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An Economic Study of the Impact of Climate Change on the Rice Productivity in Egypt

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Abstract: Achieving of the food security is one of the most important economic problems that threaten economic and social development in Egypt, through the imbalance between supply and demand, thus the occurrence of a food gap due to the increase in food demand as a result of the increase in the population growth rate, in addition to the inability to increase agricultural production to meet the increases demand of food. The inability of production to meet the growing needs leads to increases the imports of crops and food commodities, and an increase in the deficit in the Egyptian trade and agricultural balance. The cereal crops are the most important strategic crops for achieving food security and meeting the needs of the population in terms of demand for them. The agricultural production of these crops is affected by climatic changes by negatively effect of agricultural production (CAPMAS). In this paper we examine how the Climate Change affected on the rice productivity in Egypt, with the aim of determining the extent to which productivity has changed due to climate change in Egypt, using the Autoregressive Distributed lagged (ARDL) methodology, where it was found that there is an inverse relationship between climate changes and the rice productivity. The results indicates that a similar negative impact of the maximum temperature change on the rice productivity in the long term, which is consistent with an economic theory.
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Key words: Rice productivity, climate changes, temperature, ARDL Approach, Bound Tests, Diagnostics test.

1. Introduction:

Many studies discussed the impact of climate change on the agricultural production. This section is overviews the impact of climate change on the agricultural production. The study of Cramer and et al. (2018) studied the climate change and interconnected risks to sustainable development in the Mediterranean. The study showed that the recent accelerated climate change has exacerbated existing environmental problems in the Mediterranean Basin that are caused by the combination of changes in land use, increasing pollution and declining biodiversity. For five broad and interconnected impact domains (water, ecosystems, food, health and security), current change and future scenarios consistently point to significant and increasing risks during the coming decades. Policies for the sustainable development of Mediterranean countries need to mitigate these risks and consider adaptation options, but currently lack adequate information — particularly for the most vulnerable southern Mediterranean societies, where fewer systematic observations schemes and impact models are based. A dedicated effort to synthesize existing scientific knowledge across disciplines is underway and aims to provide a better understanding of the combined risks posed.

Perry and Tack (2020) studied using insurance data to quantify the multidimensional impacts of warming temperatures on yield risk. The study predicted significant negative yield impacts from warming temperatures, but estimated the effects on yield risk and disentangling the relative caused of these losses remained challenging. The study presented new evidence on the issues by leveraging a unique publicly available dataset consisting of roughly 30,000 county by year observations on insurance-based measures of yield risk from (1989–2014) for U.S. to corn and soybeans. The study results suggested that yield risk will increase in response to warmer temperatures, with a 1 °C increase associated with yield risk increases of approximately 32% and 11% for corn and soybeans, respectively. The study using caused of loss information, the study also found that additional losses under warming temperatures primarily result from additional reported occurrences of drought, with reported losses due to heat stress playing a smaller role. The study showed that an implication of the findings is that the cost of purchasing crop insurance will increase for producers as a result of warming temperatures.

Ebrahim (2021) studied climate changes and food security in Egypt, the study showed that the elimate change is one of the environmental challenges facing humanity because it affects all aspects of life on Earth, especially food security, as Egypt suffers from food shortages in light of population growth and a low self-sufficiency rate in some basic commodities. The study showed that the agricultural sector in Egypt is one of the important sectors affected by climatic changes, which is expected to affect the productivity of agricultural lands and then the productivity of crops, and among the crops affecting food security in Egypt, which is expected to be affected by climatic changes is the wheat crop. Therefore, the study aimed the impact of climatic changes on food security in Egypt by focusing on the productivity of one of the strategic crops for Egypt, which is the wheat crop. The research showed that the productivity of the wheat crop during the period (2000-2019) did not undergo significant changes due to the efforts made by the state to reduce the impact of climate changes on the two most important elements of wheat cultivation, namely land and water.

Mansour and Hasan (2022) studied the impact of climate changes on the productivity of the most important grain crops using the (ARDL) model, with the aim of determining the extent to which productivity changes the most important grain crops with climate change, and to identify the extent to which the actual reality corresponds to the economic theory that emphasizes that temperature change it leads to a change in agricultural production, and the Autoregressive distributed lagged model (ARDL) was used, as it was found that there is an inverse relationship between climate changes and the productivity of the most important grain crops, a relationship that is consistent with economic logic, and it was also shown that there is a long-term equilibrium relationship between climate changes and the productivity of the most important grain crops, where it was found that there is a negative effect of the change in the maximum temperature on the productivity of the most important grain crops in the long term.

Zureikat (2022) studied the impact of climate change and land use change on water resources and food security in Jordan. The study showed that the Jordan has a dry climate with limited arable land and water resources, where the per capita share of water is less than 145 m3 per year. The study focused on the impact of agriculture on climate change in light of the trends of expected climate change and population growth in Jordan.

Fuldauer et al. (2022) studied the targeting climate adaptation to safeguard and advance the Sustainable Development Goals. The study showed that the international community has committed to achieve 169 Sustainable Development Goal (SDG) targets by 2030 and to enhance climate adaptation under the Paris Agreement. The study showed that despite the potential for synergies, aligning SDG and climate adaptation efforts were inhibited by an inadequate understanding of the complex relationship between SDG targets and adaptation to impacts of climate change. The study proposed a framework to conceptualize how ecosystems and socio-economic sectors mediate this relationship, which provided a more nuanced understanding of the impacts of climate change on all 169 SDG targets. The study showed that the global application of the framework reveals that adaptation of wetlands; rivers, cropland, construction, water, electricity, and housing in the most vulnerable countries were required to safeguard achievement of 68% of SDG targets from near-term climate risk by 2030. The study discussed how the framework can help align National Adaptation Plans with SDG targets, thus ensuring that adaptation advances, rather than detracts from, sustainable development.

Proctor et al. (2022) studied the more accurate specification of water supply showed its importance for global crop production, the study warming temperatures tend to damage crop yields, the influence of water supply on global yields and its relation to temperature stress remains unclear. The study used the satellite-based measurements to provide empirical estimates of how root zone soil moisture and surface air temperature jointly influence the global productivity of maize, soybeans, millet and sorghum. The study used the empirical models precipitation as a proxy for water supply; the study found that models used soil moisture explain 30–120% more of the inter-annual yields variation across crops. The study Models used soil moisture also better separate water-supply stress from correlated heat stress and show that soil moisture and temperature contribute roughly equally to historical variations in yield. Globally, the models project yield damages of −9% to −32% across crops by end-of-century under Shared Socioeconomic Pathway 5-8.5 from changes in temperature and soil moisture. The study showed that the projections were used the temperature and precipitation overestimate damages by 28% to 320% across crops both because they confound stresses from dryness and heat and because changes in soil moisture and temperature diverge from their historical association due to climate change. The study results demonstrated the importance of accurately representing water supply for predicting changes in global agricultural productivity and for designing effective adaptation strategies.

Ballarin et al (2023) studied the climate change dataset for Brazil. The study showed that the General Circulation and Earth System Models were the most advanced tools for investigating climate responses to future scenarios of greenhouse gas emissions, played the role of projecting the climate throughout the century. Nevertheless, climate projections were model-dependent and may showed systematic biases, requiring a bias correction for any further application. The study provided a dataset based on an ensemble of 19 bias-corrected CMIP6 climate models projections for the Brazilian territory based on the SSP2-4.5 and SSP5-8.5 scenarios. The study used the Quantile Delta Mapping approach to bias-correct daily time-series of precipitation, maximum and minimum temperature, solar net radiation, near-surface wind speed, and relative humidity. The study showed that the bias-corrected dataset is available for both historical (1980–2013) and future (2015–2100) simulations at a $0.25° \times 0.25°$ spatial resolution. Besides the gridded product, the study provided area-averaged projections for 735 catchments included in the Catchments Attributes for Brazil (CABra) dataset. The dataset provides important variables commonly used in environmental and hydro climatological studies, paving the way for the development of high-quality research on climate change impacts in Brazil.

Ting et al (2023) studied the impacts of dry versus humid heat on US corn and soybean yields. The study showed that the impact of extreme heat on crop yields is an increasingly pressing issue given anthropogenic climate warming. The study showed some of the physical mechanisms involved in these impacts remain unclear, impeding adaptation-relevant insight and reliable projections of future climate impacts on crops. The study used a multiple regression model based on observational data; the study showed that while extreme dry heat steeply reduced U.S. corn and soy yields, humid heat extremes had insignificant impacts and even boosted yields in some areas, despite having comparably high dry-bulb temperatures as their dry heat counterparts. The study suggested that conflating dry and humid heat extremes may lead to underestimated crop yield sensitivities to extreme dry heat. Rainfall tended to precede humid but not dry heat extremes, suggested that multivariate weather sequences play a role in these crop responses. The study results provided evidence that extreme heat in recent years primarily affected yields by inducing moisture stress, and that the conflation of humid and dry heat extremes may lead to inaccuracy in projecting crop yield responses to warming and changing humidity.

Carrea et al (2023) studied the satellite derived multivariate worldwide lake physical variable time series for climate studies. The study showed that the consistent dataset of lake surface water temperature, ice cover, water-leaving reflectance, water level and extent is presented. The study showed the collection constitutes the Lakes Essential Climate Variable (ECV) for inland waters. The data span combined satellite observations from (1992 – 2020) inclusive and quantifies over 2000 relatively large lakes, which represented a small fraction of the number of lakes worldwide but a significant fraction of global freshwater surface. Visible and near-infrared optical imagery, thermal imagery and microwave radar data from satellites have been exploited. The study showed that all observations were provided in a common grid at 1/120° latitude-longitude resolution, jointly in daily files. The data/algorithms have been validated against in situ measurements where possible. The study showed the consistency analysis between the variables has guided the development of the joint dataset. It was the most complete collection of consistent satellite observations of the Lakes ECV currently available. The study showed that the Lakes were of significant interest to scientific disciplines such as hydrology, limnology, climatology, biogeochemistry and geodesy, it was a vital resource for freshwater supply, and key sentinels for global environmental change.

Balvino et al. (2023) studied the long-term spatiotemporal patterns in the number of colonies and honey production in Mexico. The study showed the Honey bee declined was currently one of the world's most serious environmental issues, scientists, governments and producers have generated interest in understanding it’s caused and consequences in honey production and food supply. The study showed that the Mexico is one of the world’s top honey producers; however, the honey bee population's status has not been documented to date. The study used the generalized additive mixed models to measure the associations between the percent change in honey bee hives and the percent change in honey yield per hive in relation to land-use, climate, and socioeconomic conditions. The study showed that the average annual yield per hive increased from (1980 to 2012), the study detected a significant decline in the percent change in the number of honey bee hives across the time period studied. The study found a relationship between climatic conditions and agricultural land use, with agriculture increased and high temperatures producing a decreased in the percent change in honey yield. It found a relationship between a reduction in the temperature range (the difference between maximum and minimum temperatures) and a decreased in the percent change in the number of hives, while socioeconomic factors related to poverty levels have an impact on the number of hives and honey yields. The study showed that the long-term declined in hive numbers was not correlated with poverty levels, socioeconomic factors in states with high and medium poverty levels limit the increase in honey yield per hive. The study results provided evidence that land-used changes, unfavorable climatic conditions, political, and socioeconomic factors were partially responsible for the reductions in the percent change in honey bee hives in Mexico.

This research aims to study the impact of climate changes on the productivity of rice crop in Egypt during the period (2005-2021), by using the Autoregressive Distributed lagged Model (ARDL) to ensure the existence of a long-term co-integration relationship between climate changes and rice productivity, to identify the extent to production changes with climate changes through the study of: Develop the rice productivity in Egypt during the period (2005-2021). Evaluate the temperatures, precipitation and humidity levels during the study period. Estimate the impact of climate change on rice productivity in Egypt by using the Autoregressive Distributed lagged (ARDL).This research relied on the descriptive and quantitative statistical analysis method, where some statistical analytical methods were used, such as time series analysis, and the Autoregressive Distributed lagged Model (ARDL) (Pesaran, et al., 2001). The research relied on secondary data published in many official agencies such as the Ministry of Agriculture and Land Reclamation, the Department of Climate Research, the website of the Central Agency for Public Mobilization and Statistics (CAPMAS), some researches, studies and scientific books related to the climate changes.

2. Material and Methods

The research relied on the use of statistical analysis and econometrics tools, where the unit root test (AlSawai, K. 2012) was used to ensure the stability of the time series by using the Augmented Dickey Fuller Test, the Bounds test to identify the extent of the existence of co-integration between variables. Normality Test, Stability test, Autoregressive Distributed lagged Model (ARDL).

Autoregressive Distributed lagged Model (ARDL):

The research uses the Autoregressive Distributed lagged methodology (ARDL) (AlYousef, 2013; AlSawai, 2012) developed by Pesaran, et al. (2001), where the methodology is distinguished by that it does not require that the time series be integrated of the same degree, as Pesaran believes that the (Pound tests) in the (ARDL) can be applied if the time series is stable at the zero level I(0) or integrated of the first degree I(1), and the only condition for applying this test is that the time series should not be integrated of the second degree I(2), and it can also be used in the case of short time series, compared to the co-integration test such as the Granger method (Engle-Granger 1987) or the co-integration test (Johannsen Contegration Test (VAR) model 1999).

Also, the (ARDL) methodology can be applied in the case of the small-sized samples, unlike the co-integration test, which requires that the sample size be large. It is also possible to obtain estimates for the long and short term together at the same time in one equation instead of two separate equations, and it gives the best results for the parameters in the long term, it is also possible to rely on (Diagnostics test) to determine the validity of the estimated model. The (ARDL) can separate the effect of the short term over the long term, determining the size of the influence of each of the independent variables on the dependent variable, and estimating the parameters of the independent variables in the long and short terms.

To test the equilibrium relationship between the variables in the (ARDL) model which were achieved, in the unrestricted error correction model (UCEM), using the Bounds test, where the (ARDL) model includes testing a long-term equilibrium relationship between the variables of the model. The existence of this relationship, then the parameters of the long and short term are estimated, through the (F) statistic using the (WALD Test), where the null hypothesis is tested that there is no co-integration between the variables of the model:

$\mathbf{H_0: \beta_1 = \beta_2 = \beta_3 = \beta_n}$

While the alternative hypothesis is the existence of co-integration between the model variables in the long run:

$\mathbf{H_0: \beta_1 \neq \beta_2 \neq \beta_3 \neq \beta_n}$

The Autoregressive distributed lagged methodology (ARDL) (AlSawai2012; AlYousef, 2013) in:

1- Testing the stability of the time series using the Unit Root Test.
2- Cointegration test using (Bounds Test).
3- Estimating the long-term model using (ARDL).
4- Evaluation of the error correction model (ECM).
5- Residuals test for the stability of the model.

Where the (ARDL) methodology consists of: (p, q_1, q_2……q_n) of a dependent variable and a number of independent explanatory variables (X_1, X_2……X_n) as:
C = Fixed term
D_1 = First degree differences. K = Number of independent variables.
P = Lagged period of the dependent variable Y_1
q_1, q_2……q_n = period of slowing down of explanatory variables.
a_1, a_2……a_n = long-term transactions.
β1, β2…… βn = Short-term transactions.

3. Results and Discussion

First: Development of the study variables during the period (2005-2021):

A study of rice productivity in Egypt (CAPMAS, 2022) showed that it ranged between a minimum of about 3.79 tons and a maximum of about 4.24 tons during the study period. By estimating the time trend equation for the development of rice productivity in Egypt, it was found a statistically significant decreasing trend, by amounting about 0.021

tons, representing about 0.52% of the average for the study period (2005-2021) of about 4.0 tons. While by estimating the time trend equation for the development of the maximum temperature in Egypt, it was found a statistically significant increasing trend of about 0.104 **C°**, which represents about 0.35% of the average study period of about 29.41 **C°**, while it was found a statistically significant increasing trend for the development of the minimum temperature in Egypt by about 0.175 degrees Celsius, which represents about 1.03% of the study period average of about 16.98 degrees Celsius. While by estimating the time trend equation for the relative humidity in Egypt, it was found a statistically significant decreasing amounted to about 0.714%, representing about 1.4% of the study period average of about 50.97%, while it turns out for the evolution of the amount of precipitation in Egypt, that it was found a statistically significant decreasing trend of about 0.174 mm, representing about 5.55 % of the study period average of about 3.14 mm (Table 1).

Table (1): Time trend of rice productivity, temperatures, rainfall and humidity during (2005-2021)

Variable	Equation	Average	Growth	R^2	F
Rice productivity (tons)	$\hat{Y}_t$= 4.190- 0.021 T *(-5.55)***	4.00	-0.52	0.672	30.8**
Max. Temperature (C°)	$\hat{Y}_t$= 28.46+ 0.104 T *(2.33)**	29.41	0.35	0.266	5.4*
Min. Temperature (C°)	$\hat{Y}_t$= 15.39+ 0.175 T *(4.32)***	16.98	1.03	0.554	18.6**
Relative humidity (%)	$\hat{Y}_t$= 57.41- 0.714 T *-4.69)***	50.97	-1.40	0.595	22.0**
Amount of rain (mm)	$\hat{Y}_t$= 4.721- 0.174 T *(-3.15)***	3.14	-5.55	0.398	9.9**

**Sig. at 0.01 levels. *Sig.at the 0.05 levels.
Source: www.capmas.gov.eg

Second: Estimation of the Autoregressive Distributed Lagged Model (ARDL).

In order to estimate the model of the impact of climate change on rice productivity in Egypt by using the (ARDL) methodology, the conditions for the stability of the time series (Augmented Dickey Fuller test) must be met (Elbadry, M., et al. 2022), whether stable at the zero level I(0) or integrated of the first level I(1), and to ensure the stability of the time series in time, the unit root test was performed using the (ADF)Test, where it was found that some of the model variables It is stable at the zero level with a degree of 95% confidence and does not have a root unit (Mostafa and Elbadry, 2015), while it was found that some of them are unstable at the zero level and have a root unit so the first difference was taken, as it was found after taking the first difference that the value of (t) calculated is greater than its tabular value at the level of significance 0.05, which means the absence of a unit root and the stability of the time series, which necessitates the use of the Autoregressive Distributed Lagged methodology (ARDL) presented by Pesaran, et al. (2001) Table (2).

Table (2): Results of Augmented Dickey Fuller test (ADF)

Variable	Difference	With Constant	With constant and trend	Without constant and trend	degrees of integration
Rice productivity (ton)	**Zero**	-1.806	-2.674	-0.137	I(1)
	Frist	-5.059**	-5.681**	-5.191**	
Max. Temperature (C°)	**Zero**	-2.845	-5.351**	1.168	I(0)
	Frist	-4.844**	-4.706**	-4.622**	
Min. Temperature (C°)	**Zero**	-1.863	-4.650**	1.504	I(0)
	Frist	-4.574**	-4.390**	-7.375**	
Relative humidity (%)	**Zero**	-1.295	-2.871	-1.106	I(1)
	Frist	-6.291**	-6.70**	-6.154**	
Amount of rain (mm)	**Zero**	-3.202*	-3.390	-0.946	I(0)
	Frist	-4.778**	-4.603**	-4.912**	

**Sig. at 0.01 levels. *Sig. at 0.05 levels.
Source: Outputs of E-views 10, table (1).

The ARDL models consist of dependent and numbers of explanatory variables (X_1, X_2……X_n):

a = constant **Y = Rice yield (ton)**
X_1= Max. temperature **X_2= Min. temperature**
X_3 =Humidity rate (%) **X_4= Amount of rain**
Rice Yield Model **Y=** $a + b_1 X_1 + b_2 X_2 + b_3 X_3 + b_4 X_4$

After ensuring the stability and integrity of the time series, whether at the zero degree or the first degree, the (ARDL) model is estimated through the following steps:

1- Bounds Test (AlSawai, K. 2012; Mansour and Hasan 2022):

The bounds test was conducted to find out whether or not there is co-integration between the variables of the model. If the calculated (F) value is greater than the upper limit of the critical values, then the null hypothesis is rejected, which states that there is no long-term equilibrium relationship between the variables, and the alternative hypothesis is accepted that there is a relationship, by the presence of Co-integration between the variables of the study, but if the value of (F) calculated is less than the min. critical values, then the alternative hypothesis is rejected and the null hypothesis is accepted because there is no equilibrium relationship in the long term, there is co-integration between the variables of the study according to the Bounds Test approach it was found from the limits test results that the calculated (F) value was about 24.2 for the rice productivity model, which is greater than the upper limit of the critical values of the limits, which means rejecting the null hypothesis and accepting the alternative hypothesis of the existence of a long-term equilibrium relationship between the variables of the model at the level of significance 5% - Table (3).

Table (3): Results of the (F Bound Tests)

F	Sig. F	Min. level I(0)	Max. level I (1)
24.2	1%	3.74	5.06
	5%	2.86	4.01
	10%	2.45	3.52

Source: Outputs of E-views 10, table (1).

Second: Estimating the equilibrium relationship in the long term (Mansour and Hasan 2022):

It was concluded that there is a long-term relationship between the variables of the study, and a maximum number of slowing periods was determined, and therefore the (ARDL) (3,0,2,2,2) was chosen for the rice crop model, as it is considered the best model for estimating the equilibrium relationship in the long term.

The results of estimating the impact of climate change on the rice productivity in Egypt using Autoregressive Distributed Lagged (ARDL) during the study period showed that there is a long-term inverse relationship between the dependent variable (rice productivity) and the independent variable (maximum temperature), it meaning that a decrease in the maximum temperature by 1% leads to an increase in the rice productivity by about 0.17%, as it was found that there is a Positive relationship in the long-term between the rice productivity and both the minimum temperature and the relative humidity, it meaning that an increase in both the minimum temperature and the relative humidity, by 1% leads to an increase in the rice productivity by about 0.07% and 0.03%, respectively. It was also shown that there is a Positive relationship in the long-term between the rice productivity and the amount of rainfall, that is meaning an increase in the amount of rainfall by 1% leads to an increase in the rice productivity by about 0.04%, and this is consistent with the economic theory.

It was also found that the determination coefficient was about 0.991, which means that the estimated model variables explain about 99.1% of the fluctuations in rice productivity due to the change in the maximum temperature, the minimum temperature, the relative humidity and the amount of precipitation, while the rest of the fluctuations are due to other factors, was not included in the model. It was also shown through the calculated F value that it amounted to about 105 at a significant level of 0.01, then the significance of the estimated the whole model, this means that the model was accepted from a statistical theory.

The significance of the error correction coefficient and its negative sign, as it reached about (-0.534) at a significant level of 0.01, this indicates the existence of a co-integration relationship between the variables explaining the rice productivity. That is mean, when rice productivity deviates from the equilibrium value in the short term, it quickly returns to its equilibrium value in the long term, and about 53.2% of the imbalance is corrected during period (t) until it reaches equilibrium again.

Table (4): Results of Estimating the ARDL model in the long term and the error correction in the short term

long term model	Error correction in the short term
$Y_1 = -0.1752X_1 + 0.0651X_2 + 0.0278X_3 + 0.0346X_4$ R^2=0.991 F= 105^{**}	-0.534^{**}

**Sig. at 0.01 levels. *Sig. at 0.05 levels.
Source: Outputs of SPSS, table (1).

Third: Diagnostics Test (Azouzi and Amiri, 2019)

Diagnostic tests are used to judge the suitability of the model used in measuring the estimated elasticities in the long term, to ensure the quality of the model used in the analysis and not to include errors and measurement problems:

1- **The Autocorrelation test between errors (LM Test)** (Mansour and Hasan 2022)

This test is used to detect the possibility of a serial correlation between errors, in order to find out the possibility of accepting the null hypothesis that there is no problem of serial autocorrelation between the parameters of the estimated models.Where, it was found that the significant value of (F) was about 0.164 for the rice model, which is greater than the significant level of 0.05,therefore the null hypothesis is accepted that there is no serial autocorrelation problem between the errors of the estimated model parameters - Table (5).

Table (5): Results of examining the residuals

Normality Test ***Jarque-Bera Test***	***Heteroskedasticity ARCH Test***	**Serial Correlation *(LM Test)* Breusch-Godfrey Serial Correlation**
***Jarque-Bera** = 1.199* *Prob.= 0.549*	***F** = 0.937* *Prob.(1,15)= 0.346*	***F** = 5.11* *Prob.(2,2)= 0.166*

Source: Outputs of E-views 10, table (1).

2- Testing the Autoregressive condintional Heteroskedasticity (ARCH Test) (Elbadry, M., et al. 2022;Mostafa and Elbadry 2015; Mansour and Hasan 2022)

This test is used to detect the problem of instability of the variance of the error limit as it depends on the Lagrangian multiplier, as it was found that the significant value of (F) reached about 0.349, which it greater than the significant level of 0.05, and therefore we reject the null hypothesis and accept the alternative hypothesis that there is no existence the stability of the variance of the error limit for the estimated model parameters (Table 5).

3- Normality Test (Elbadry, M., et al. 2022; AlYousef, 2013)

This test is used to detect the normal distribution of the rest of the estimated models, as it depends on the Jarque-Bera test, as it was shown from Table (5) that the Jarque-Bera statistic reached about 1.199, which is less than the tabular value of the Kai distribution of the rice productivity model with degrees of freedom 18, also the critical probability ratio is greater than of the significance ratio of 0.05, then, we accept the null hypothesis H_0 that the residuals are distributed normally, in addition to that the skewness coefficient was about 0.611, so the probability distribution of the residuals of the estimated model is moderate, which indicates the symmetry of the probabilistic distribution of the residuals of the estimated model, where it turns out that the probability distribution curve of the estimated model is positive, which slightly to the right - Figure (1).

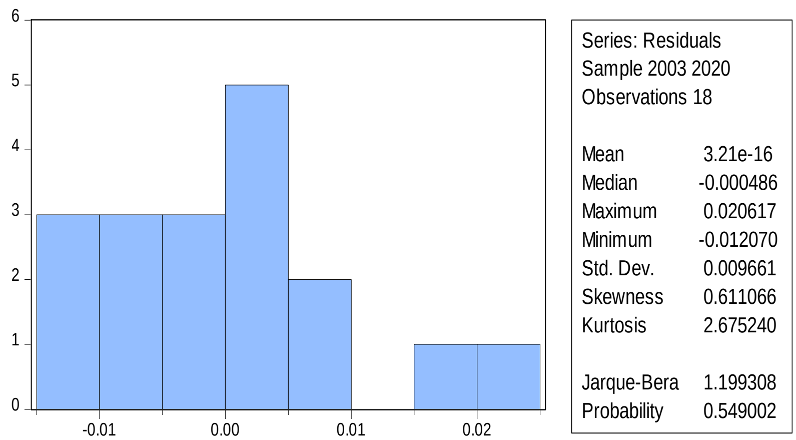

Fig.(1): Normal distribution test for the residues of the Rice productivity Model

Source: Outputs of E-views 10, table (1).

4- Stability (Test: Dickey and Fuller 1979**;** Elbadry, M., et al.2022; Mansour and Hasan 2022)

The cumulative sum squares test (Cumulative Sum Squares) is used to detect the presence of any structural changes and to indicate the stability and consistency of the parameters of the long-term models with the short-term parameters, to verify the structural stability of the estimated coefficients to correct the error of the Autoregressive Distributed Lagged (ARDL), if the graph falls within the critical limits at a significant level of 0.05, it means that the model parameters are stable throughout the study period - Figures (2:3). It was found from the figures are structurally stable over the study period, and we also notice a harmony in the model between the results of error correction in the long and short term, as the figures fell within the critical limits at a significant level of 0.05.

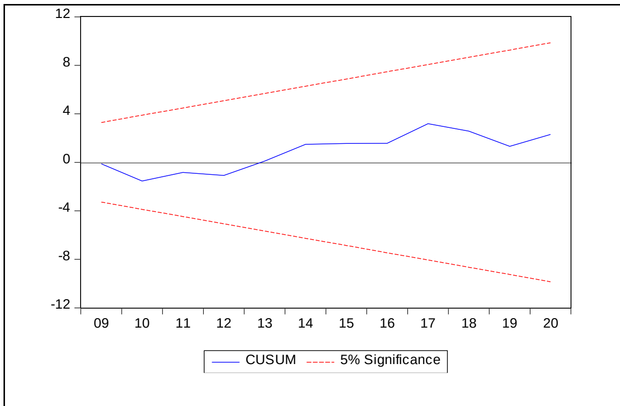

Fig.(2): Stability test of the rice yield (Residuals cumulative) (Cusum test)

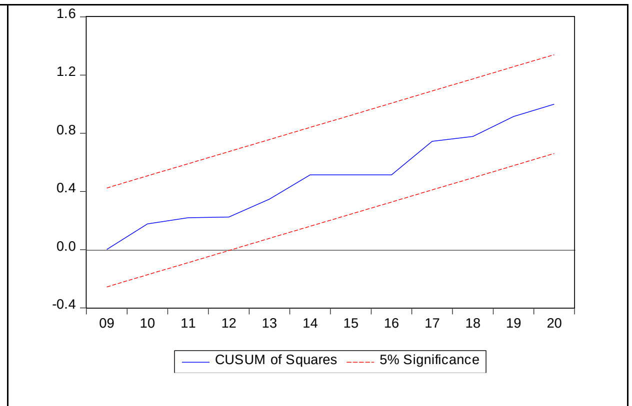

Fig.(3): Stability test of the rice yield (Residuals square cumulative) (Cusum of Squares test)

Source: Outputs of E-views 10, table (1).

Conclusion and Recommendation

This research deals study the impact of climate changes on the productivity of the rice crop in Egypt during the period (2005-2021), with the aim of determining the extent of the climate change on the rice productivity in Egypt, by using the Autoregressive Distributed lagged (ARDL), where it was found that there is an inverse relationship between climate change and the rice productivity, a relationship that is consistent with economic logic, where it was shown that there is a negative impact of the change of maximum temperature on the rice productivity in the long term. That is, an increase in the maximum temperatures by 1% leads to a decrease in rice productivity by about 0.17%, which is consistent with the economic theory. It also shows that there is a long-term equilibrium relationship between climate changes and the rice productivity, as its estimated significance was proven. It was also found that the value of the error correction coefficient was about (-0.534), which indicates that when the rice productivity deviates from the value of equilibrium during the short term, the speed of it's to return the value of equilibrium in the long term is about 53.4% for from the imbalance, during the unit of time to reach the equilibrium after about 1.62 year to return the long term of the equilibrium position. The research recommended of choosing genetically improved varieties and seeds with high productivity that can withstand the climate changes, drought and humidity. Use the modern technology for storing the cereals to reduce the losses of storage. Rely on the early warning systems for sudden climatic changes to achieve food security stability. Expand of the green economy projects and environmentally friendly projects. Develop the economic policies that take into account adaptation to climate change. Use the optimal of available water resources.

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