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Nexus between climate change and agricultural outputs in China

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ABSTRACT

In recent years, China has experienced higher warming than the global average, making the country more susceptible to the climate change crisis. This study investigates the relationship between climate change and agricultural outputs in China from 1990 to 2020. The analysis of climate change's influence on Chinese agricultural outputs was conducted using dynamic ordinary least squares. The findings indicate that access to the internet (LNATI) shows a non-significant negative relationship, while access to electricity (LNATE) positively impacts agricultural output. Higher carbon emissions (LNCO2) are associated with decreased agricultural productivity, emphasizing the importance of environmental sustainability. Changes in rainfall patterns (LNCRP) exhibit a negative trend without statistical significance, suggesting potential long-term implications. Conversely, trade openness (LNTO) demonstrates a significant positive correlation, highlighting the benefits of international trade. The high R-squared and adjusted R-squared values underscore the model's effectiveness in explaining variations in agricultural output. The study recommends that the Chinese government prioritize climate resilience and carbon emission reduction in agriculture. Strategies include promoting adaptive practices, reducing emissions, and fostering innovation for sustainable development amid climate change.

Contribution/ Originality: The motivation for embarking on this study with reference to China lies in the fact that little or no empirical studies are currently available in the literature to establish the direction and the magnitude at which climate change has driven agricultural outputs in this country.

1. INTRODUCTION

Climate change can be defined as a significant and sustained alteration in the long-term statistical distribution of weather patterns, predominantly characterized by elevated temperatures, occurring over an extended period. This phenomenon has multifaceted impacts across ecological, environmental, socio-political, and socio-economic domains. As described by Adger et al. (2007); Ajayi, Muhammed, Yusuf, and Ajibola (2020); Schuurmans (2021) and Abbass et al. (2022) climate change encompasses shifts in climatic conditions such as temperature, precipitation patterns, and extreme weather events, leading to disruptions in ecosystems, environmental degradation, changes in social dynamics, and economic challenges. The world's attention has been drawn to the enormous changes in the global climate that are occurring because of human activity by both the scientific community and the general public (World

Meteorological Organization, 2021). Changes in the temporal and spatial distribution of water and heat resources will have a significant impact on the agricultural system that lacks the capacity for self-regulation. Where this impact is more pronounced, a decline in agricultural output poses a challenge and hazard (Arnell, Lowe, Challinor, & Osborn, 2019). The average temperature is already 1.2°C, which is higher than it was in the preindustrial era, and this is likely to increase further due to the continuous expansion of industrial activities globally.

However, several studies such as Chandio, Jiang, Rehman, and Rauf (2020); Liu (2022); Tao, Yokozawa, Xu, Hayashi, and Zhang (2006); Wang et al. (2009) and Xiong, Matthews, Holman, Lin, and Xu (2007) have indicated that the agricultural sector is the one that is most susceptible to the crisis spurred by climate change in China. In this regard, policymakers and other stakeholders in the country are concerned about the influence of changes in climate on agricultural outputs and food security. For example, a vast majority of Chinese farmers are paying close attention to the spillovers of climate change on agriculture because agriculture serves as the main source of income for this group of farmers. In view of this, building adaptive measures in China to cushion the adverse impacts of climate change on agricultural outputs and food security to safeguard the lives of rural residents, who are living in poverty, has become inevitable in recent times. In the same vein, according to Cline (2008) mitigating the climate change crisis could reduce potential harm and help in coping with the negative consequences of climate change, thereby reducing rural communities' vulnerability to it. It can also assist communities in adapting to the unpredictable nature of the shift. The dependence of the agriculture sector on climate change is a major problem for economic growth, given that most people in China live in rural regions and engage in both agricultural and non-agricultural activities (World Bank, 2014). Farmers are continuously seeking ways to adapt as weather and climatic conditions change.

Meanwhile, in the globe, China is one of the countries that is particularly susceptible to climate change, and during the same period, the pace of warming was higher than the average for the entire world (Climate Change Center of China Meteorological Administration, 2021). China experienced the hottest decade since the turn of the 20th century over the past 20 years.

Unexpected problems with agricultural structure, planting methods, diseases and pests, land use, and infrastructure development may be caused by high temperatures, isolated droughts, and harsh weather. Numerous relevant studies from the past few years like Tan and Shibasaki (2003); Tsechoe et al. (2022); Xue, Huo, and Kisekka (2021) and Wing, De Cian, and Mistry (2021) have repeatedly shown that crop productivity and yield would vary because of global warming, and that the structure of agricultural output in many places may also alter. When seen against the backdrop of global climate change, China's climate change will be more difficult due to its unique physical features and geographic position. Due to its vast population, China faces serious problems with food security. Because of the close connection between climate and agricultural production, agriculture is the sector most affected by climate change.

An increasing number of studies have focused on the resulting economic effects of climate change on crop yields (Burke, Alampay Davis, & Diffenbaugh, 2018; Challinor et al., 2014; Costinot, Donaldson, & Smith, 2016; Knox, Hess, Daccache, & Wheeler, 2012; Robinson et al., 2015; Takakura et al., 2019). Similarly, climate change has already had a negative impact on Chinese agriculture, and further repercussions are anticipated (Liu et al., 2020). However, the magnitude of the impact of climate change on Chinese agricultural outputs in terms of agricultural value added remains relatively unknown in the literature. This represents a gap that this current study aims to fill, as agriculture plays a significant role in China's national economy, making it difficult to disregard the spillovers of climate change on the country's economy. Therefore, it is crucial to consider how global warming is affecting China's agriculture. The primary purpose of this article is to examine the effects of climate change on China's agricultural output.

This study is arranged in this format: Section One contains the introductory aspect of the study. The review of relevant studies is presented in Section 2. The third section of the study consists of methodology, and the final section presents the discussion of results and policy recommendations of the study.

2. LITERATURE REVIEW

Assessing the impacts of climate and other variables on agricultural productivity.

Chandio et al. (2020) used Autoregressive Distributed Lag data spanning the years 1982 to 2014 to analyze the impacts of climate change on China's agricultural production. According to the study's findings, CO2 emissions have a considerable short- and long-term interference with agricultural productivity, while rainfall and temperature demonstrated an adverse impact on it. Additionally, both a long-term and short-term examination shows that energy consumption, fertilizer use, and land acreage all contribute to increased agricultural output.

In five different spheres, such as agricultural management, agricultural pests and diseases, agricultural production potential, agricultural planting structure and structural architecture, and agricultural ecology, Liu (2022) investigated the outcomes of global warming on the output of farming activities in China. It was established from the study that there was an inverse relationship between farming activities and global warming. Rahim and Puay (2017) utilized the vector error correction model (ECM) to assess the nexus between Malaysia's economic growth and climate change between 1983 and 2013. It was reported from the study that arable land, precipitation, temperature, and GDP all had a long-run convergence. Additionally, climate, GDP, and arable land were all causally related in one direction.

Alam (2013) used annual data collection between 1971 and 2011 to investigate the responses of agricultural output to climate change and economic growth over the long term. The author applied ARDL modeling and ECM-based methodologies to estimate the relationship between CO2 emissions, agricultural output, and economic growth from both short- and long-term perspectives. Findings from the study indicated that climate change and agricultural output have a strong connection.

Consequently, the impact of CO2 emissions on grain production in Ghana was examined by Asuamah-Yeboah, Amponsah, and Hoggar (2015) using the ARDL approach. Data from Ghana's time series, collected between 1961 and 2010, were utilized in the empirical study. The results indicated that while there is a strong, positive, and persistent correlation between grain output and income, there is only a marginal yet significant correlation between cereal production and CO2 emissions.

In their research on CO2 emissions and agricultural output in Pakistan, Rehman, Ozturk, and Zhang (2019) used an ARDL limits testing approach. The study's findings showed that while increasing seed dispersal and overall food grains had a negative correlation with CO2 emissions in Pakistan, cropped area, energy consumption, fertilizer offtake, GDP per capita, and water accessibility did not. We are unaware of any empirical studies on how climate change affects agricultural products in China. This study aims to examine the immediate and long-term relationships between agricultural output and climate change-related factors in the context of China. In Turkey, rainfall has a significant and positive impact on agricultural outputs; however, temperature has a detrimental effect, according to a study by Dumrul and Kilicaslan (2017) which employed the ARDL bounds testing approach as an estimation technique.

To assess how the impacts of change in climate change interfere with agricultural products in Asia from 1980 to 2016, Ozdemir (2022) employed dynamic and asymmetric panel ARDL. Despite the data indicating a long-term link between agricultural output and the causes of climate change, only the emission of CO2 may have a short-term influence on agricultural outputs. Consequently, the effect is beneficial in the short term; it switches to an inverse direction in the long term, supporting the hypothesis that atmospheric carbon fertilization may, to some extent, have a direct influence on agricultural products. This article uses the GTAP model to analyze the effects of climatic factors on China's trade in agriculture from the viewpoints of agricultural output, trade policy, supply, and substitution of energy. The objective is to clarify the connection between climate change and China's agricultural trade. (1) From a general perspective, risks associated with trade policy negatively influence China's import trade, whereas risks related to production supply and energy substitution have a favorable impact. (2) Due to concerns over production and supply caused by climate change, the number of imports has increased to varying degrees across several economic sectors.

Australia, Canada, and the United States are the primary sources of the growing import trade. This article examines the effects of climate change on China's agricultural trade from the perspectives of energy substitution, agricultural output and supply, and trade policy using the GTAP model.

Previous authors in the study of fuel substitution possibilities and technical progress in Pakistan's agriculture sector have sought to explore the potential for substituting fuels and technical advancements across labor, capital, and energy consumption using a trans-log production function.

In another development, Raza, Wu, and Lin (2023a) employed the logarithmic mean Divisia index method to examine the linkage between the trends in agricultural energy consumption and its decoupling from economic advancement in Pakistan between 1981 and 2020. The following strategic variables, such as land use, economic output, agricultural energy intensity, and labor intensity, were assessed. The findings established the existence of a significant linkage between economic advancement and energy consumption, with economic output being the major factor that propelled the rise in energy usage. Chen and Gong (2021) in their study, the researchers applied a country-panel dataset spanning 35 years to estimate the influence of climate change on farming and the mechanisms of longer-term adaptation in China. Findings revealed that, in the short term, extreme heat negatively affects China's agricultural TFP and input utilization, consequently leading to decreased agricultural output measured by yield. However, longer-term adaptation has alleviated 37.9% of the short-term effects of extreme heat exposure on TFP, with climate adaptation moderating agricultural output loss more significantly through flexible adjustments in labor, fertilizer, and machinery over time. Despite observed climate adaptation, projections under future climate change scenarios suggest substantial agricultural losses in China.

Raza, Zhongpan, and Pengju (2023b) delved into the primary carbon-emitting factors in agriculture, stemming from human activities such as transportation, land use, crop diversity, distribution, and consumption across various crops. Its aim was to outline a strategy for reducing carbon emissions in the food supply chain and shaping food policy. By integrating renewable energy technologies (RETs) and sustainable energy sources into agricultural practices, emissions can be mitigated. Key concerns addressed include CO_2 emissions across the food supply chain, agricultural activities, energy consumption, and the transition to sustainable farming practices. The analysis underscores the potential of RETs and mitigation strategies in reducing carbon emissions, contingent upon farm type and energy utilization. The study underscores the need for Pakistan to adopt efficient agricultural practices, emphasizing water management, energy efficiency, and modern machinery to enhance productivity and sustainability.

In 2015 and 2016, China experienced significant capital outflows, impacting economic stability. Hence, assessing an acceptable range for cross-border capital flows became imperative to prevent adverse effects. Using a system dynamics simulation model, Ma (2023) analyzed China's current cross-border capital flow characteristics and proposed desirable ranges for the next decade. The results of the study suggested a preferred net capital inflow range for 2025 and 2030. To maintain economic stability, China should adopt managed capital account opening, supervising cross-border capital flows with key indicators. Policies involving exchange rates, monetary, fiscal, and foreign debt should regulate these flows. The goal is transitioning from defensive to active capital flow control, leveraging China's economic influence to benefit from global capital flows. In the context of China's agricultural productivity, managing cross-border capital flows becomes crucial in that effective supervision of capital flows enables policymakers to channel investments strategically into the agricultural sector, promoting innovation, efficiency, and sustainable practices.

3. METHODOLOGY

In examining the nexus between changes in climate and agricultural output in China, this study built on the empirical studies previously cited. These studies laid a foundation of the variables and measures of climate change and agricultural productivity, which was used in this study. They also provided knowledge of other factors that could possibly affect agricultural productivity, which were selectively used as control variables. To conduct its research, this study used secondary data from 1990 to 2020. The selection of this period was primarily driven by data availability for all variables of interest. World Development Indicator (WDI) data on CO_2 emissions, agricultural output, trade openness, access to electricity, access to the internet, and changes in rainfall patterns were obtained. For data analysis, E-Views software was employed.

3.1. Model Specification

3.1.1. Model 1

In specifying the model for this study, vital insight was drawn from these works. The general model to achieve the objective of the study can be written as follows:

$$AO = F\,(CRP, CO2) \qquad (1)$$

To improve the robustness of the model and results, control variables were included in the original Model 1. The control variables included were access to electricity (ATE), access to the internet (ATI), and trade openness (TO). Hence, the linear form of the model can be written as:

$$LnAO_t = \beta_1 + \beta_2\, LnCO2_t + \beta_3\, LnCRP_t + \beta_4\, LnATE_t + \beta_5\, LnATI_t + \beta_6 TO + \mu_i \qquad (2)$$

Where;

AVA= Agricultural value added as a percentage of GDP, measured in percentage.

CO_2= Carbon Emissions.

CRP = Change in rainfall patterns. This is measured by average precipitation in depth in mm per year.

ATE= Access to electricity as a percentage of the population.

ATI= Access to internet as a percentage of the population.

TO = Trade Openness. Consequently, the detailed description of the utilized variables is contained in the table below.

β_1 = Intercept.

$\beta_2 - \beta_5$ = Parameters of explanatory variables. It should be emphasized that β_2 and β_4 are expected to have a negative sign, while β_3 and β_5 are expected to have a positive sign.

μ_i = Stochastic or error term.

t = 1990- 2020.

Table 1. Description of variables for the effect of climate change and agricultural output in China.

Variables	Description	Unit	Source	Apriori expectation
CO_2	CO_2 emissions, primarily from human activities such as fossil fuel combustion, significantly impact Earth's climate by trapping heat in the atmosphere.	Metric tons per capita	WDI (2022)	Negative
Change in rainfall patterns	Change in rainfall patterns entails shifts in precipitation distribution, intensity, and timing, impacting weather events and seasonal variations.	Average precipitation in depth (mm per year)	WDI (2022)	Positive
Access to electricity	Access to electricity denotes the ability to connect and utilize electrical power, which is crucial for development and societal well-being.	% of Population	WDI (2022)	Positive
Access to internet	Access to the internet is the ability of individuals and organizations to connect to the global network, facilitating information access, communication, and online services.	Individuals using the Internet (% of population)	WDI (2022)	Positive
Trade openness	Trade openness gauges a country's engagement in international trade, measuring the extent of market openness to foreign goods and services.	Trade (% of GDP)	WDI (2022)	Positive
Agricultural value added	Agricultural value-added measures the net economic contribution of the agricultural sector by subtracting input costs from total outputs.	% of GDP	WDI (2022)	Dependent variable

Table 1 shows the description of the various variables of interest and how these variables are measured in this study.

4. RESULT AND DISCUSSION

4.1. Descriptive Statistics of Annual Data Series (1990-2020)

Descriptive statistics offer numerical summaries that encapsulate and delineate the principal attributes of a dataset. They provide valuable insights into the behaviors of the variables under study.

Table 2. Descriptive statistics result.

	ATE	ATI	AVA	CO2	CRP	TO
Mean	98.2	21.6	13.2	4.65	645	41.6
Median	97.9	8.52	11.6	4.46	645	38.5
Maximum	100	70.0	26.5	7.75	646	64.4
Minimum	96.7	0.00	7.04	1.91	645	22.1
Std. Dev.	1.37	23.8	5.41	2.18	0.24	11.5
Skewness	0.21	0.62	0.77	0.14	3.54	0.40
Kurtosis	1.26	1.84	2.55	1.33	13.5	2.36
Jarque-Bera	4.11	3.78	3.36	3.69	209	1.39
Probability	0.12	0.15	0.18	0.15	0.00	0.49
Sum	304	669	411	144	199	128
Sum Sq. Dev.	57.1	1709	880	142	1.87	398
Observations	31	31	31	31	31	31

The descriptive statistics presented in Table 2 is a comprehensive glimpse unveiling the characteristics of various key variables that underpin the complex relationship between environmental factors and agricultural performance.

One of the variables considered is the Access to Electricity (ATE). With a mean value of 98.30%, it is evident that a vast majority of China's population has access to electricity.

This high level of access underscores the importance of energy infrastructure in driving agricultural productivity and rural development. However, the slight variability indicated by the standard deviation of 1.38% hints at potential disparities in access across China, necessitating targeted interventions to ensure equitable distribution of energy resources. Access to the internet shows a different result, with a mean value of 21.60%, indicating that internet access is less widespread compared to electricity consumption.

The range from 0.00% to 70.05% highlights major disparities in internet access levels across various locations and demographics. The high standard deviation of 23.87% attests to significant variability in internet access, suggesting a digital divide that could impede the dissemination of agricultural information and technology adoption in specific regions. Furthermore, agricultural value added (AVA) has a mean value of 13.27%, signifying that agriculture substantially contributes to China's GDP. Meanwhile, carbon emissions (CO2) depict a critical environmental dimension of agricultural production. The mean value of 4.66 indicates the average quantum of carbon emissions, reflecting the sector's environmental footprint. The range from 1.91 to 7.76 shows variations in emissions intensity among different agricultural activities and regions.

Moreover, change in rainfall patterns (CRP) provides vital information about the influence of climate change on the dynamics of precipitation. The mean value of 645.1 mm/year indicates that rainfall patterns are affected by major fluctuations. Finally, trade openness has a mean value of 41.6, which points to the Chinese economy's integration into global trade dynamics. It is important to highlight that enhancing trade openness can catalyze market access, stimulate the transfer of technology, and promote agricultural growth.

Table 3. Unit root test.

Variable	Augmented Dickey-Fuller						
	Level	Probability	1st difference	Probability	2nd difference	Probability	Order of variable
CO2	-0.55	0.86	-2.49	0.12	-6.19	0.00	I(2)
CRP	-5.68	0.00	-9.00	0.00	-6.05	0.00	I(0)
AVA	-4.89	0.00	-3.36	0.02	-4.69	0.00	I(0)
ATE	-0.70	0.83	-2.57	0.10	-7.56	0.00	I(2)
TO	-1.77	0.38	-4.09	0.00	-8.13	0.00	I(1)
ATI	0.87	0.99	-1.16	0.67	-5.16	0.00	I(2)

4.1.1. Unit Root Test

The unit root test results presented in Table 3 offer crucial insights into the stationarity properties of the variables under consideration, shedding light on their behavior over time. Stationarity is a fundamental concept in time series analysis, indicating whether a series exhibits stable statistical properties or if it evolves over time in a systematic manner. The ADF test is a widely used method for assessing stationarity by examining the presence of unit roots in a time series.

Carbon Emissions (CO2) are a key variable in the context of climate change and environmental sustainability. The ADF statistic for CO2 at the level is -0.559118 with a probability of 0.8649, indicating non-significance. However, after differencing once, the ADF statistic becomes -2.495132 with a probability of 0.1269, suggesting significance at the 10% level. Further differencing to the second order yields an ADF statistic of -6.199942 with a probability of 0.0000, indicating significance at a high confidence level. Therefore, CO2 is integrated of order 2, denoted as I(2), suggesting that it becomes stationary after differencing twice. This implies that carbon emissions exhibit a certain level of persistence in their behavior, with changes occurring gradually over time.

In contrast, the Change in Rainfall Patterns (CRP) demonstrates different characteristics. The Augmented Dickey-Fuller (ADF) statistic for CRP at the level is -5.683986 with a probability of 0.0001, indicating significance. This suggests that CRP is already stationary in its original form, denoted as I(0), as it does not require differencing to achieve stationarity. This indicates that rainfall patterns in China exhibit stable statistical properties, without significant trends or systematic changes over time. The ADF statistic for Agricultural Value Added (AVA) at the level is -4.890979 with a probability of 0.0004, indicating significance. However, after differencing once, the ADF statistic becomes -3.362197 with a probability of 0.0210, suggesting significance at the 5% level. Further differencing to the second order yields an ADF statistic of -4.690297 with a probability of 0.0009, indicating significance at a high confidence level.

Therefore, AVA is integrated of order 2, denoted as I(2), similar to CO2. This suggests that agricultural value added also exhibits persistence in its behavior, with changes occurring gradually and requiring multiple differencing to achieve stationarity. Access to Electricity (ATE) and Access to Internet (ATI) are variables reflecting technological access and infrastructure. ATE demonstrates similar characteristics to CO2 and AVA, requiring second-order differencing to achieve stationarity. However, the data for ATI is not available in the table, preventing a detailed analysis of its stationarity properties.

The ADF statistic for TO at the level is -1.775430 with a probability of 0.3846, indicating non-significance. However, after differencing once, the ADF statistic becomes -4.094090 with a probability of 0.0036, suggesting significance at the 1% level. Further differencing to the first order yields an ADF statistic of -8.132617 with a probability of 0.0000, indicating significance at a high confidence level. Therefore, TO is integrated of order 1, denoted as I(1), indicating that it becomes stationary after differencing once.

Table 4. Correlation matrix.

Correlation probability	ATE	ATI	AVA	CO_2	CRP	TO
ATE	1.00					

ATI	0.95	1.00				
	0.00	-----				
AVA	-0.85	-0.80	1.00			
	0.00	0.00	-----			
CO_2	0.99	0.95	-0.90	1.00		
	0.00	0.00	0.00	-----		
CRP	-0.11	-0.15	0.07	-0.09	1.00	
	0.53	0.41	0.68	0.62	-----	
TO	0.32	0.12	-0.59	0.37	0.14	1.00
	0.07	0.48	0.00	0.03	0.42	-----

4.2. Correlation Analysis

The correlation matrix presented in Table 4 is a comprehensive display of the interrelationships between various key variables related to agricultural productivity and environmental factors in China. The strong negative correlation between agricultural value added (AVA) and carbon emissions (CO_2), with a coefficient of -0.900504, indicates that as agricultural outputs increase, carbon emissions tend to decrease. In this type of inverse relationship, it is important to state that sustainable agricultural practices could mitigate environmental impacts, such as greenhouse gas emissions, while also promoting food security. Meanwhile, changes in rainfall patterns (CRP) possess weak correlations with agricultural value added (AVA) alongside other variables, indicating that changes in rainfall patterns have no significant linear relationships with agricultural value added (AVA), access to electricity, access to the internet, carbon emissions, or trade openness.

Table 5. Regression analysis result.

Panel fully modified least squares (DOLS) Dependent variable: LNAO (Natural log of agricultural output)			
Variables	**Coefficient**	**t-statistic**	**Probability**
LNATI	-0.056	-2.55	0.06
LNATE	22.8	3.10	0.03
$LNCO_2$	-1.23	-3.53	0.02
LNCRP	-108	-1.20	0.29
LNTO	0.58	6.08	0.00
C	600	1.02	0.36
R-squared	0.99	Mean dependent var	0.99
Adjusted R-squared	0.98	S.D. dependent var	0.98
S.E. of regression	0.03	Sum squared residuals	0.00
Long-run variance	0.00		

4.3. Impact of Climate Change on Agricultural Output in China (1990-2021)

Table 5 presents the estimated Dynamic Ordinary Least Squares (DOLS) results, which provide valuable insights into the relationship between agricultural outputs (LNAO) and climate change in China. Understanding these results is essential for researchers, policymakers, and stakeholders aiming to promote agricultural development without compromising environmental sustainability. Firstly, the results reveal that access to the internet (LNATI) has a negative coefficient of -0.056014, with statistical significance at the 10% level. This may be due to limited or non-utilization of internet facilities in powering agricultural activities in the country over time. Conversely, access to electricity (LNATE) shows a positive and statistically significant coefficient of 22.86573, with a probability of 0.0360. This indicates that increased access to electricity correlates with higher agricultural outputs, emphasizing the importance of reliable energy access in promoting agricultural productivity, mechanization, and value chain development. Additionally, carbon emissions (LNCO2) demonstrate a negative and statistically significant relationship with agricultural outputs. This suggests that higher levels of carbon emissions lead to reduced agricultural productivity, likely due to soil degradation and extreme weather events caused by increased emissions, which negatively impact crop yields and overall agricultural performance.

The estimated coefficient of change in rainfall patterns (LNCRP) is negative, though not statistically significant. This indicates a potential detrimental effect of changes in rainfall patterns on agricultural output. In the short run, changes in rainfall patterns may not pose a significant detrimental effect on agricultural output, but it is important to stress the potential long-term effects of climate variability on agricultural outputs. Trade openness (LNTO) and agricultural outputs have both positive and statistically significant relationships, suggesting that higher levels of trade openness relate to a rise in agricultural outputs. This attests to the crucial role international trade plays in enhancing agricultural development. The R-squared and adjusted R-squared values in the DOLS regression model are 0.998014 and 0.988086, respectively. These values indicate that approximately 99.8% and 98.8% of the variation in the natural logarithm of agricultural output (LNAO) can be explained by the independent variables included in the model. Such high values suggest an excellent fit of the model to the data, indicating that the chosen explanatory variables, access to internet (LNATI), access to electricity (LNATE), carbon emissions (LNCO2), change in rainfall patterns (LNRCRP), and trade openness (LNTO), collectively account for a significant portion of the variation in agricultural output.

5. CONCLUSION

The focus of this study is on the investigation of the connection between climate change and agricultural outputs in China from 1990 to 2021. Descriptive statistics were employed to evaluate the validity of the normal distribution of the dataset, and the ADF test was run to determine the degree of stationarity in the dataset. Subsequently, the analysis of the influence of climate change on Chinese agricultural outputs was carried out using dynamic ordinary least squares. Therefore, this study presents the following findings: while access to the internet (LNATI) shows a non-significant negative relationship, access to electricity (LNATE) positively impacts output. Higher carbon emissions (LNCO2) are linked to decreased agricultural productivity, emphasizing the importance of environmental sustainability. Changes in rainfall patterns (LNCRP) show a negative trend without statistical significance, suggesting potential long-term implications. However, trade openness (LNTO) demonstrates a significant positive correlation, highlighting the benefits of international trade.

6. POLICY RECOMMENDATION

Based on the findings of this study, this study recommends that the Chinese government, considering the significant impact of changes in rainfall patterns (CRP) and carbon emissions (CO_2) on agricultural outputs in China, policymakers should focus on strategies that promote climate resilience measures, which are essential to assist stakeholders in the farming business to adapt to erratic precipitation patterns. In the same vein, implementing adaptive agricultural practices such as investing in drought-resistant crop varieties and agricultural technologies, conservation tillage, crop rotation, and agroforestry, as well as improving irrigation systems and water-saving technologies like drip irrigation, is crucial. Also, reducing carbon emissions from agricultural activities cannot be undermined in ensuring environmental sustainability in the country. This can be achieved through policies promoting sustainable farming practices like reducing tillage, cover cropping, and integrated pest management, transitioning to renewable energy sources such as solar and wind power for energy on the farm, and enhancing carbon sequestration efforts. Moreover, policies and programs to foster research and innovation in climate-smart agriculture are very paramount in developing effective solutions to climate change threats in the country. By integrating these strategies into agricultural policy frameworks and fostering policy coordination, China can enhance the resilience of its agricultural sector and promote sustainable development in the face of climate change.

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