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An Econometric analysis of the factors affecting the food production index in Iraq during the period 1993-2022

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Abstract

The research aimed to analyze the effects of climate change on the food production index in Iraq during the period (1993-2022) based on a set of factors represented by total greenhouse gas emissions (tons of carbon dioxide equivalent), crop production index, livestock production index, rainfall rate, and average temperature using a standard model, which is ARDL. The research concluded the importance of improving agricultural and livestock production to positively reflect on the food production index, and this can only be achieved by providing the technical conditions to achieve this. The impact of rainfall was also positive, but this impact will be governed by other conditions, including the fact that the distribution of rainfall during the season is more important than the amount of precipitation. As for the variable of carbon dioxide emissions, it had a negative impact and there is a lack of awareness of the process of addressing the negative impacts. The same applies to temperatures, which had negative impacts. From this, we conclude that Iraq has neglected many of the measures and procedures that would have reduced rising temperatures, including the establishment of green belts around cities facing the desert and the dust storms it causes. The research also indicated that the factors affecting food production will continue to have a lasting impact in the long term, underscoring the importance of addressing them and mitigating their effects in the future. The research recommended the adoption of a green economy and the promotion of sustainable development projects, as well as encouraging farmers to cultivate drought- and heat-resistant crops with high productivity, such as grains and desert grasses. It also recommended expanding protected agriculture, such as greenhouses, particularly in areas most affected by climate change, given its impact on stabilizing production, improving soil fertility, and enhancing community awareness of the risks of climate change. It also called for launching awareness campaigns targeting agricultural communities to increase understanding of the impacts of climate change and methods of adapting to it, and to encourage sustainable agricultural practices and modern technologies.

Keywords: Climate change, global warming, environmental pollution, ARDL, food production index

Introduction

Climate change is one of the most significant challenges facing the world, especially in recent times, due to its difficulty in controlling it and its direct and indirect impact on many human needs, most notably food. Climate change, resulting from rising temperatures, increased flooding, widespread droughts and storms, and rising sea levels, poses a significant threat to food security.

Climate change has had a clear impact on the lives of many animal and plant food sources, such as marine life, livestock, and plants, as well as other organisms that together form a single ecosystem. It is noteworthy that the recent rise in temperatures has led to the loss of many species, more than 1,000 times the loss in past human history. Furthermore, forest fires, the spread of diseases and pests, and everything related to climate change directly impact the quantity and quality of food [1].

Climate change has been identified as a major cause of food shortages and rising rates of hunger, poverty, and malnutrition. This represents a major violation of one of the most important sustainable development goals, namely the eradication of poverty. This is due to increased ocean acidification, melting glaciers, and rising sea levels, which have caused the migration and death of many marine species and the destruction of fishing grounds. Furthermore, rising temperatures have strained crops, destroyed many grazing and fishing resources, reduced water resources, and deforestation. All of this has negatively impacted plant and animal wealth. Furthermore, increased rainfall has recently caused floods and strong hurricanes, leading to soil erosion and soil erosion, thus deteriorating soil condition and reducing its suitability for agriculture. This has also led to a decline in crop yields and plant nutrition sources. This has also led to the spread of pests and fungi, the growth of harmful weeds, and plant viruses, which can harm plants [1].

On the other hand, the impact of climate on animal nutrition is evident, as high temperatures negatively impact livestock quality, thus affecting their reproduction and breeding, the quality and quantity of their animal product resources, and contributing to a decline in fish stocks.

Developing countries have been the most vulnerable to the negative impacts of climate change. A two-degree increase in global temperature or more could result in a permanent decline in GDP of 4%-5% [2].

Research Problem

The research problem can be formulated through the following questions:

1- What is climate change and its impact on food production in Iraq?

2- What is the extent of the impact of climate change on food?

3- Does Iraq have clear strategies to address the risks of climate change in a manner that reduces the risks of this phenomenon at the local level and fulfills the commitments it has undertaken?

Research Objective

The research aims to study the impact of climate change on the food production index in Iraq by identifying the most important factors that contribute negatively or positively over a period of more than 30 years, in order to explore the effects caused by these factors.

Previous Studies

The topic of climate change and its impact on countries' economies has been a focus of interest for many researchers, particularly when it comes to food security. The impact of climate change on humans, animals, nature, and the economy has become clear.

Fahim (M.A. 2021)2studied the relationship between the food production index and several factors in Egypt through a econometric analysis. He concluded that there is an inverse relationship between food production and both total greenhouse gas emissions and average temperatures, confirming the negative impact of these factors on the country's food security[2]. Shukr (A.S. 2021) concluded that there are factors that influence the increase in CO2 emissions, including the average per capita GDP, which indicates an increase in economic activities that increase CO2 emissions. The study indicated a negative relationship between the per capita energy consumption coefficient and carbon emissions, and the researcher attributed this to the country's circumstances in 2003[3]. Meanwhile, A report issued by the United Nations indicated that climate change, represented by declining rainfall, rising temperatures, declining soil moisture levels, and imbalances in food production, have affected food production by placing significant stress on crops and livestock [4].

(Ahmed, M.2024) highlighted the reality of climate change and food security in Algeria through the negative impact on the decline in agricultural crops and food quality due to drought, heat waves and floods, which made the country unable to achieve food security for its population, in addition to the increase in plant pests and diseases [5]. The research (Khalid, A.H, 2023) relied on measuring the most important indicators of food security, as well as applying the Ricardo method to assess the economic impacts of climate change in Egypt during the period 2012-2022. The research showed the positive impact of low minimum temperatures and low relative humidity on wheat crops and their negative effects on rice, in addition to the negative impact of high relative humidity on wheat and positive on rice. The research also showed a decrease in food security levels for wheat and an increase for rice as a result of simulating the impact of climate change[6]. Khadim (A.A., 2019) studied climate changes in some climatic elements represented by climate cycles and their impact on some field crops in different regions of Iraq. The research revealed that the temperature is trending towards positive change for most of the climate cycles and the most popular plants studied in Iraq, in addition to the negative trend in the amount of change in rainfall, which in turn is reflected in the area of field crops, and thus their production will be negatively affected[7]. Fawaz (M.M., 2015) indicated that the phenomenon of climate change is a global phenomenon, but its impact on Egypt will be more severe. This has been manifested in rising temperatures, changing rainfall patterns, rising sea levels, and the increasing frequency of climate-related disasters, which pose risks to agriculture, agricultural lands, water supplies, and food security, causing problems and losses in the agricultural economy [8]. As for (Duraid Rasmi, 2024), he attributed the cause of climate change, especially in recent decades, to natural factors and human activities, represented by the burning of fossil fuels and deforestation, which led to an increase in greenhouse gas emissions and led to an increase in the Earth’s temperature [9].

Ali.S.T. (2012) warned of the environmental consequences for humans if the necessary measures are not taken to avert the accompanying dangers, and that climate change has become an unequivocal reality that is beyond scientific doubt. The researcher pointed out that the phenomenon of rising temperatures in Iraq has led to the recurrence and increase of severe weather events, which has led to a decrease in rainfall during the period 1990-2007. Rising temperatures cause a decrease in relative humidity in the atmosphere and an increase in the number of dry months, thus drying out the soil and reducing the natural growth of plants, which means soil disintegration and makes it vulnerable to rapid movement. The phenomenon is reflected in human health and various activities [10]. A report on climate change and its impact on the environment indicated that greenhouse gas emissions caused by human activities affect ecosystems (such as changes in the distribution of forests and deserts), natural and human[11]. (M.Kumar, 2013) indicated that the effects of climate change appear on human well-being because the surrounding environment and the decisions people make affect their health. The researcher also pointed out that rural communities are exposed to environmental change and their ability to adapt is declining [12].

The results of Qin Zhuo (2025) show that severe ozone pollution mainly occurs under conditions of high temperature and low humidity, and climate change influences local weather conditions leading to severe pollution by altering the patterns of large-scale and regional circulations[13]. Yuan Yu (2025) reviewed the most significant extreme weather and climate events in China under the backdrop of intensified global warming from 2010 to 2023, focusing on analyzing the characteristics and socioeconomic impacts of these events. It also summarizes the latest progress in attribution research for these events. Among the ten most significant annual weather and climate events in China from 2010 to 2023, heavy rainfall and flooding, along with typhoons, accounted for the highest proportions at 27% and 15%, respectively. Extreme heat, drought, low temperatures, and snow events associated with hail, as well as pollution events associated with fog and dust, accounted for 11%–12%, while severe convective weather and other meteorological events accounted for 7% and 6%, respectively. With the intensification of global warming, the frequency and intensity of extreme heat, heavy rainfall, and drought events in China have increased significantly. The increase in extreme heat and drought events is mainly attributed to human factors, while extreme rainfall, drought, forest fires, and other extreme events are closely linked to human-induced warming. Human activities, particularly greenhouse gas emissions, are the main drivers of long-term changes in extreme events in China [14].

The research paper by (LYU XUE, 2025) examines the definition and origins of climate finance, analyzing its development, current status, challenges, and opportunities at the domestic and international levels. It also explores how multilateral development banks (MDBs) are innovating in climate finance and discusses the lessons and benefits that can be drawn from their approaches. Finally, the paper proposes seven recommendations to promote the future development of climate finance in China: improving the climate finance policy system, establishing diversified financing channels, strengthening the construction of climate finance service systems, enhancing the use of digital technology, building a high-quality climate finance and investment project pool, exploring quantitative approaches to climate finance, and intensifying international cooperation and exchange [15].

Materials and Methods

The research relied on the econometric quantitative approach to arrive at the research results through time series data for the period (1993-2022). The research relied on a set of models to arrive at the best results to explain the relationship between the dependent variable, represented by the food production index, and the set of independent variables, represented by the crop production index, the livestock production index, temperature, rainfall, and total greenhouse gas emissions. Here, carbon dioxide emissions will be relied upon, as they currently represent 86 percent of global carbon dioxide emissions. (This data includes carbon dioxide emissions from the burning of fossil fuels and the cement industry, but not emissions resulting from land use such as deforestation. Emissions resulting from international shipping or fuels used in transportation are not included in these tables, which can make a significant difference for small countries with important ports. These indicators will be reviewed as follows:

First: Food Production Index

According to the World Bank's definition, the food production index covers food crops that are considered edible and contain nutrients. Coffee and tea are excluded because they lack nutritional value despite being edible [16].

The index ranges from zero to 100 points. The higher the index value, the more food security is achieved, and vice versa (Al-Waleed Talha, 2022). The world's interest in food and the need to achieve food security has increased since the 1970s. Many countries, especially developing countries, embarked on developing their agricultural sectors with the aim of increasing agricultural production to a level that meets local food demand. This was due to the global food crisis that the world's peoples suffered from in the early 1970s. One of the most important duties of a state, whether developed or developing, is to achieve food security for its citizens, as food has become a top priority in every problem, whether economic, social, or political. Food has become a leading commodity in global markets, either as a consumer good or as a raw material necessary for many industries around the world[17].

Second: Crop Production Index (2004-2006 = 100)

The crop production index shows agricultural production for each year relative to the base period 2004-2006. It includes all crops except forage crops. Area aggregates and income group aggregates for the FAO production indicators are calculated from base values in international dollars adjusted for the base period 2004-2006[16].

The agricultural sector is one of the main production sectors in the Iraqi economy. Agriculture in Iraq is one of the most important things known to ancient man. It was considered the main factor in the establishment and development of ancient civilizations in the land of the Tigris and Euphrates Valley, but it did not benefit from all that cultural heritage dating back thousands of years of agricultural activity that provided the Iraqi people with food throughout those eras. Instead of developing in line with the increase in population size and the development of life, it has declined in the current era, standing unable to meet the growing needs of the Iraqi population, which is estimated at more than (40) million people according to the latest statistics. The circumstances that the Iraqi economy went through after the year (2003) contributed to increasing the suffering of the sectors and their decline to a large extent, as the suffering of the agricultural sector increased, and many farmers were forced to abandon their lands, and many orchards died and many crops were damaged, and most of the lands were transformed into barren lands that need a lot of attention and support in order to restore life to them. The random import policy of agricultural products also contributed significantly to the decline of this sector, which greatly affected the domestic product, which was unable to compete with the foreign product due to the large difference between the cost of the domestic and foreign product[18].

Third: Livestock Production Index (2004-2006 = 100)

The livestock production index includes meat and milk from all sources, dairy products such as cheese, eggs, honey, natural silk, wool, and leather[16].

Livestock represents a distinguished position in the agricultural sector, and this stems from the role it can play in developing this sector in particular and the economic development process in general, some of which is represented by: Livestock is an important basis for providing food, as nutritionists estimate the individual's daily protein needs at about (70) grams, i.e.: about (1 gram per kilogram of weight), and that 2/3 of these needs should be derived from animal sources such as meat, eggs, and milk. One study indicates that the minimum human need for animal protein during the day is subject to differences in estimation, as a United Nations expert estimated it at about (23) grams per person, the National Nutrition Institute in the Iraqi Ministry of Health estimated it at (18) grams, and other experts estimated it at an average of (24) grams per person. The development of livestock contributes effectively to reducing the leakage of foreign currencies abroad, as it contributes to meeting local demand and achieving a state of self-sufficiency. In addition, there is the possibility of developing livestock development further, allowing for a surplus in production over local demand, which would enable us to export this surplus and contribute to bringing foreign currency into the country, which would help in developing other projects that contribute to achieving economic development.

Fourth: Total greenhouse gas emissions

Global warming is a natural phenomenon that occurs when certain gases accumulate in the Earth's atmosphere and absorb and re-emit heat radiation from the Earth. These greenhouse gases act as a blanket that traps heat in the atmosphere and prevents it from escaping into outer space as quickly as the sun. Laws regulating global warming and climate change vary from country to country and are subject to important regulations and agreements. In this regard, the United Nations Framework Convention on Climate Change (UNFCCC), which was established in 1992 and signed by most countries in the world, have been held annually under the name of the Conference of the Parties, where representatives of countries meet to develop and implement strategies and measures to address climate change and global warming. This was followed by the Paris Climate Agreement in 2015, where countries agreed to work together to limit the global temperature rise to less than 2 degrees Celsius compared to pre-industrial levels. In addition, international treaties, laws, and regulations define the environmental responsibilities and obligations of companies and industries regarding global warming and environmental conservation in general. This has legal importance at the global level, which achieves a lot of cooperation. Between countries towards environmental protection and achieving sustainable development. Accordingly, we will divide the requirement into two sections: the first to define global warming and the second to the legal nature of global warming [19].

Results

The results chapter focuses on analyzing the relationship between the dependent variable, represented by the food production index, and the explanatory variables, which will be mentioned in the description of the model variables. A set of standard models was used to describe the relationship, and it was decided to use one of the models due to its suitability to the time series data used in the research, which is the ARDL model.

Description of model variables

This description is derived from the general description of the standard model used, which explains the relationships between the variables used, where the dependent variable is the food production index, while the independent variables include (total greenhouse gas emissions (tons of carbon dioxide equivalent), crop production index, livestock production index, rainfall rate, and average temperature). Accordingly, the following relationship is assumed to be tested:

$$Y_i = b_0 + b_1X_1 + b_2X_2 + b_3X_3 + b_4X_4 + b_5X_5 + e_i \dots\dots\dots\dots\dots\dots..(1)$$

Where:

Y_i= Food Production Index (base year 2004-2006) represents the dependent variable.

The independent variables are:

X_i= Total greenhouse gas emissions (tons of carbon dioxide equivalent)

X_2= Crop production index (base year 2004-2006)

X_3= Livestock production index (base year 2004-2006)

X_4= Rainfall rate (mm)

X_5= Average temperature (C^o)

It should be noted that the selection of the appropriate standard model should be accompanied by analytical steps, including:

First: Testing the stationarity of time series

Conducting a time series stationarity test is a condition for cointegration, and unit root tests are the most important method for determining the stability of time series. We notice from the figures that the time series of the dependent variable and the independent variables are not stationary. To confirm this, the augmented Dickey-Fuller (ADF) test will be conducted.

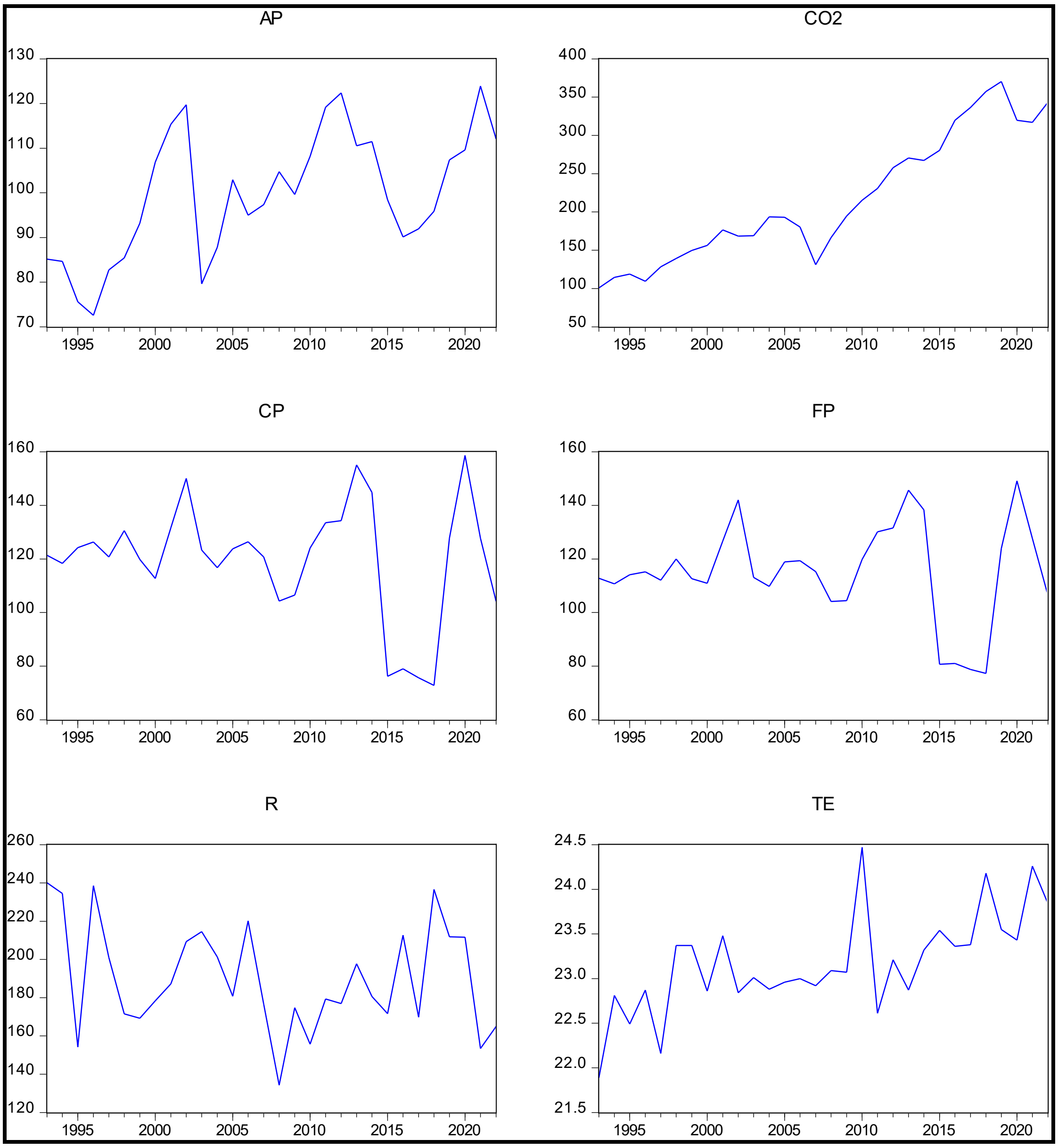

Figure 1. Time series data for study variables during the period (1993-2022)

Augmented Dickey-Fuller (ADF) unit root test

This analysis aims to test the stability of the study variables by conducting the augmented Dickey-Fuller (ADF) test. This analysis is important for determining the stability of the variables.

We can distinguish between two different types of time series: stationary time series and non-stationary time series. This difference enables us to determine the appropriate forecasting technique. A stationary time series is one whose level changes over time without the mean changing, over a relatively long period of time. In a non-stationary time series, the mean changes continuously, either increasing or decreasing.

The absence of a stationarity study can cause several problems. Therefore, unit root tests are sufficient to ensure that there are no stable variables at the second difference.

The augmented Dickey-Fuller (ADF) test is among the most important tests that reveal the presence of a unit root. It is based on the first-order regression model and is known by three models, which are as follows:

The first model: without trend and without a constant:

$$\Delta y_t = (\emptyset - 1)y_{t-1} + £_t \dots\dots\dots..(2)$$

The second model: without trend and with a constant presence:

$$\Delta y_t = c + \lambda y_{t-1} + £_t \dots\dots\dots\dots..(3)$$

The third model: in trend and with a constant presence:

$$\Delta y_t = c + b_t + \lambda y_{t-1} + £_t \dots\dots\dots.(4)$$

According to the test:

$H_0: \lambda = 0$ There is at least one-unit root in the series, i.e. the time series is non-stationary.

$H_1: \lambda < 0$ There is no unit root in the series, i.e. the time series is stationary.

According to this test, the null hypothesis is tested, which indicates the presence of a general trend for the variable for which the unit root is to be extracted in the time series. If the time series is stationary or stable at the level, then the ordinary least squares (OLS) method can be used without obtaining spurious regression coefficients, which lead to incorrect interpretations that deviate from the goal of interpreting the parameter. However, if the time series is not stationary at the level, the null hypothesis is retested after taking the initial difference of the data for the targeted variable or variables.

Table 1. Augmented Dickey-Fuller (ADF) unit root test

	Level			First Deference		
FP	**Constant**	**Constant &trend**	**Without constant & trend**	**Constant**	**Constant &trend**	Without constant & trend
t-Statistic	-3.91373	-4.015705	-0.16581	-4.442052	-4.33043	-4.543113
1%	-3.689194	-4.323979	-2.65015	-3.699871	-4.33933	-2.653401
5%	-2.971853	-3.580623	-1.95338	-2.976263	-3.58753	-1.953858
10%	-2.625121	-3.225334	-1.6098	-2.62742	-3.22923	-1.609571
Prob	0.0058	0.0199	0.6174	0.0017	0.0102	0.0001
CP	**Constant**	**Constant &trend**	**Without constant & trend**	**Constant**	**Constant &trend**	Without constant & trend
t-Statistic	-3.706349	-4.057161	-0.23966	-4.650598	-4.53965	-4.75482
1%	-3.689194	-4.323979	-2.65015	-3.699871	-4.33933	-2.653401
5%	-2.971853	-3.580623	-1.95338	-2.976263	-3.58753	-1.953858
10%	-2.625121	-3.225334	-1.6098	-2.62742	-3.22923	-1.609571

		Prob	0.0096	0.0182	0.5908	0.001	0.0064	0.000
		AP	Constant	Constant &trend	Without constant & trend	Constant	Constant &trend	Without constant & trend
		t-Statistic	-2.387249	-3.01237	0.40886	-4.570446	-4.4828	-4.543815
		1%	-3.689194	-4.323979	-2.65015	-3.699871	-4.33933	-2.653401
		5%	-2.971853	-3.580623	-1.95338	-2.976263	-3.58753	-1.953858
		10%	-2.625121	-3.225334	-1.6098	-2.62742	-3.22923	-1.609571
		Prob	0.1542	0.1467	0.7946	0.0012	0.0072	0.0001
		R	Constant	Constant &trend	Without constant & trend	Constant	Constant &trend	Without constant & trend
		t-Statistic	-3.67009	-3.590653	-0.68237	-5.976248	-5.77119	-6.092974
		1%	-3.689194	-4.323979	-2.65015	-3.699871	-4.33933	-2.653401
		5%	-2.971853	-3.580623	-1.95338	-2.976263	-3.58753	-1.953858
		10%	-2.625121	-3.225334	-1.6098	-2.62742	-3.22923	-1.609571
		Prob	0.0105	0.049	0.4123	0.000	0.0004	0.000
		TE	Constant	Constant &trend	Without constant & trend	Constant	Constant &trend	Without constant & trend
		t-Statistic	-1.989951	-3.859647	0.917895	-6.484063	-6.34344	-6.313852
		1%	-3.689194	-4.323979	-2.65015	-3.699871	-4.33933	-2.653401
		5%	-2.971853	-3.580623	-1.95338	-2.976263	-3.58753	-1.953858
		10%	-2.625121	-3.225334	-1.6098	-2.62742	-3.22923	-1.609571
		Prob	0.2892	0.0279	0.8996	0.000	0.0001	0.000
		CO2	Constant	Constant &trend	Without constant & trend	Constant	Constant &trend	Without constant & trend
		t-Statistic	-0.016335	-1.908881	2.02375	-4.958196	-4.98919	-3.951327
		1%	-3.689194	-4.323979	-2.65015	-3.699871	-4.33933	-2.653401
		5%	-2.971853	-3.580623	-1.95338	-2.976263	-3.58753	-1.953858

		10%	**-2.625121**	**-3.225334**	**-1.6098**	**-2.62742**	**-3.22923**	**-1.609571**
		Prob	**0.9492**	**0.6233**	**0.9875**	**0.0005**	**0.0022**	**0.0003**

Source: Prepared by the researcher based on the outputs of E-views 10

Notes;

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

b: Lag Length based on SIC

c: Probability based on Mackinnon (1996) one-sided p-values.

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Table 2. Critical values for the Dickey-Fuller test

Critical values for Dickey–Fuller *t*-distribution.				
	Without trend		With trend	
Sample size	1%	5%	1%	5%
T = 25	−3.75	−3.00	−4.38	−3.60
T = 50	−3.58	−2.93	−4.15	−3.50
T = 100	−3.51	−2.89	−4.04	−3.45
T = 250	−3.46	−2.88	−3.99	−3.43
T = 500	−3.44	−2.87	−3.98	−3.42
T = ∞	−3.43	−2.86	−3.96	−3.41

Source: Fuller, W. A. (1976). Introduction to Statistical Time Series. New York: John Wiley and Sons. ISBN 0-471-28715-6.

By examining Tables 1 and 2 and drawing on their insights, we note that the results of the variables at the level indicate, in some cases, the presence of a unit root in the time series, which indicates the presence of a time trend, in addition to the non-stationarity of the time series, which can give us unreliable results if adopted in the analysis and the emergence of interpretations that may be far from reality. Therefore, in order to address this issue, it was necessary to take the first difference of the data of the studied variables, which is one of the treatments for time series non-stationarity. The results indicate that all variables were stable at the first difference.

The stability of the data at the first difference means that they are integrated to the same degree at the first degree, indicating the existence of a joint integration relationship between the value of the dependent variable and the values of the explanatory variables.

Cointegration - Johansen Test

Unit root tests revealed that the time series variables are stationary at the first difference, meaning they are integrated to the same degree (at the first degree), which indicates the existence of a cointegrating relationship between the dependent and explanatory variables.

It is worth noting that cointegration means that the two integrated series behave similarly over time, which represents a long-term equilibrium relationship. Furthermore, it results in a linear combination between them with a zero mean and constant variance.

From the above, it is now possible to conduct a cointegration test according to the Johansen methodology using the effect test and the maximum likelihood test. The results are shown in the following table:

Table 3. Results of the cointegration test using the trace test and the Maximum likelihood value test

Hypothesized No. of CE(s)	Eigenvalue	Trace statistic	0.05 Critical value	Prob.**
None *	0.818976	135.5035	95.75366	0.0000
At most 1 *	0.739548	87.64800	69.81889	0.0010
At most 2 *	0.690005	49.97860	47.85613	0.0311
At most 3	0.357841	17.18501	29.79707	0.6264
At most 4	0.140145	4.783277	15.49471	0.8314
At most 5	0.019644	0.555500	3.841466	0.4561
Trace test indicates 3 cointegrating eqn(s) at the 0.05 level				
* denotes rejection of the hypothesis at the 0.05 level				
**MacKinnon-Haug-Michelis (1999) p-values				

Hypothesized No. of CE(s)	Eigenvalue	Max-Eigen statistic	0.05 Critical value	Prob.**
None *	0.818976	47.85550	40.07757	0.0055
At most 1 *	0.739548	37.66940	33.87687	0.0168

At most 2 *	**0.690005**	**32.79358**	**27.58434**	**0.0097**
At most 3	**0.357841**	**12.40174**	**21.13162**	**0.5085**
At most 4	**0.140145**	**4.227777**	**14.26460**	**0.8346**
At most 5	**0.019644**	**0.555500**	**3.841466**	**0.4561**
Max-eigenvalue test indicates 3 cointegrating eqn(s) at the 0.05 level				
*** denotes rejection of the hypothesis at the 0.05 level**				
****MacKinnon-Haug-Michelis (1999) p-values**				

Table (3) indicates that there are three cointegration vectors among the model variables. The results of the trace statistics test indicate that the calculated value (trace statistics) exceeded the critical values at a significance level of 0.05 in three cointegration equations.

(Trace test indicates three cointegrating eqn(s) at the 0.05 level).

This means accepting the alternative hypothesis, which states that the equation is integrated and contains three cointegration vectors.

The results of the maximum likelihood test (maximum eigenvalue) indicate the same results above, with three cointegration vectors (Max-eigenvalue test indicates three cointegrating eqn(s) at the 0.05 level). Furthermore, there is a long-term equilibrium relationship between the study variables. This is typical of climate variables, which experience a continuous relationship that extends over the long term.

VAR Lag Order Selection Criteria

Table 4. VAR Lag Order Selection Criteria

VAR Lag Order Selection Criteria
Endogenous variables: FP LOGCP LOGAP LOGR LOGTE LOGCO2
Exogenous variables: C
Date: 04/24/25 Time: 00:37
Sample: 1993 2022
Included observations: 29

Lag	LogL	LR	FPE	AIC	SC	HQ
0	63.61792	NA	7.58e-10	-3.973649	-3.690761	-3.885052
1	138.3198	113.3409*	5.57e-11*	-6.642748*	-4.662526*	-6.022567*

It is worth noting that the selection of the Lag period relies more on the (SC) criterion, as it is one of the most sensitive tests to the degree of Lag. According to Table (4), we note that the selection of the degree of Lag is 1.

Choosing one econometric model over another requires certain criteria. There are also restrictions, sometimes related to the accuracy of the data used in the econometric analysis. Data inaccuracy affects the results of the analysis, whether econometric or mathematical. Data differences between sources prompt researchers to rely on a single source to overcome the source of variation. Some variables require averages, or sources do not include detailed data for the variable, such as temperature and rainfall. Data vary from one region to another, prompting researchers to use averages for the data. Although the arithmetic mean criterion has undesirable characteristics, such as being affected by extreme values, which may affect the results of the analysis, this does not prevent its use. However, caution should be exercised when interpreting parameters, especially when their significance is affected and the size of the parameters is high or low.

Based on the above, the research relied on the Autoregressive Distributed Lag (ARDL) model because of its features that are compatible with the research data and the tests that were previously conducted.

Estimation of an Autoregressive Distributed Lag (ARDL) Model

The ARDL methodology is used in many econometric studies that aim to examine the relationship between variables due to its ease of application. It differs from other econometric methodologies in terms of application and analysis. The ARDL model takes the following equation:

$$y_t = B + B_0 x_t + B_1 x_{t-1} + u_t \dots\dots\dots\dots\dots\dots..(5)$$

The dynamic behavior can be expressed by the previous values (time-lagged) of the dependent variable y_tThis means that the dependent variable itself is an independent (explanatory) variable, provided that it is time-lagged for a previous period, i.e. y_{t-1}. This represents the autoregressive model and is represented by the following formula:

$$y_t = \lambda_1 y_{t-1} + \lambda_2 y_{t-2} + \cdots + \lambda_p y_{t-p} + u_t \dots\dots\dots....\textbf{(6)}$$

According to equation (5), the right side includes a time-lagged explanatory variable, x_{t-1}, in addition to the fact that the dependent variable itself contains previous values, i.e. y_{t-1}, so it will take the following equation:

$$y_t = a + a_1 y_{t-1} + B_0 x_t + B_1 x_{t-1} + u_t \dots\dots....(7)$$

Where (x, y) represent variables that are stationary at degree zero, one, or a combination of both.

Table No. (5) indicates the results of estimating the ARDL model during the period under study.

Table 5. Estimation results of the autoregressive distributed lag (ARDL) model

Variable	Coefficient	Std. Error	t-Statistic	Prob.*
FP(-1)	-0.143358	0.223507	-0.641405	0.5298
LOG_CP	84.4921	2.247784	37.58906	0.000
LOG_CP(-1)	13.81519	20.31342	0.680102	0.5056
LOG_AP	22.81043	3.921336	5.817006	0.000
LOG_AP(-1)	2.027102	5.809649	0.34892	0.7317
LOG_R	2.737999	2.451585	1.116828	0.2797

LOG_R(-1)	**-1.846597**	**2.497639**	**-0.739337**	**0.4698**
LOG_TE	**-50.78794**	**20.13688**	**-2.522135**	**0.0219**
LOG_TE(-1)	**-39.27879**	**17.91197**	**-2.192879**	**0.0425**
LOG_CO2	**-3.165528**	**4.124338**	**-0.767524**	**0.4530**
LOG_CO2(-1)	**12.81153**	**4.056081**	**3.158598**	**0.0057**
C	**-223.845**	**150.6834**	**-1.485532**	**0.1558**
R-squared	**0.996132**		**Mean dependent var**	**115.1552**
Adjusted R-squared	**0.99363**		**S.D. dependent var**	**18.69802**
S.E. of regression	**1.492343**		**Akaike info criterion**	**3.932076**
Sum squared resid	**37.86051**		**Schwarz criterion**	**4.497854**
Log likelihood	**-45.0151**		**Hannan-Quinn criter.**	**4.10927**
F-statistic	**398.0485**		**Durbin-Watson stat**	**2.115034**
Prob(F-statistic)	**0.000**			

Source: Prepared by the researcher based on the outputs of E-views 10

The results of Table (5) indicate that the crop production index (CP) had a positive and significant impact on the food production index. This is logical based on the results of some studies that were relied upon, including the study by (, Fahim, M.A. & R. A. Tolba 2021), which indicated a positive and significant impact of the crop production index on the food production index. A 1% increase in the crop production index will result in a ratio of more than 1%, according to the coefficient value of (84.4921). As previously mentioned, the crop production index expresses grain production in metric tons and is calculated on the basis of the period (2004 - 2006 = 100) as a base period. The value of this coefficient is expected to differ depending on the base period used. However, in general, the crop production index coefficient had a positive and significant impact, because increasing grain production will positively reflect on a group of indicators, including self-sufficiency, food security, and others.

The same applies to the livestock production index (AP) variable, which was positive and significant at acceptable statistical levels, giving a positive impression that an increase in this index will lead to an increase in the food production index. This can be explained by the fact that an increase in livestock production of meat, milk, wool, hides, etc. indicates a clear interest in livestock and an improvement in the quality of its products. This will be positively reflected in the food production index, which covers a wide range of foods, including livestock products. Therefore, we believe that the positive result reflects a positive perception of the status of livestock in the country, although this may seem relative. As we previously indicated, the results are related to the values of the index variable calculated for a period of time (2004-2006), which may be positive for one country and negative for another.

Regarding the rainfall variable, although the result was positive, it was not significant at the acceptable statistical levels. This can be explained by the fact that rainfall amounts are not a decisive and positive factor for the food production index, which is primarily linked to increased crop production of various types. Rather, the distribution of rainfall during the agricultural season plays a crucial role in raising production rates of various crops. Due to the global warming phenomenon that our planet has suffered from, we have observed in recent years very large amounts of rainfall, causing major floods and dangerous soil erosion. This gives the impression that rainfall amounts are not always a positive factor, as much as the distribution of rainfall during the season and the appropriate quantities required by crops and agricultural land. In addition, global warming has another effect, represented by the interruption of rainfall for periods that may extend to months or years, which means the occurrence of droughts, causing a decline in crop production and consequently impacting the food production index.

Regarding the temperature variable, the effect was negative and significant at acceptable statistical levels. This is logical, especially since global reports clearly indicate an increase in temperature rates in various countries of the world that may reach two degrees, in addition to the side effects of the global warming phenomenon, as mentioned above. Temperature has a significant impact on all life functions, as all chemical metabolism processes, the natural processes necessary for the formation of cell walls and others, such as diffusion and deposition, depend on temperature. They are activated when this temperature rises to the optimal level, and vice versa if the temperature decreases to a certain minimum. Temperature determines the length of the growing season and the type of plant. Heat stress, represented by high temperatures, also affects grain production. Climate change, including high temperatures, has had negative effects, which makes the analysis results logical. Temperature data were also used as averages for the time period under study. As we mentioned earlier, the use of averages is fraught with many caveats, especially in econometric studies. It would have been more accurate if the analysis had been divided into the northern, central, and southern regions of Iraq, something that could be used for this variable but could not be used for another variable.

The same applies to the carbon dioxide emissions variable, which had a negative impact on the food production index. Although this variable was insignificant, it may be attributed to other factors, including the model's influence by the problem of multi- collinearity, which cannot be overcome, especially in macro-level studies. Furthermore, the model's variables are interrelated, as evidenced by the high value of the coefficient of multiple determination R^2. However, the negative impact of carbon dioxide emissions is one of the negative effects of climate change that the planet has witnessed in recent times, requiring strenuous efforts from countries and international organizations that have sounded the alarm to save the planet.

Other statistical criteria also indicate the significance of the model as a whole based on the F value of 398.04 at a significance level of 0.01.

Error correction model

Table (6) shows the error correction coefficient (ECM) estimate, which shows the speed of converting short-term to long-term results. This coefficient must be negative and significant. From Table 6, the error correction coefficient (CointEq(-1)) appears negative and significant, indicating the existence of a long-term equilibrium relationship and that the model has an error correction rate capable of converting short-term results to long-term results at a speed of 1.14 per period.

Table 6. Results of the short-term error correction model

ECM Regression				
Case 2: Restricted Constant and No Trend				
Variable	Coefficient	Std. Error	t−Statistic	Prob.
D(LOG_CP)	84.4921	1.444922	58.4752	0.000
D(LOG_AP)	22.81043	2.449053	9.31398	0.000
D(LOG_R)	2.737999	1.299812	2.106457	0.0503
D(LOG_TE)	−50.78794	10.47182	−4.849964	0.0002
D(LOG_CO2)	−3.165528	2.710963	−1.167677	0.2588
CointEq(−1)*	−1.143358	0.156188	−7.320419	0.000

Source: Prepared by the researcher based on the outputs of E-views 10

Estimating long-term equations

This equation illustrates the sustainable relationship between variables, reflecting the sustainable impact of each variable over the long term. Table 7 indicates this; the crop production index continued to have a positive and significant impact over the long term, which is logical and cannot be taken for granted. The same applies to the livestock production index; it remained positive and significant over the long term, and this is typical of aggregate variables, whose impact is clearly evident in the long term. Their path may sometimes change, and the short term does not clearly reflect their impact, as this is linked to circumstances that cannot be resolved in the short term, requiring a longer period, as is the case when all production factors become variable in the long term.

As for the rainfall variable, it did not show a clear impact on the food production index. This is attributed to climate change, which had a clear and severe impact on the environment and subsequently on crop production, and subsequently food production. Meanwhile, the temperature variable had a negative and significant impact in the long term, clearly indicating climate change, the effects of which have become clear on the environment and agricultural lands. Moreover, global reports continue to warn that human intervention and violation of the ecological balance will deepen the negative effects and, consequently, increase temperatures. As for the effects of emissions, represented by carbon dioxide emissions, their impact has appeared positive, and we may not find an explanation other than the efforts of organizations and countries that may emerge in the future, especially through addressing emissions and transforming them into positive impacts due to technological progress, the effects of which we can sense in all environmental, technical, and economic aspects.

Table 7. Results of estimating long-term equations

Conditional Error Correction Regression				
Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	-223.845	150.6834	-1.485532	0.1557
FP(-1)*	-1.143358	0.223507	-5.115543	0.0001
LOG_CP(-1)	98.30729	19.9516	4.927289	0.0001
LOG_AP(-1)	24.83753	5.302658	4.683978	0.0002
LOG_R(-1)	0.891401	3.813865	0.233726	0.818
LOG_TE(-1)	-90.06672	31.76281	-2.835603	0.0114
LOG_CO2(-1)	9.646001	2.19648	4.391572	0.0004
D(LOG_CP)	84.4921	2.247784	37.58906	0.0000
D(LOG_AP)	22.81043	3.921336	5.817006	0.0000
D(LOG_R)	2.737999	2.451585	1.116828	0.2796
D(LOG_TE)	-50.78794	20.13688	-2.522135	0.0219
D(LOG_CO2)	-3.165528	4.124338	-0.767524	0.4533
* p-value incompatible with t-Bounds distribution.				
Levels Equation				
Case 2: Restricted Constant and No Trend				
Variable	Coefficient	Std. Error	t-Statistic	Prob.
LOG_CP	85.98118	2.254637	38.13526	0.0000
LOG_AP	21.72332	3.376805	6.433098	0.0000
LOG_R	0.779634	3.289367	0.237017	0.8155
LOG_TE	-78.77384	33.09603	-2.38016	0.0293
LOG_CO2	8.436551	1.56111	5.40420	0.0000
C	-195.7785	107.1061	-1.827894	0.0852

Source: Prepared by the researcher based on the outputs of E-views 10

Cointegration Test Using Bound Test

This test was used according to the ARDL autoregressive model, where the results of Table (8) for the Bounds Test indicate that the F-Statistical value reached 5.658548, which is greater than the critical values at all its significance levels, meaning that there is a long-term joint integration relationship between the food production index as a dependent variable and the rest of the independent variables (crop production index, livestock production index, rainfall rate, average temperature, greenhouse gases). This means rejecting the null hypothesis and accepting the alternative hypothesis.

Table 8. Results of the cointegration test for the study variables according to the bound test

F-Bounds Test	Null Hypothesis: No levels relationship			
Test Statistic	**Value**	**Signif.**	**I(0)**	**I(1)**
			Asymptotic: n=1000	
		10%	**2.08**	**3**
F-statistic	**5.658548**	**5%**	**2.39**	**3.38**
k	**5**	**2.5%**	**2.7**	**3.73**
		1%	**3.06**	**4.15**

Source: Prepared by the researcher based on the outputs of E-views 10

Econometric Problem Tests

1- Breusch-Godfrey test

The LM test shows that the Prob values are greater than 5%, which means we accept the null hypothesis that there is no autocorrelation.

Table 9. Breusch-Pagan-Godfrey Serial Correlation LM Test

Breusch-Pagan-Godfrey Serial Correlation LM Test			
F-statistic	**0.701716**	**Prob. F(2,15)**	**0.5113**
Obs*R-squared	**2.481160**	**Prob. Chi-Square(2)**	**0.2892**

Source: Prepared by the researcher based on the outputs of E-vies 10

2- Heteroskedasticity Test

To verify the conditions that must be met to accept the model, the Heteroscedasticity test must be used according to the White test. We note from Table (10) that the values are not significant and are greater than 0.05, meaning that the error variance is homogeneous.

Table 10. Heteroskedasticity Test

Heteroskedasticity Test: White			
F-statistic	**1.058639**	**Prob. F(11,17)**	**0.4436**
Obs*R-squared	**11.78933**	**Prob. Chi-Square(11)**	**0.3797**

Scaled explained SS	**3.064720**	**Prob. Chi-Square(11)**	**0.9898**

Source: Prepared by the researcher based on the outputs of E-vies 10

3- Testing the normal distribution of random errors Jarque-Bera test:

To verify the acceptance of the model, the normal distribution test for random errors must be conducted according to the Jarque-Bera test. We note from the figure 2, that the null hypothesis is accepted, that the data are distributed normally, as the value of Jarque-Bera reached 0.367390 with a significance level of Prob of 0.832190, since the value of Prob is greater than 0.05, meaning that the series follows the normal distribution.

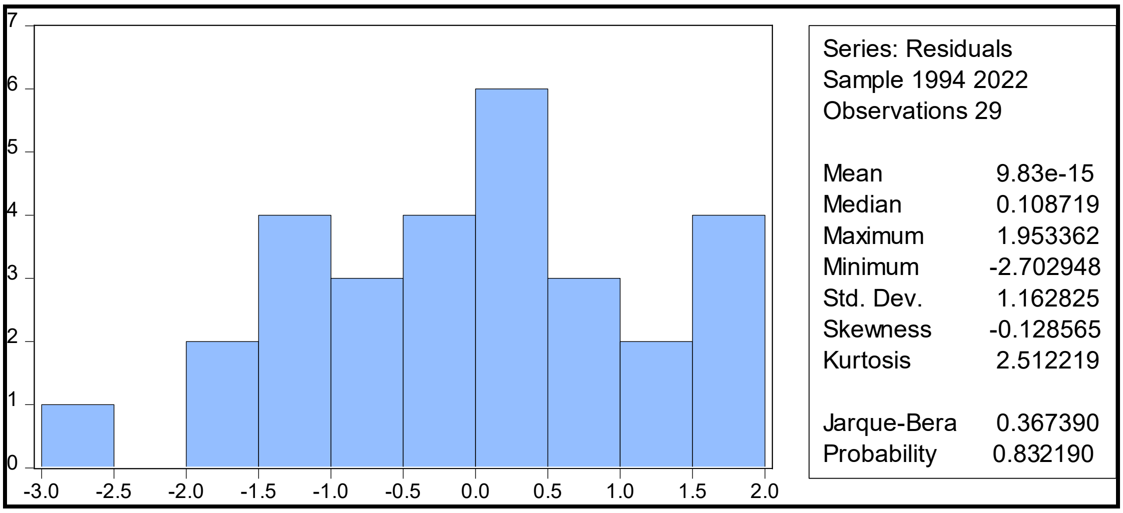

Figure 2. Normal distribution of random errors test

3. Test the structural stability of the model

To verify short- and long-term structural stability—that is, the absence of any structural changes over time—two tests must be conducted:

A. Cumulative sum of residuals test

B. Cumulative sum of squares residuals test

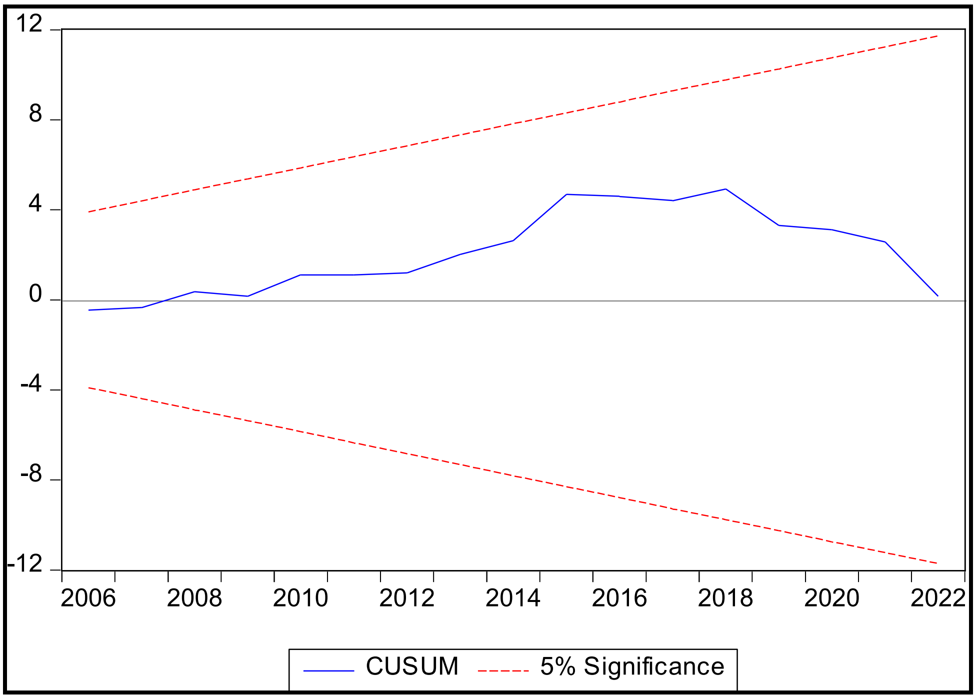

Figure 3. CUSUM TEST

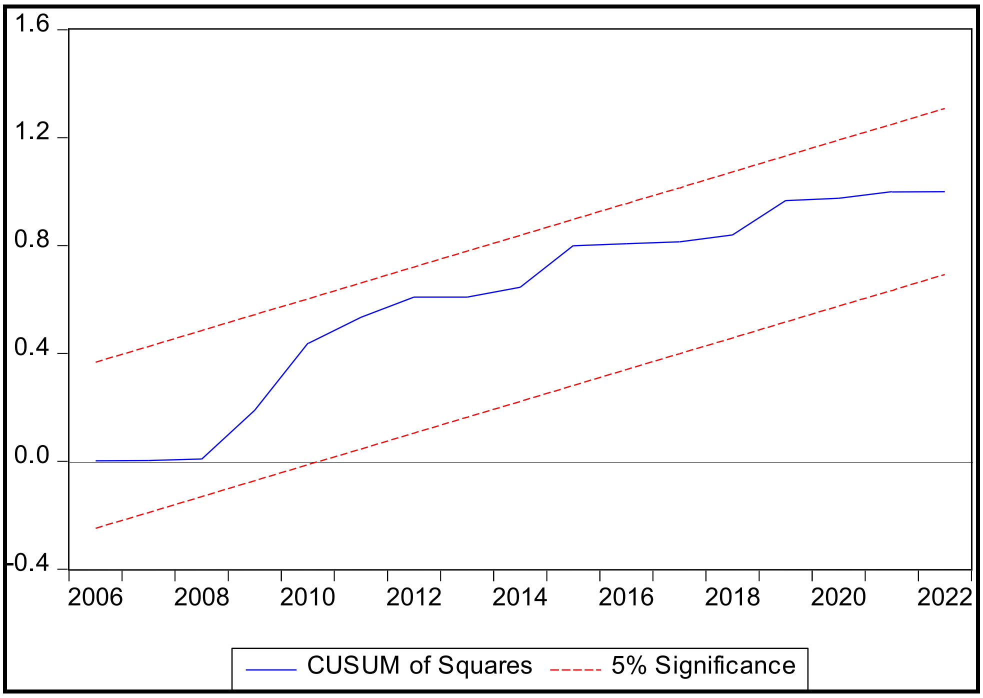

Figure 4. CUSUM of Squares

From figures (3, 4) we find that the cumulative sum of residuals (Cusum) and the cumulative sum of squares of residuals (Squares Cusum) fall within the critical limits at the 5% level, and this indicates the stability of the model in the long and short term.

Conclusion

The most important conclusions that can be drawn through quantitative analysis are as follows:

1- The results of the quantitative analysis indicated the importance of improving agricultural and livestock production to positively impact the food production index. This can only be achieved by providing the necessary technical conditions. Although the impact of rainfall was positive, this effect will be governed by other factors, including that the distribution of rainfall throughout the season is more important than the quantity of rainfall. This was evident in years of heavy rainfall, but agricultural production did not keep pace with the annual increases in rainfall. Furthermore, global warming, and the resulting droughts and floods, led to imbalances in water availability, negatively impacting the stability of agricultural production.

2. The impact of carbon dioxide emissions had a negative impact, and we conclude that there is a lack of awareness about addressing these negative effects, in addition to a lack of adequate government oversight of the impacts of industries that release their waste into the environment without pre-treatment. The rise in temperatures had negative effects. We conclude that Iraq neglected many of the measures and procedures that could have mitigated the rise in temperatures, including the establishment of green belts around cities overlooking the desert and the resulting dust storms, especially in the summer, which raise temperatures above acceptable levels. This is in addition to the increase in global warming, which has negatively impacted plants, animals, and the environment.

3- The results of the quantitative analysis demonstrated that the factors affecting the food production index will continue to influence the long term, underscoring the importance of addressing and mitigating their impact in the future.

Recommendation

1- Placing environmental protection at the core of the state's priorities and all its governmental institutions, with a focus on supporting development efforts, improving citizens' living standards, and reducing poverty, given its direct link to environmental pollution and the spread of disease. Working to reduce greenhouse gas emissions (methane, carbon dioxide, and nitrogen oxides) by adopting a green economy and encouraging sustainable development projects, conducting a comprehensive survey of environmental problems based on their geographical locations, and accurately identifying the type of pollution to better guide environmental policies.

2- Developing irrigation infrastructure and utilizing modern technologies such as drip irrigation systems, constructing dams and reservoirs for water storage, and improving water resource management in the context of climate change. Encouraging farmers to cultivate drought- and heat-resistant crops with high productivity, such as grains and desert grasses, in addition to expanding protected agriculture such as greenhouses, especially in areas most affected by climate change, as this has an impact on production stability and improving soil fertility.

3- Increasing investment in scientific research and adopting modern technologies, such as climate-smart agriculture, to develop effective solutions to adapt to the effects of climate change. Developing and updating environmental legislation to address the effects of climate change, while enhancing the country's ability to monitor extreme phenomena such as drought and floods by building a national monitoring and early warning system, in coordination with relevant authorities.

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