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Estimating the climate response function for net wheat crop revenues for the period (2000-2022) using the ricardo method

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ABSTRACT

The study aimed to identify the essential climatic factors that significantly affect the financial returns of wheat production from 2000 to 2022 to draw up a clear agricultural policy to confront these changes. It was estimated using the ARDL model to explain the correlation between the dependent variable (revenues) and the independent variables temperature, rainfall, and relative humidity. And wind speed. The research reached several conclusions, the most important of which is that 96% of the observed fluctuations in the dependent variable can be attributed to the explanatory variables included in the model. The remaining 4% of fluctuations are due to other variables not included in the model and are absorbed by the random variable. The results showed a positive, significant relationship between average rainfall and wheat yields and a significant inverse relationship between temperature, relative humidity, and average wind speed on wheat yields. The study suggested the necessity of cultivating high-yielding varieties that are resistant to climate change and suitable for the Iraqi environment. In addition, she stressed the importance of investing in renewable energy sources that can support agricultural activities, mitigate the effects of climate change, and enhance crop productivity.

تقدير دالة الاستجابة المناخية لصافي إيرادات محصول القمح للفترة (2000-2022) باستخدام أسلوب ريكاردو

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المستخلص

هدفت الدراسة إلى التعرف على العوامل المناخية الأساسية التي تؤثر بشكل كبير على العوائد المالية لإنتاج القمح من عام 2000 إلى عام 2022 لرسم سياسة زراعية واضحة لمواجهة هذه التغيرات. وتم التقدير باستخدام نموذج ARDL لتوضيح العلاقة الارتباطية بين المتغير التابع (الإيرادات) والمتغيرات المستقلة درجة الحرارة وهطول الأمطار والرطوبة النسبية. وسرعة الرياح . وتوصل البحث إلى عدة استنتاجات أهمها أن 96% من التقلبات الملحوظة في المتغير التابع يمكن أن تعزى إلى المتغيرات التفسيرية التي يتضمنها النموذج. أما نسبة الـ 4٪ المتبقية من التقلبات فهي بسبب متغيرات أخرى غير مدرجة في النموذج ويتم امتصاصها بواسطة المتغير العشوائي. أظهرت النتائج وجود علاقة موجبة ومعنوية بين متوسط هطول الأمطار ومحصول القمح وعلاقة عكسية معنوية بين درجة الحرارة والرطوبة النسبية ومتوسط سرعة الرياح على محصول القمح. واقترحت الدراسة ضرورة زراعة أصناف عالية الإنتاجية مقاومة للتغير المناخي ومناسبة للبيئة العراقية. بالإضافة إلى ذلك، شددت على أهمية الاستثمار في مصادر الطاقة المتجددة التي يمكن أن تدعم الأنشطة الزراعية، وتخفف من آثار تغير المناخ، وتعزز إنتاجية المحاصيل.

الكلمات المفتاحية :ايرادات القمح ,نموذج ARDL,سياسات.

INTRODUCTION:

Climate change is one of the fundamental challenges affecting food security by affecting crop productivity, leading to a lower self-sufficiency rate, higher food prices, and increased imports (Abdel Hamid ,2023). Due to increasing human demand and rapid economic growth, these changes will affect the entire biosphere, often negatively (Mohammad *et al*.,2021). Among them is the problem of desertification, which causes a decline in agricultural production and affects productivity while increasing costs (Ali *et al*.,2021; Al-Lami *et al*.,2023). Therefore, climate change is no longer just studies and predictions but has become clear and measurable, especially in the agricultural sector, given its danger (AL-Badri and AI-Tamimi,2023). Because agricultural production activities are the most sensitive and affected by climate change (Abdullah and Radwi, 2023), abnormal climate changes cause crops to become infected with diseases (Al-Sabhany and Al-Jubouri, 2021). Climate change adaptation efforts in developing countries are still in the early stages of development. It seeks to help adapt to and confront the effects of climate change to mitigate them as much as possible to preserve the safety of the environment and the health of society (Al-Halafi and Al-Azzawi, 2022).

Therefore, improving the level of the economic performance of farms is an important goal pursued by economic systems (Al-Badri and Muhammad,2016), as biotechnology is necessary to enhance agricultural production and develop high-yielding varieties and seeds resistant to salinity, drought, and diseases (Fakhri *et al*., 2023). Therefore, it is necessary to enhance food security, increase agricultural productivity, and reduce poverty, especially in poor communities (Ali *et al*., 2023). The wheat crop represents the basis of global agricultural and food production, as evidenced by the quantities produced, consumed, and traded globally (Jisam *et al*., 2021). Hence, it has become necessary to study climate changes and know their direct and indirect effects on wheat revenues, given the increasing need to formulate an agricultural policy to improve resource use efficiency in light of the current climate conditions.

Moreover, it contributes to reducing greenhouse gas emissions. The most critical problem facing the agricultural sector is that it is more sensitive to and affected by climate change. The research aims to measure and analyze the impact of climate change on revenues, and the most critical variables that will be highlighted are temperature, rain, wind speed, and relative humidity. According to the Ricardian approach, the study assumes the significant impact of climate change on wheat revenues, identifies the positive and negative effects of these variables, and develops strategies to confront these changes.

MATERIALS AND METHODS

The Ricardo approach was used to evaluate the impact of climate conditions on net revenues. Data for this analysis were obtained from the Ministry of Agriculture (Iraqi Ministry of Agriculture/National Seed Council). The ARDL model will be used to derive net revenues for a period extending from 2000 to 2022.

1. **ARDL Model**: Most economic series data show a noticeable trend over time and lack stability. Therefore, estimating this series using traditional regression models can give misleading results. The time series is analyzed utilising the co-integration method to avoid spurious regression (Nouri and Al-Hayali, 2019; Al-Wasti Al-Atabi, 2023). Through three methods:

1. Model description stage: The standard model is built, and its variables are identified. (Jihad and Abdullah,2021).

   • NR: The dependent variable is wheat revenues at the Iraq level, tons/thousand dinars.
   • LNX1: represents the annual rainfall rate (mm/year).
   • LNX2: represents the average annual temperature (°C).
   • LNX3: represents the annual humidity rate (%).
   • LNX4: represents the average annual wind speed (km/h).

2. Methodology of analysis and estimation of model parameters.
   At this stage, the model parameters are estimated. Suppose that both the dependent and independent variables in the current year (1) are affected by their values in past years (t-1). In this case, these variables will be included in the model, and accordingly, we will have a dynamic, kinetic model; in such a case, we will deal with time-delay models. The best example is Pesaran Shin and Smith's lagged or distributed regression model (Al-Bayati and Al-Dulaimi,2022).

3. Model testing phase: This phase consists of several steps, the most important of which are:
   - Unit root test for variable data.
   - Determine the optimal slowdown period through the VAR model.
   - Bounds test for co-integration.
   - Estimating the ARDL model.
   - Final exams.(Al-Hashemi and Bakr, 2023)

2. The Ricardian model:

The Ricardian approach uses agricultural surveys or country-level data to analyze the relationship between agricultural capabilities, land value, and climate variables, such as rainfall, temperature, relative humidity, and wind speed (Rizkallah, 2020). Its purpose is to correct for any significant biases in the production function. (ECLAC, 2011) Mendelsohn *et al*. used net revenues and land values to represent farm income. By directly estimating net revenues, this approach considers the direct impacts of climate change on different crop yields, indirect substitution of other inputs and potential adaptation to other climatic conditions, which is reflected in costs. This model assumes that markets are functioning correctly, allowing the economic effects of climate change to be measured on the monetary value of different activities(Mendelsohn and Shaw,1994). A vital feature of the Ricardian model is its ability to incorporate adjustments made by farmers to adapt to climate change to maximize profits by changing crop mixes, planting and harvesting dates, and various other agricultural practices.

Farmers' response is reflected in costs, causing economic damage to net revenues. Therefore, the overall calculation of the fees or benefits of adaptation should be reflected in the dependent variable, net revenue or land value, not productivity (Darwin, 1999). Another advantage of this model is that it is cost-effective, as it may be relatively easy to collect secondary data on cross-sectional sites based on climatic, productivity and socio-economic factors. The main criticism of this model is that it needs to consider price changes. Mendelsohn believes that the assumption of price stability is justified because it does not pose a serious problem when using the model. Another weakness of the Ricardian model is that it must rely on controlled experiments on the farm. Farmers' responses vary across different lands not only due to climatic factors but also due to many social and economic conditions. The model rarely fully includes these non-climatic factors (World Bank,2007).

To overcome the criticisms directed at the Ricardian model as one of the models of the econometric approach, (Zaied, 2013) believes that using the econometric method allows for estimating the correct relationship between climate change and agricultural production and productivity. The micro database uses econometric techniques to depict reality accurately by exploring accurate, not empirical, data.

RESULTS AND DISCUSSION

Table (1) above shows the unit root test for the climate model variables in Iraq, as the first part of the table refers to the test results at the Level (At Level). In contrast, the second part relates to the results when taking the first difference (At First Differences), as it becomes clear to us that the variables independent and dependent variables all stabilized after taking their first difference, which means accepting the null hypothesis, which indicates that these variables contain a unit root, so the (ARDL) model can be applied.

The first step: unit root tests for the study variables

Table1.unit root results

Augmented Dickey- Fuller Test						
Variables	**At Level**			**At First Difference**		
	With Constant	**With Constant & Trend**	Without Constant & Trend	**With Constant**	**With Constant & Trend**	Without Constant & Trend
NR	-0.237730	-0.629891	-0.013536	-1.482650	-1.484123	-1.454253
t-State	-1.527416	-2.921487	-0.142604	-6.533366	-6.320068	-6.389003
Prob	0.5014	0.1751	0.6231	0.0000***	0.0002***	0.0000***
Ln(x1)	-0.899381	- 0.900704	-0.015544	-2.692956	-2.692691	-2.691892
t-State	-4.019215	-3.927758	-0.364344	-5.027395	-4.858706	-5.179828
Prob	0.0058***	0.0282**	0.5397	0.0008***	0.0054***	0.0000***
Ln(X2)	-0.910578	-1.289654	0.000411	-1.840600	-1.840612	-1.833395
t-State	-4.131176	-4.059753	0.123380	-5.103159	- 4.951740	-5.230011
Prob	0.0045***	0.0226**	0.7115	0.0006***	0.0041***	0.0000***
Ln(X3)	-0.702915	-0.910275	0.000729	-1.421314	-3.591529	-1.414433
t-State	-3.461020	-3.930600	0.242935	-6.664052	-4.350811	-6.843327
Prob	0.0195**	0.0281**	0.7469	0.0000***	0.0151**	0.0000***
Ln(X4)	-1.000106	-1.464777	-0.000540	-1.727452	-1.728959	-1.722222
t-State	-4.628579	-6.942110	-0.487373	-10.78126	-10.55549	-10.98688
Prob	0.0015***	0.0001***	0.4925	0.0000***	0.0000***	0.0000***

Source: Prepared by the researcher based on Eviews 10 program

a : (*)Significant at the 10%; (**)Significant at the 5%; (***) Significant at the 1% and (no) Not Significant.

THE SECOND STEP: determine the optimal lag periods, Table (2) displays the ideal lag periods selected for the variables using the VAR model. The selection is based on the AIC criterion, and it ensures that the model is free from the issue of autocorrelation between the residuals. In this case, the optimal lag period is (0).

Table 2. Optimal lag periods for the climate model

Lag	LogL	LR	FPE	AIC	SC	HQ
0	36.57240	NA*	3.90e-08*	-2.870218*	-2.622254*	-2.811805*
1	58.36072	31.69210	5.61e-08	-2.578247	-1.090462	-2.227769

Source: Prepared by the researcher based on Eviews10 program

Hence, the model selection will be based on the autoregressive lag time lag (ARDL) methodology, where the lag length that yields the minimum value for this criterion is identified. Figure (1) below illustrates this based on the Akaike Information Criterion (AIC) test.

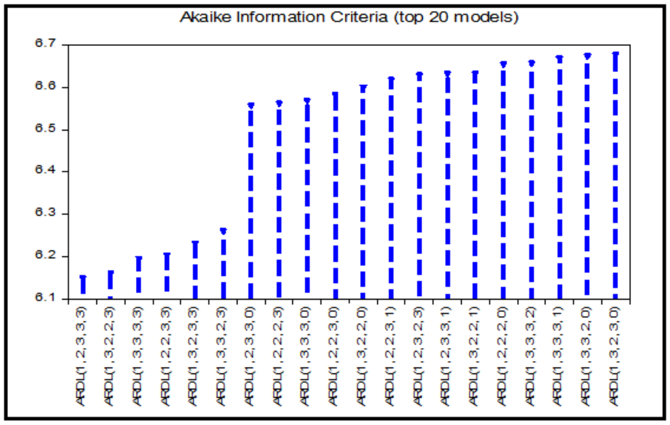

Figure1. shows the results of the slowdown(periods according to the Akaike Criterion (AIC) method for the climate model)

Source: Prepared by the researcher based on Eviews10 program

THIRD: COINTEGRATION TEST: Table (3) displays the use of the marginal test method for identifying co-integration among the variables in the model. The results indicate that the computed (F) value is 10.18547, which exceeds the maximum value at the 1% significance level at both lower bounds. A greater value of this shows the rejection of the null hypothesis and the acceptance of the alternative hypothesis, which asserts the presence of co-integration, i.e., a long-term link between wheat revenues and all independent factors (climatic variables).

Table 3. Results of the co- integration test using the bounds test

F-Bounds Test		**Null Hypothesis: No levels relationship**		
Test Statistic	Value	Signif.	I(0)	I(1)
F-statistic	10.18547	10%	1.9	3.01
k	4	5%	2.26	3.48
		2.5%	2.62	3.9
		1%	3.07	4.44

Source: Prepared by the researcher based on Eviews10 program

STEP FOUR: estimate and analyze the long- and short-run results and the error correction parameter:

FIRST: The immediate outcomes of the relationship, the short-term: Table (4) shows the estimation results, representing the short-run function with slowdown periods, as the ARDL model is susceptible to slowdown periods. When testing the goodness of fit, it was found that the value of the coefficient of determination R^2 amounted to about (0.96). This means that 96% of the fluctuations occurring in the dependent variable are due to the explanatory variables present in the model, 4% is due to other variables that were not included in the model and their effect was absorbed by the random variable. The coefficient for average rainfall for the specified time period was(37.8). This coefficient is both positive and statistically significant at a 1% level of significance. This is consistent with the principles of economic theory, as it shows the causal relationship between average rainfall and higher wheat revenues, indicating that a 1% increase in rainfall will lead to a corresponding increase of one unit per ton in wheat revenues. There is a clear and strong relationship between average temperatures and wheat yield with one lag period at a significance level of less than 1%. The parameter value was 240, indicating that a 1% increase in average temperature would result in a 1 unit increase in wheat revenue per ton. A strong negative relationship exists between average relative humidity and wheat yield over a single period. This means that % increase in average wind speed by 1% leads to a decrease in wheat yields. The result will be a decrease in wheat revenues by 296 units per ton. A significant and negative relationship exists between average wind speed and wheat yield, with statistical significance reaching 1%. This means that a 1% increase in average wind speed will decrease wheat revenue productivity by 349 units per ton.

Second: evaluating the capabilities of the unrestricted error correction model (ardl-ecm) : Table 4 indicates that the error correction factor (Coint Eq) determines the rate at which short-run variables adjust to long-run variables. The factor must be negative and statistically significant to prove the existence of a long-term association between the variables in the function analyzed. Table 4 shows that the error correction factor (ECM) has a negative value of 0.587, statistically significant at a significance level of less than 1%. This indicates that about 59% of short-term errors are automatically corrected to achieve long-term equilibrium. This value confirms the validity of the.

Table 4. Results of estimating the model using the ARDL method (short-run equation

ARDL Error Correction Regression
Dependent Variable: D(NR)
Selected Model: ARDL(1, 2, 3, 3, 3)
Case 1: No Constant and No Trend
Sample: 2000 2022
Included observations: 20
ECM Regression

Case 1: No Constant and No Trend				
Variable	Coefficient	Std. Error	t-Statistic	Prob.
D(LNX1)	7.319700	2.467135	2.966883	0.0413
D(LNX1(-1))	37.75587	5.035725	7.497604	0.0017
D(LNX2)	-227.5631	24.64643	-9.233103	0.0008
D(LNX2(-1))	240.9192	26.16289	9.208431	0.0008
D(LNX2(-2))	29.52384	21.89379	1.348503	0.2488
D(LNX3)	-42.10397	22.90889	-1.837888	0.1399
D(LNX3(-1))	-296.1298	41.25988	-7.177186	0.0020
D(LNX3(-2))	-57.44918	16.26938	-3.531122	0.0242
D(LNX4)	-349.9036	77.48997	-4.515469	0.0107
D(LNX4(-1))	-236.4571	98.27676	-2.406033	0.0739
D(LNX4(-2))	-239.6195	81.15027	-2.952788	0.0419
CointEq(-1)*	-0.587159	0.058179	-10.09231	0.0005
R-squared	0.963007	Mean dependent var		2.408333
Adjusted R-squared	0.912141	S.D. dependent var		12.54746
S.E. of regression	3.719195	Akaike info criterion		5.748601
Sum squared resid	110.6593	Schwarz criterion		6.346040
Log likelihood	-45.48601	Hannan-Quinn criter.		5.865227
Durbin-Watson stat	1.861643			

Source: Prepared by the researcher based on Eviews 10 program

Third: long-term results of the relationship: Table (5) shows that there is an inverse and significant relationship between average rainfall and wheat production revenues, meaning that increasing average rainfall by (1%) leads to a decrease in revenues by (65) units, and this result was contrary to expectations with short-term results. An inverse and significant relationship exists between average temperatures and wheat yields, meaning that an increase in temperature by (1%) leads to a decrease in wheat yields by (629) units per ton, identical to the short-term results. There is a direct and significant relationship between the average humidity and wheat revenues at a significance level of 1%, meaning that increasing the average humidity by (1%) will increase wheat revenues by (680) units per ton. This result was contrary to the short-term effect. There is an inverse and significant relationship between the average wind speed and wheat production at a significance level of 1%, meaning that increasing the average wind speed by (1%) leads to a decrease in wheat production by (378) units per ton, and this result was identical to the result of the short-term effect.

Table 5. Results of estimation the long-run equation

Ratio of short-term impact % to long-term impact	Evaluate the long-term impact	Evaluate the short-term impact	Variables
-0.57	-65.97402	37.75587	X1
-0.38	-629.5128	240.9192	X2
- 0.44	680.6835	-296.1298	X3
0.92	-378.8089	-349.9036	X4

Source: Prepared by the researcher based on Eviews 10 progra

STEP The Five: ARDL MODEL TESTS:-The diagnostic tests listed below are the standard criteria used to evaluate the efficiency of the research model.

1. typical quality tests:

- Testing the normal distribution of random errors :The figure (2) below demonstrates that the Jarque- Bera test confirmed the fulfillment of the requirement of a normal distribution of the residuals, with a probability value of 0.57 and a significance level exceeding 5%. Thus, we conclude that the null hypothesis is valid, indicating that the random errors in the calculated model follow a normal distribution.

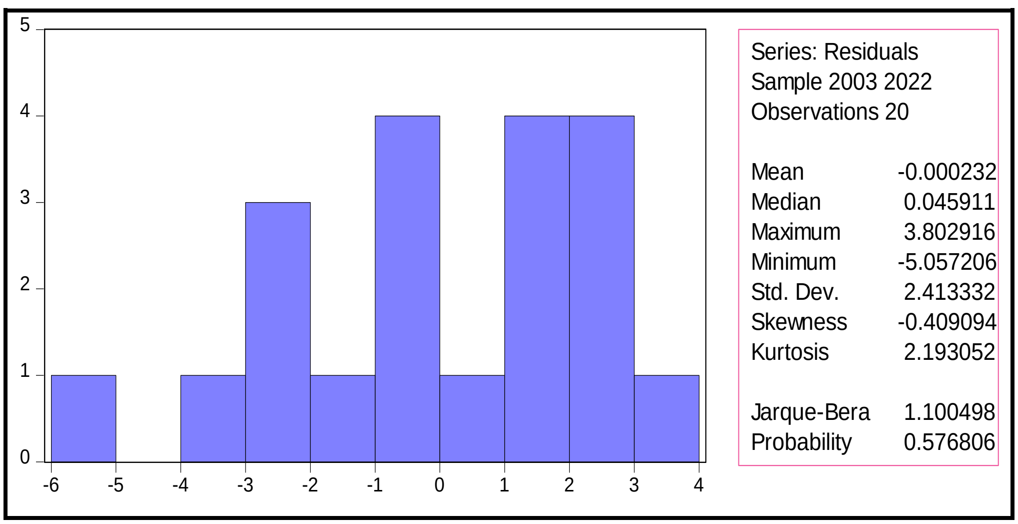

Figure2.of the residual distribution test

Source: Prepared by the researcher based on Eviews10 program

- Testing the problem of autocorrelation between the residuals:The following table (6) demonstrates that the model successfully meets the standard criteria. The text refers to the Breusch-Godfrey serial correlation (LM) test. The Lagrange multiplier test for autocorrelation indicates that the model is not affected by autocorrelation, with a probability of 0.89. Therefore, we can confidently accept the null hypothesis that the model is free from the issue of autocorrelation.

Table 6.LM test Results Non- Stationarity of variance test

Breusch-Godfrey Serial Correlation LM Test:			
F-statistic	0.114097	Prob. F(2,2)	0.8976
Obs*R-squared	2.048236	Prob. Chi-Square(2)	0.3591

Source: Prepared by the researcher based on Eviews 10 program

- **Testing the problem of non-constancy of contrast:** Table 7 indicates that the model successfully passes the Breusch-Pagan-Godfrey heterogeneity test and ARCH test, demonstrating that it does not exhibit non-stationarity of variance. This is supported by the probability value (0.4746 - 0.6870), which exceeds the threshold of 0.05, enabling acceptance of the null hypothesis. There is no issue with the instability of contrast.

Table7. Results of non-stationary test

Heteroskedasticity Test: Breusch-Pagan-Godfrey			
F-statistic	0.683147	Prob. F(16,3)	0.7381
Obs*R-squared	15.69286	Prob. Chi-Square(16)	0.4746
Scaled explained SS	0.374499	Prob. Chi-Square(16)	1.0000
Heteroskedasticity Test: ARCH			
F-statistic	0.168072	Prob. F(1,17)	0.6870
Obs*R-squared	0.186006	Prob. Chi-Square(1)	0.6663

Source: Prepared by the researcher based on Eviews 10 program

secondly: testing the stability of the estimated model It is clear from Figure (3) that the estimated coefficients of the model used are stable, which confirms the presence of stability between the study variables and consistency in the model in the long and short term, as the model fell within the critical limits at a 5% significance level. (Al-Khafaji).

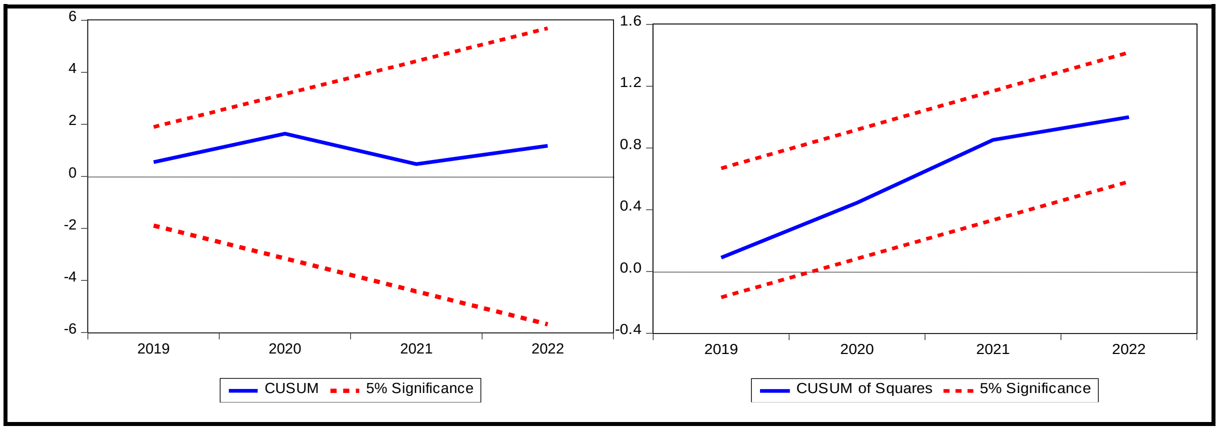

Figure 3. The cumulative sum of the successive remainders (CUSUM) and the cumulative sum of the squares of the successive remainders (CUSUMSQ).
Source: Prepared by the researcher based on the Eviews10 program

Third: Testing the predictive performance of the error correction limit model:
- It is clear from the figure (4) below:

- The Thiel coefficient (T) has a value of 0.040976, which is lower than the accurate value and in near proximity to zero.
- The bias ratio, denoted as BP, has a value of 0.000284, which is smaller than the right value and approaching zero.
- The variance ratio (VP) attained a value of 0.000, which is lower than the correct value and near zero
- The variance ratio, denoted as CP, attained a value of 0.999663, which falls below the correct value.

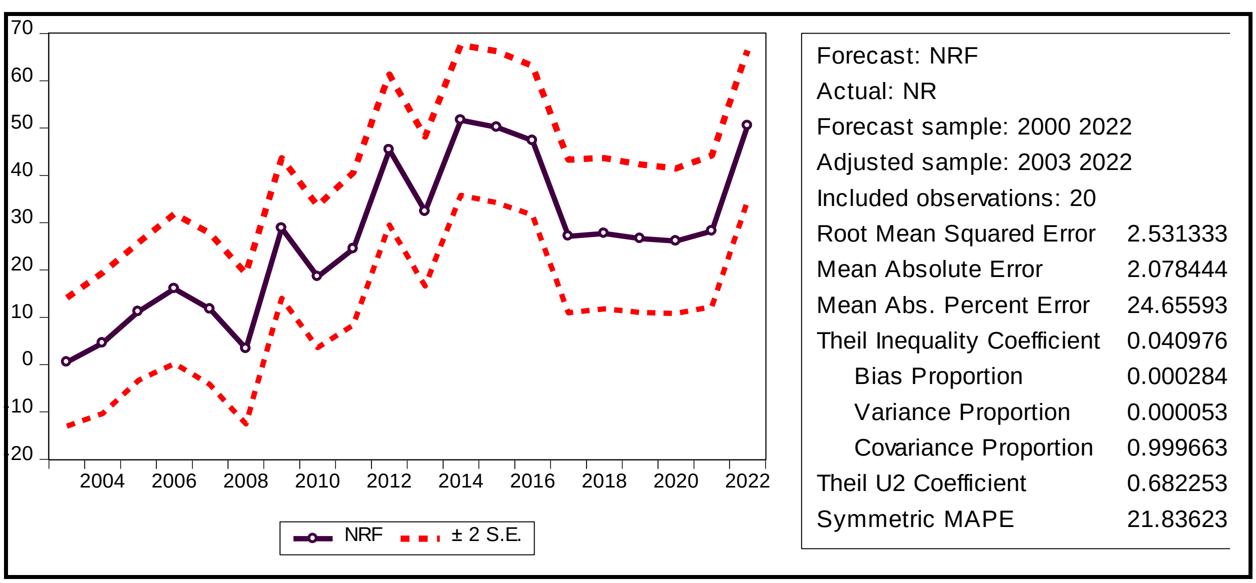

Figure 4. shows the actual and estimated values of the climate model
Source: Prepared by the researcher based on Eviews10 program

Consequently, the estimated climate model in Iraq has a high degree of predictive capacity across the study period, meaning that the model's output may be trusted for analysis, policy assessment. and other applications. and predictions in the future.

Conclusion:

1. Increased rainfall rates significantly impact wheat revenues in the short term. In contrast, in the long term, there is an inverse and significant relationship between the impact on revenues due to climate change and reduced rainfall rates.
2. The temperature variable has a positive significance in affecting wheat revenues in the short term. In contrast, in the long term, there is an inverse and significant relationship in the impact on revenues due to high average temperatures.
3. an inverse and significant relationship to the relative humidity variable affects wheat revenues in the short term. In contrast, in the long term, there is a positive and significant relationship in affecting revenues, as the wheat crop is a winter crop, and the varieties that adapt to the climate are grown.
4. There is an inverse and significant relationship to the wind speed variable in affecting wheat revenues in the short term and similar in the long term in affecting revenues.

Recommendations:

1. Implementing innovative agricultural techniques and systems to address the challenges posed by climate change.
2. Learn from the experiences of other nations in effectively adjusting to the consequences of climate change and implementing their strategies concerning climate-smart agriculture, sustainable agriculture, and the green economy due to their influence on food security and environmental preservation. The environment.
3. Formulate a concise plan to counteract and adjust to the impacts of climate change, particularly the escalation of temperatures, and guarantee that clean technology significantly reduces ecologically harmful emissions.
4. Modifying the timing of planting to accommodate altered weather conditions
5. Creating novel cultivars that exhibit resilience to elevated temperatures, salinity, and drought, which are the predominant environmental conditions in response to climate change.

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