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Do Climate Changes influence the Agriculture Productivity in Pakistan? Empirical Evidence from ARDL Technique

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Abstract

Agriculture Productivity is an important measure of the agricultural performance in developing countries, which measures the quantity of output that can be produced from a given quantity of inputs. However, agriculture output is affected by the rainfall and temperature. In the literature on emerging economies, rainfall and temperature are found to have a significant impact on the agriculture productivity in different regions of the world. The goal of this study is to assess the impact of rainfall and temperature variations, as a result of climate change, on Pakistan's agriculture output. Time series data from 1984 to 2019 is used to investigate this issue. An Autoregressive Distributed Lag (ARDL) model with Bound Testing Cointegration and Error Correction Model (ECM) are used to analyze the relationship between the variables of interest. Unit Root tests were used to check the stationarity of time series data which revealed that some variables are stationary I (0) while others are integrated at level 1. The findings of the study show that temperature increase has a positive and significant impact on agriculture productivity, both in the short and long run. Moreover, rainfall has a negative and significant impact on agriculture productivity in the short and long-run. The stability tests have confirmed the stability of the econometric model.

Keywords: Agriculture productivity, Pakistan, Rainfall, Temperature, ARDL

JEL Classification: O13, Q1, Q15

1. Introduction

Pakistan's second-largest economic sector is agriculture, which generates 19.2% of the nation's GDP and employs half of its workforce, around 45% (Pakistan Economy Survey, 2020). Over 65% of the population is engaged in the agriculture sector (Shah et al., 2020). Pakistan is ranked 28th among the nations severely impacted by climate change, and 22 of the 28 countries are in Africa (IPCC,2021). Studies have found that Climate Change is lowering the agriculture

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production in the country (Ullah, 2017). Farmers in drought and arid areas, as well as those who live in mountainous and coastal regions, are particularly vulnerable to climate change and natural disasters. Agriculture is impacted by climate change by reducing the growing season, increasing heat stress during important reproductive times, and increasing crop water requirements (Misra, 2014). In dry and semi-arid conditions, these factors cause a yield loss of between 6-18%.

Agriculture is the most important source of income, revenue and is the backbone of an emerging economy like Pakistan, therefore increasing agricultural productivity is crucial (Ahmad and Heng, 2012; Aslam, 2016; Awan and Mukhtiar, 2020; Shah et al., 2020). It improves the living standard of human beings, provides food and employment in rural regions, contributes to the country's overall economic growth, and reduces labor migration rates (Shah et al., 2020). Rapidly increasing population has increased the demand for agricultural output since the 20th century. It assists farmers in revising their input strategies to boost productivity and fulfilling the fast-growing demand (Koondhar, Li, Wang, Bold and Kong, 2020).

Climate change influences the productivity which is a major challenge for economic growth because the bulk of the country's population lives in rural areas and is involved in agricultural and non-agricultural related activities. Farmers are always looking for new strategies to adapt to changes in weather and climate. However, the scale required for farmers to design and execute resilience methods has increased as a result of global climate change. One strategy to prevent climate change risks and maintain livelihoods and national food security is to adapt to the changes in the climate. Adaptation techniques vary in kind and extent from region to region, and socio-economic and agro-ecological conditions are always changing. As a result, weather and climate change have an impact on food production. In order to meet the demands of humans, which are predicted to number roughly 10 billion by 2100, it is necessary to analyze the impact of global climate change on agriculture (Wit et al., 2019; Keyzer et al., 2002).

Agriculture productivity is affected by climate changes (Chandio, Ozturk, Akram, Ahmad, and Mirani, 2020) through changes in rainfall patterns, temperature variations (Misra, 2014), changes in planting time and water availability (Deshmukh and Lunge, 2012). Climate change has significantly impacted the agricultural productivity, particularly in emerging nations (IPCC,2021). Climate change influences the productivity of agricultural commodities and the country's economic stability, altering the supply and demand balance, profitability, trade, and pricing of commodities.

In recent decades, climate change is found to have a considerable influence on productivity, particularly in low-income nations. According to individuals who have not made any attempts, the most significant barriers to rural people's adaptation to projected climate change are a lack of information, land access, and institutional agricultural finance. Climate change has prompted tremendous concern since it has the potential to bring societal disasters. As a result, the first step in combating climate change is to analyze economic vulnerability (Wang et al., 2014).

The aim of this study is to empirically assess the impact of rainfall and temperature on the total agriculture productivity of Pakistan from 1990 to 2019, by utilizing the ARDL Model with bound testing technique to cointegration and the Error Correction Model. This study investigates the influence of temperature and rainfall (as climate change variables) on the agricultural output of Pakistan. It contributes to the existing literature by examining the effect of rainfall and temperature on agriculture productivity in Pakistan, which is the need of the hour.

The remaining portions of the study are organized as follows: Section 2 reviews the previous studies while, section 3 discusses the model of the study, section 4 discusses the methodology, section 5 presents the empirical findings and section 6 concludes the study.

2. Review of Literature

Pakistan is the world's fifth most populated country and uses just 8% of the world's agricultural area (Pakistan Economic Survey, 2020). Pakistan Government’s long-term aim is to provide food security for the country's rapidly rising population. Due to population increase and economic development, the country's food consumption continues to rise, while arable land and other productive resources are decreasing as agricultural productivity declines as a result of climate change. Other elements, such as social, cultural, institutional, and political aspects, may help or impede the process of adaptation. The final section delves into the various adaptation scales. Climate adaptable capacities and adaptation tactics range in scale from a single plot to a whole farm and national and global levels. As a result, the scale analysis should be considered while evaluating a system's adaptive capability and relevant adaptation approaches. (Dumrul and Kilicaslan, 2017; Vincent, 2007).

Several researchers (Abbas, Muhtaraom, Badriyah and Kadir, 2020; Abukari, Oztoronci and Veziroglu, 2016; Ademola, 2019; Brown and Iyabode, 2020; Kakar, Kiani and Baig, 2016) have recently explored the influence of climate change agriculture output using various econometric methodologies. Rashid, Husnain, Shakoor and Husnain (2020) empirically found the influence of climate fluctuations on Pakistan's cotton crop and found out that the negative effect of increasing the minimum temperature outweighs the beneficial effect of increasing the maximum temperature. Thus, crop productivity must be protected from increases in minimum temperature. It is suggested, based on the empirical evidence that productivity varieties that are more resistant to temperature fluctuations be introduced.

Chandio, Ozturk, Akram, Ahmad, and Mirani (2020) empirically investigated the impact of climate changes and carbon dioxide emissions on cereal crops for Turkey and concluded that rainfall, energy consumption and labor help to boost cereal productivity. Carbon dioxide emissions and other greenhouse gases raise global temperatures, causing substantial environmental impacts. The agricultural productivity decreases as a result of substantial environmental impacts. Carbon dioxide emissions are a growing concern globally these days, and Turkey is taking measures to minimize CO_2 emissions to improve agricultural and economic growth.

Further Chandio, Jiang, Rehman and Rauf (2020) studied the effects of weather fluctuations on agriculture and economic growth in China . Their empirical findings showed that rainfall and temperature harmed Agriculture output in the long- run, while CO_2, land area, and fertilizer consumption increase the agricultural productivity. However, this study relied on a national data collection, which is unable to provide the true picture of rainfall and temperature impact on productivity. To have a deeper understanding of the country and regional inequalities, area or zone-specific studies should be conducted.

Shah et al. (2020) found out the impact of rainfall, spray, average humidity, and temperature on rice productivity using the Multiple Linear Regression Model. Their findings concluded that rainfall, temperature, and humidity had not affected rice productivity. The spray adversely affects the supply of labor positively impacted agriculture productivity. As a result, it would be beneficial to the government to reduce subsidies and imports of rice from other nations to increase output and ensure the survival of local rice producers.

Lachaud and Ureta (2020) in Latin America studied the influence of temperature and precipitation on agriculture production and found out that climatic changes had a negative impact on agricultural productivity. Kilicarslan and Dumrul (2017) performed empirical research to assess climate change's influence on agriculture production and its long-run influence on economic growth. The findings demonstrated that increases in precipitation significantly impact agricultural GDP, but temperature increases negatively impact it. Technological development is crucial in increasing the steady-state level of climatically adjusted total factor production. A study from Malaysia analyzed the association between temperature, precipitation and GDP on agriculture productivity using the Johansen Cointegration and the vector error correction model (Rahim and Puay, 2017). The findings concluded that GDP, precipitation, temperature, and arable land had a long-run cointegration connection.

Ahmed and Schmitz (2011) investigated rainfall and temperature's impact on agriculture productivity and the results of the study found out that rainfall and temperature adversely impacted the crop productivity and agriculture growth. Pakistan's government should develop programs to compensate farmers for their losses. The introduction of new cropping patterns, heat and drought tolerant crop types, and water collection, especially in years where weather patterns indicate water shortages from precipitation, are all examples of the new adaptation techniques.

A previous study explores the influence of climate change on one selected crop from agriculture sector in different provinces by using different techniques and by adding control variables (M. Ahmad et al., 2014; Ahmed and Schmitz, 2011a; Chandio, Magsi, et al., 2020; Siddiqui et al., 2012). However, this study contributed by using specific climatic variables (rainfall and temperature) that influences agriculture productivity. According to Godfray and Garnett (2014), we cannot separate climate changes from agriculture productivity. This study is unique in the sense that it only focuses on the rainfall and temperature variables without including other control variables as the previous studies have done. It is needed to conduct the latest study to explore the effect of climate changes on the agriculture productivity of Pakistan. This study fills this gap by examining the agriculture productivity in Pakistan by including impact of the rainfall and temperature on agriculture productivity in Pakistan. By adding these variables, this study examines all aspects of climate on productivity.

3. Research Methodology and Model

3.1 Model

In the theory of production, the production function describes how firms combine various inputs (resources) to produce output (goods) (Koutsoyiannis, 1979). Production functions define the relationship between inputs and outputs (Thirlwall, 1994). Over time, production functions have been refined to cover several factors rather than the fundamental, widespread land, labor, and capital contributions. The production function approach primarily investigates climate changes (rainfall and temperature) (Dormady et al., 2017). According to Rashid, Husnain, Shakoor and Husnain (2020), this method analyzes climatic and environmental changes that directly affect agricultural productivity and considers farmers' reactions to local climate adaptations. This approach estimates the impact of climate variations directly affecting productivity and assesses indirect input substitution by incorporating different activities and other likely climate adoption practices.

This study used the Production function approach to examine factors that influence agriculture productivity. According to this theory, agriculture output is correlated with traditional and modern factors in agriculture. The choice of production function is practical because it is easy to specify and interpret. Aside from that, the application of the production function has been proven to apply in similar scenarios to this one (Kakar, Kiani and Baig, 2016; Khaledi and Shirazi, 2013; Sheng and Chancellor, 2019). The present study employs the same theoretical framework as the previous one. The study used the following proposed model

$$TAP_t = f(\, RF_t, TEMP_t) \qquad (1)$$

In equation (1), TAP shows the agriculture productivity, which is the function of (RF) rainfall, and (TEMP) temperature. The t represents the time for all the variables used in the study.

The economic and functional form is converted into the econometric model for empirical analysis. The values of parameters, which are the coefficients of the mathematical form of economic connections, are obtained using the econometric model. Econometric models are statistical approaches that support the explanation of economic phenomena. The model incorporates all of the fundamental parameters needed to describe the phenomenon, and the other variables are categorized as "disturbances," or error terms (Klein, 1947).

The econometric model is estimated and evaluated on the observed set of data. The econometric technique is applied for forecasting and policy development, which are critical components of every policy decision. According to Gujarati, Porter and Gunasekar (2012), the econometric form of the above functional form is

$$TAP_t = \beta_o + \beta_1 RF_t + \beta_2 TEMP_t + \varepsilon_t \qquad (2)$$

Where βo is the constant, β_1 and β_2 is the coefficient, t is representing the time period. TAP_t shows the total agriculture productivity at time t, RF_t is the rainfall at time t while the $TEMP_t$ is temperature at time t. ε_t is a random disturbance term,

In order to estimate our model, we used a time-series dataset for Pakistan spanning the years 1984 to 2018. Total agriculture productivity measures the quantity of output produced with many inputs. Several indicators have been used to find agriculture products, such as total factor productivity (TFP), agriculture value-added, and agriculture growth share of gross domestic product (percentage of GDP) (Abukari et al., 2016; Anik et al., 2017). The study used the crop production index as proxy for total agriculture productivity and the data of the index has taken from the World Development Index. This index had contained all the crops of Pakistan (Kakar, Kiani and Baig, 2016) and is taken as a dependent variable in the study.

All crops needed a minimum amount of water. The most important source of water is rainfall. It affects total agriculture productivity. At the same time, a regular rainfall pattern is usually significant. However, too much or too little rainfall could harm the crops. According to theory, rainfall has positive and negative impacts (Kakar, Kiani and Baig, 2016; Rashid, Husnain, Shakoor and Husnain, 2020). We measured the annual average rainfall in millimeters and utilized the data from World Development Indicator. When it comes to crop ripening, temperature is crucial. Temperature has an impact on plant growth and development. Inputs such as light, water, and other factors also affect how plants develop, which in turn affects crop yields. These elements must be perfectly balanced. Temperature affects plant and agricultural productivity in both the short and long term (How Air Temperature Affects Plants, 2021). Temperature has a significant effect on production, according to theory (Rashid, Husnain, Shakoor and Husnain, 2020). We used temperature data from the World Development Indicator and measured temperature in Celsius.

3.2 Research Methodology

Most empirical and theoretical research in economics has focused on an econometric analysis of long-term connections. The Autoregressive Distributed Lag model with Bound Cointegration Approach is used to find the relationship between study variables (Pesaran and Shin, 1999). The econometric equation of the model used in this study possesses the following ARDL model with bound testing cointegration technique equation.

$$TAP_t = \beta_o + \beta_1 ATAP_{t-1} + \beta_2 RF_t + \beta_3 RF_{t-1} + \beta_4 TEMP_t + \beta_5 TEMP_{t-1} + \varepsilon_t \quad (3)$$

The coefficients of the long-run dynamic with the past time $_{t-1}$ range from β_1 to β_5. This estimation approach has many benefits. The first is that an ARDL approach does not require all variables to be stationary at the same order. An Autoregressive Distributed bound testing cointegration approach has been used (Nkoro and Uko, 2016) when variables are integrated at different orders (Kim and Choi, 2017). ARDL model has an advantage over the Engel Granger and Johansen cointegration approaches to check the cointegration. Engel Granger cointegration approach is used when variables are stationary at 1(0), while Johansen cointegration approaches are used when all the variables are at the order of 1(1) (Engle and Granger, 1987; Johansen, 1988).

$$\Delta TAP_t = \beta_0 + \sum_{i=t}^{n} \Delta\beta_1 TAP_{t-1} + \sum_{i=t}^{n} \Delta\beta_2 RF_{t-1} + \sum_{i=t}^{n} \Delta\beta_3 TEMP_{t-1} + \beta_4 TAP_{t-1} + \beta_5 RF_{t-1} + \beta_6 TEMP_{t-1} + \varepsilon_t \quad (4)$$

From the above equation, $\boldsymbol{\beta_0}$ Indicates the intercept, n shows the number of lags, $\triangle$ represents the first difference.

To check the existence of long-run relationships among variables, the ARDL bounds test (test of cointegration) has been used. The value of F statistics is used to check the long-run relationship among the TAP, RF, TEMP (Pesaran et al., 2001). The hypothesis for finding the cointegration among the variables is as

H_0 = There is no long-term connection.

H_1 = There is long-term connection.

Dependent and independent variables exhibit a long-run association if the upper critical limit values are greater than the expected F statistics value at a 1%, 2%, 5%, and 10% significance level, we reject the null hypothesis. If F computed values were smaller than the upper critical bound, there would be no long-run connection.

The long-run coefficient can be found by following the ARDL equation.

$$TAP_t = \beta_0 + \sum_{i=t}^{n} \beta_1 TAP_{t-1} + \sum_{i=t}^{n} \beta_2 RF_{t-1} + \sum_{i=t}^{n} \beta_3 TEMP_{t-1} + \varepsilon_t \quad (5)$$

A long-term relationship is found between the variables, then the Error Correction Model (ECM) could estimate short-run relationships among variables. In that case, ECM shows how quickly the speed of adjustment converges shocks from short run to long run.

The following equation can find the short-run coefficient:

$$TAP_t = \beta_0 + \sum_{i=t}^{n} \Delta\beta_1 TAP_{t-1} + \sum_{i=t}^{n} \Delta\beta_2 RF_{t-1} + \sum_{i=t}^{n} \Delta\beta_3 TEMP_{t-1} + ECM_{t-1} + \varepsilon_t \quad (6)$$

ECM_{t-1} has shown the speed of adjustment and short-run effect.

The diagnostic test can estimate the consistency of the ARDL bound cointegration approach. For this purpose, to check the autocorrelation, Breusch-Godfrey Serial Correlation LM Test (serial correlation) is used. To find the heteroscedasticity problem, we use the Glejser test. Ramsey RESET test has been used to check the correctly specified functional form of the Model (Shrestha and Bhatta, 2018). The stability of the model has been checked by performing a stability test of recursive residuals. For the ARDL bound cointegration approach, CUSUM tests have been used (Caporale and Pittis, 2004; Sarkodie and Owusu, 2016). Model is stable if the series or graph is within the upper and lower critical line at a 5% significance level.

4. Empirical Findings

Table 1 displays the findings of descriptive statistics. Maximum and minimum values show that data has a minor variation (Kaliyadan and Kulkarni, 2019). All the variables have minimum dispersion from their mean. Rainfall is positively skewed. However, total agriculture productivity and temperature are negatively skewed. All the variables are platykurtic because kurtosis values less than 3. It has Confirmed no outlier in the data. The probability of the Jarque-Bera test has been used to check that data is normally distributed. The probability value of the Jarque-Bera of all the variables is greater than 5% in the following table, which indicates all variables is normally distributed. We can use data for further estimation.

Table 1: Result of Descriptive Analysis

Variables	TAP	RF	TEMP
Mean	95.97200	25.71407	20.57129
Median	98.80000	25.48808	20.65272
Maxi	120.6700	35.27298	21.41462
Mini	67.67000	15.98308	19.44474
Std. Dev.	17.11013	4.87208	0.505126
Skew	-0.080553	0.032281	-0.525559
Kurtosis	1.690193	2.208130	2.595925
Jarque-Bera	2.176939	0.789032	1.585157
Prob.	0.336732	0.674006	0.452676
Sum	2879.160	771.4222	617.1386
Sum Sq. Dev.	8489.936	688.3801	7.399425
Obs	30	30	30

Source: Author's calculations

The correlation metrics in Table 2 show that all independent variables correlate with the dependent variable total agriculture productivity. A positive correlation exists between temperature and total agriculture productivity. However, the correlation of rainfall and environmental changes with total agriculture productivity is negative.

Table 2: Result of Correlation Matrix

Correlation	TAP	RF	TEMP
TAP	1.000000		
RF	-0.046237	1.000000	
TEMP	0.147498	-0.122365	1.000000

Source: Author's calculations

The study employed time-series data; it is essential to test the indicators' unit root (order of integration) before proceeding with the estimating procedure. The critical value for unit root tests is 0.05. Series is stationary there is no unit root (rejects H_0) problem when the crucial value is lower than the computed value, and vice versa. Tables 3 and 4 shows that total agriculture productivity is stable at first difference 1 (1), On the other hand, rainfall and temperature have remained constant at level 1(0). All of the variables in this research have a distinct order of integration, as can be seen. In second order, none of the variables is integrated (2). As a consequence of the findings, it was determined that the Autoregressive Distributed lag (ARDL) Model with Bound Testing Cointegration Approach is an effective method for determining the link between dependent and explanatory variables.

Table 3: Result of ADF test for unit root

Variables	At 1(0)		At 1(1)		Integrated order
	Intercept	Trend and Intercept	Intercept	Trend and Intercept	
TAP	0.7353	0.1576	0.0200	0.0000	1(1)
RF	0.0002	0.0015	0.0000	0.0000	1(0)
TEMP	0.0038	0.0439	0.0016	0.0010	1(0)

Source: Author's calculations

Table 4: Result of PP test for unit root

Variables	At level		At first different		Integrated order
	Intercept	Trend and Intercept	Intercept	Trend and Intercept	
TAP	0.7917	0.0633	0.0000	0.0000	1(1)
RF	0.0002	0.0013	0.0000	0.0000	1(0)
TEMP	0.0060	0.0118	0.0000	0.0000	1(0)

Source: Author's calculations

The results of the ARDL model are affected by the lag duration. As a result, before implementing the ARDL, the lag duration requirements must be reviewed. It is tough to choose the ideal lag duration. The model's performance is affected by both too much and too little lag duration. Several tests have been performed to determine lag length criterion. However, in this study, the Akaike information criterion (AIC) was utilized, and two lag lengths were established and chosen for all of the variables listed in Table 5.

Results shown in Table 6 there is long-run association among the TAP, RF, and TEMP variables included in the model**.**

Table 5: Result of lag length Criteria

Lag	LogL	LR	FPE	AIC	SC	HQ
0	-714.6528	NA	9.13e+14	51.47520	51.76067	51.56247
1	-649.9987	96.98119	1.26e+14	49.42848	51.42679	50.03938
2	-582.4935	72.32705*	1.97e+13*	47.17810*	50.88925*	48.31264*

Table 6: Result of ARDL Bound Test

Test Statistic	Value	K	Significance.	I (0)	I (1)
F-statistic	8.197063	5	10%	2.08	3.00
			5%	2.39	3.38
			2.5%	2.7	3.73
			1%	3.06	4.15

Source: Author's calculations

Now, we can construct and analyze the long-run coefficients of the ARDL bound testing cointegration approach of the ARDL model. Before estimating the long-run results of the ARDL bound testing cointegration technique, a diagnostic test has been applied. Table 7 displays the results of diagnostic tests. The probability value of all the tests is greater than 5%, representing that no serial correlation in the model means the error term is uncorrelated with each variable. The model has no problem with heteroscedasticity. Ramsey RESET test has confirmed that the model's functional form is correctly specified with 0.44 probability. All the tests have confirmed the model's validity. Now we can estimate the long-run co-efficient of the ARDL bound testing cointegration approach.

Table 7: Result of Diagnostic Test

Diagnostic Test	F-statistic	Prob.
Breusch-Godfrey Serial Correlation LM Test	0.666109	0.5400
Heteroscedasticity Test: Glejser	0.821657	0.652
Ramsey RESET Test	0.624802	0.449

Source: Author's calculations

The long run results are shown in Table 8. Unfavorable weather patterns, such as severe rainfall, floods, and droughts, have adversely affected agricultural productivity. Higher rainfall decreases agriculture output. In Pakistan, severe climatic conditions result in a 20% drop in crop productivity (Aslam, 2016; Sattar, 2012). RF has an unpleasant effect on TAP. The result of these findings is similar to the study of (Ahmed and Schmitz, 2011; Chandio, Jiang, Rehman and Rauf, 2020, Mahmood et al., 2012). According to Rashid, Husnain, Shakoor and Husnain (2020), the relationship between temperature and productivity is positive and substantial. Because of its vertical tap root system, crops have good endurance for high temperatures. Temperature helps ripen the crops; it is an essential element and determinant of agriculture productivity. The result concluded that TEMP has a statistically significant impact; as the temperature increases, agriculture productivity growth also increases. The result of the study is identical to the (Mahmood, Ahmad, Hassan and Bakhsh, 2012; Rashid, Husnain, Shakoor and Husnain, 2020).

Table 8: Long-run Results

Variable	Co-effi	Std. Error	t-Statistic	Prob.
RF	-0.322995	0.079370	-4.069495	0.0023
TEMP	6.900508	1.395204	4.945876	0.0006
C	-220.7326	30.98235	-7.124462	0.0000

Source: Author's calculations

The short-run results in Table 9 show that a higher rainfall damages the crops, which results in a decrease in agriculture productivity. Rainfall has a negative and significant impact in the short run. This result has shown similar results with the study of (Ahmed and Schmitz, 2011; Chandio, Jiang, Rehman and Rauf, 2020; Mahmood et al., 2012). The temperature has an impact on agriculture productivity. It directly relates to productivity in the short run and increases productivity. This finding is like the finding of (Mahmood, Ahmad, Hassan and Bakhsh, 2012; Rashid, Husnain, Shakoor and Husnain, 2020).

The coefficient value CointEq (-1) is -0.908456, which is negative and significant and describes all the independent variables that impact the agriculture's productivity in Pakistan. The error correction model shows the speed of adjustment from short run to long run. The negative sign stated that the long-run association is established (Awan and Mukhtiar, 2020).

Table 9: Short-run results

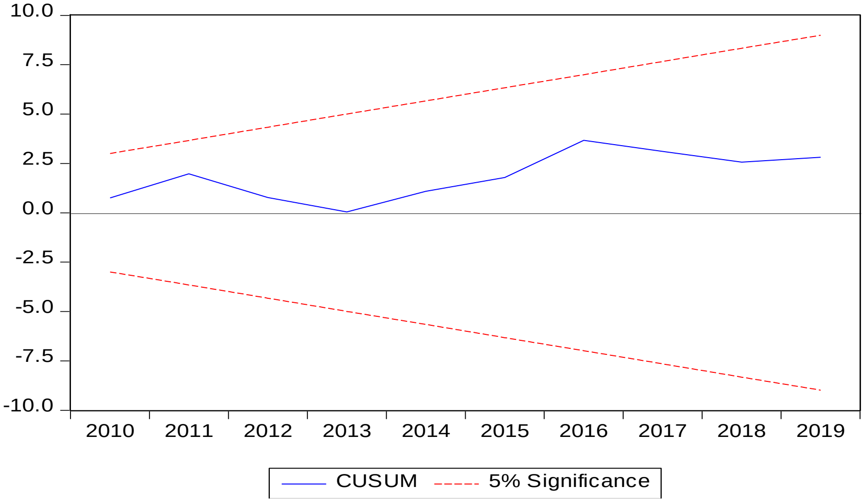
Variable	Co-effi	Std. Er	t-test	Prob.
D(RF)	-.251291	0.089596	-2.804713	0.0186
D(TEMP)	3.309980	0.862969	3.835572	0.0033
Coint Eq (-1) *	-.908456	0.118646	-7.6568616	0.0000
R^2	.660678			
Adj R^2	.448602			
D-W test	1.850793			

Source: Author's calculations

R^2 measures the goodness of fit of the model. The value of 0.66 means 66 % variation in total agriculture productivity (dependent variable) is explained by rainfall and temperature variables used in the model. The percentage of unexplained variation is 34%. This means that our explanatory variables account for a significant portion of the variation in agricultural productivity in Pakistan. The Durban Watson test lies between 1. 5 to 2. It means no autocorrelation problem in the model.

Figure 1 shows the CUSUM test's graph for the stability of ARDL Bound Testing for cointegration. This test has been used to check the stability of coefficients. The graph of CUSUM lies between the upper critical and lower critical bound at a 5 % level of significance and reveals that the model is stable.

Figure 1: Graph of CUSUM



5. Conclusion and Policy Recommendations

In Pakistan's economy, agriculture productivity plays a key role because of a number of reasons. First and foremost, this sector is crucial to meet the food needs of the entire nation. Secondly, it creates jobs for the people. Third, it has a significant impact on poverty reduction. Moreover, fourth, it increases the income of those who work in this industry. Fifth, it is a source of raw materials for the manufacturing industry. As a sixth benefit, it assists persons who move from rural areas to urban ones. Seven, the agriculture industry is a significant source of foreign exchange, which is utilized to acquire imported items such as machinery, capital equipment, and manufactured products. Last but not least, agriculture provides commodities and services to households, industry, and the global marketplace (Shah et al., 2020).

An attempt has been made in this study to investigate the influence of climate change on Pakistan's agricultural productivity. The following main empirical findings were identified in this investigation.

- The findings reveal a considerable positive relationship between temperature and agricultural productivity.

- Temperature enhances and boost the productivity and has a statistically significant influence on agriculture productivity in the long and short term, according to the findings of the study.
- However, rainfall and agriculture productivity have a negative relationship.
- High rainfall reduced and deteriorates agriculture productivity in the short and long-run

Based on the empirical analysis of this study, the following policy recommendations have been given in the study.

Pakistan's population is growing, and the country will confront food safety and security issues in the coming decades. Possible actions are required to equip the Pakistan Government to deal with the negative impacts of climate change on agriculture and to secure enough food for the rising population. In summary, the analysis indicates that lawmakers and policy experts should recognize that climate change would alter total output factors, and as a result, region and crop specific adaptation measures are recommended.

Farmers must understand the ideal conditions for the growth of their products. Historically, most farmers and producers learned the best season for planting specific plants. The majority of crop processes are influenced by temperature. As the temperature increased, productivity also improved annually. The threshold temperature's level is 33°C and 29°C (Beckmann et al., 2021). Crop productivity is projected to decline if temperatures rise above a certain threshold.

Agriculture construction still needed to increase. The Pakistani government should implement new policies and advanced technologies to forecast weather to cope with climate change. It should invest in those varieties of seeds that are more tolerant of rainfall and environmental changes. It is necessary to focus on research and development.

The study relied on a national data set, which made it difficult to depict the accurate picture of the impact of variables on different agro-environmental regions. To better understand the regional differences, area or zone-specific study investigations should be conducted. This study could be extended through work on developed and developing countries and using the most up-to-date econometric methodologies.

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