics of a good model is that its estimated residuals have a constant variance. Rejecting this assumption leads to biased standard errors and, consequently, misleading results. The White test was used to assess this assumption.

Table No. (10): Test of variance stability of errors.



```
Heteroskedasticity Test: White

F-statistic          0.786991   Prob. F(13,5)           0.6662
Obs*R-squared        12.76267   Prob. Chi-Square(13)    0.4663
Scaled explained SS  1.402182   Prob. Chi-Square(13)    1.0000
```

Source: outputs Eviews

As shown in the table above, the P-values for both the F-Statistic and the Chi-Square were greater than the 5% significance level, which confirms that the estimate residuals have homogeneous variance.

Economic evaluation of the model:

All coefficients in the estimated model are statistically significant, indicating a long-run equilibrium relationship between climate change and wheat productivity in Algeria. The model also passes the diagnostic test for serial correlation, suggesting that it is well-specified. As such, we proceed to the next stage of testing to evaluate its conformity with economic theory.

Economically, the logarithmic form of the model seems appropriate. This view is supported by the coefficient of determination (R^2) of 0.875, indicating that the model explains 87.5% of the variation in wheat yield and is well-explained by the explanatory variables, such as temperature and number of tractors and harvesters and Nitrogen consumption.

-Positive constant limit sign: c= 13.83 which represents wheat productivity, in the absence of suitable temperatures, and the absence of tractors and harvesters Nitrogen consumption

-The results obtained from the standard study can be analyzed as follows:

- The temperature signal (TEMP) was negative, meaning that there is a medium negative relationship. According to economic theory, it has a negative effect on wheat productivity, meaning that an increase in average temperature leads to a decrease in wheat productivity. This situation can be explained by the fact that high temperatures lead to a decrease in wheat productivity in Algeria. According to this model, it is clear that an increase in temperature by 01% leads to a decrease in wheat productivity by 6.0912%.
- The positive coefficient on the harvester variable is economically intuitive, implying that increased mechanization, as represented by the number of harvesters, has a positive effect on wheat productivity . This finding supports the notion that mechanization plays a crucial role in improving agricultural productivity in Algeria. The model estimates that a 1% increase in harvester usage is associated with a 2.286% increase in wheat productivity .
- As for the tractor coefficient, it was consistent with the economic theory, i.e. it has a positive effect on wheat productivity, meaning that increasing these tractors leads to increasing wheat productivity, which indicates that the machine has great importance in increasing wheat productivity in Algeria. According to this model, it is clear that increasing the latter by 1% leads to an increase in wheat productivity by 3.335%.
- The sign of the coefficient for nitrogen is consistent with economic theory, indicating a positive impact on wheat productivity. This implies that an increase in nitrogen leads to an increase in wheat productivity in Algeria . According to this model, a 1% increase in nitrogen fertilization results in a 0.115% increase in wheat yield

CONCLUSION

This study provides valuable insights into the factors influencing wheat productivity in Algeria amidst the challenges posed by climate change. The ARDL model reveals a complex interplay between temperature, mechanization, and nitrogen fertilization, with significant implications for agricultural policy. The negative impact of increasing temperatures underscores the vulnerability of wheat production to climate change and highlights the need for adaptation strategies such as the development of heat-resistant wheat varieties. The positive effects of harvesters, tractors, and nitrogen consumption emphasize the importance of investing in agricultural technology and optimizing resource management to enhance wheat yield.

The findings of this research suggest that Algeria can improve its wheat self-sufficiency by implementing policies that:

- Promote climate-smart agricultural practices.
- Encourage the adoption of modern farming techniques.
- Ensure the efficient and sustainable use of agricultural inputs.

Furthermore, this study highlights the need for ongoing research to monitor the evolving impacts of climate change on wheat production and to develop innovative solutions for ensuring food security in Algeria. By addressing the challenges identified in this research, Algeria can strengthen its agricultural sector and reduce its dependence on wheat imports.

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