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RESEARCH PAPER

Unravelling the Complexities of Agricultural Productivity in Pakistan: A Focus on Determinants

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Abstract

This study seeks to investigate the relationship between rainfall, temperature, environmental change, agricultural credit, and total factor productivity, all of which affect agricultural productivity in Pakistan from 1990 to 2020. To estimate the data, we apply the unit root test to investigate stationarity, and it is determined that some variables are $I(0)$ and others are $I(1)$. Then, the ARDL model is used to examine the long-run and short-run effects. Our empirical findings indicate that agricultural credit, temperature, and total factor productivity positively and significantly affect agricultural output in the short and long run, helping to boost productivity. In addition, rainfall and environmental change have adverse and significant short- and long-run effects on agricultural productivity. Stability experiments have confirmed the model's stability. The study concludes that it is necessary to introduce seed and crop varieties that are more resistant to rainfall and environmental change. In addition, greater emphasis should be placed on research and development.

Keywords: agriculture credit, ARDL, climate changes, environmental changes, Pakistan, total factor of production.
JEL Classification: B23, E51, Q15.

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Introduction

Growth in agricultural productivity also helps poor and developing countries alleviate poverty (Gilal et al., 2016). Agricultural productivity can be measured by the amount of output produced from several inputs (Kakar et al., 2016; Shita et al., 2018). Moreover, it also measures how efficiently farmers use land (Sial et al., 2011), labor (Awan and Aslam, 2015), capital machinery (Aslam, 2016), and fertilizers (Balogh, 2020) to produce crops. In terms of capacity, agricultural productivity can increase production for domestic consumption and exports (Ahmad et al., 2008) and contribute to foreign exchange earnings (Awan and Aslam, 2015; Shah et al., 2020). In addition, agricultural productivity is strongly linked to industrial development in Pakistan (Bonaccorsi and Daraio, 2005). It supplies raw materials to industry (Akram and Hamid, 2014). In contrast, industry supplies machinery, fertilizer, and pesticides to agriculture (Obayelu, 2011). Consumption of these inputs boosts a nation's GDP. Crop output can be improved by using fertilizer. Fungicides are used to improve land fertility and raise crop productivity. The supply of agricultural products creates demand for the industrial sector. In contrast, agricultural inputs are demanded by the industrial sector (Kakar et al., 2016).

Increases in agricultural productivity lead to agricultural expansion (Abukari et al., 2016) and can reduce income inequality (Ajmair, 2018) in countries where agriculture employs most of the workforce (Shita et al., 2018). Moreover, wages of individuals working in agriculture have also increased (Priyadarsini and Nayak, 2018). At the same time, food prices are going down, which makes food more affordable and available (Ajmair, 2018). As a direct consequence, workers now have more money to spend on food and other necessities (Mekonnen, 2017). People are drawn to agriculture because they regard it as a better way to earn a living, whether as farm owners or laborers (Enu and Obeng, 2013). According to microeconomic theory of production (Koutsoyiannis, 1979), labor, capital, land, and raw materials are the essential factors affecting the output of the agricultural sector (Brown and Iyabode, 2020). Although this sector needs land, capital, and labor to increase productivity, technological change is also needed to meet food demand and double the production function (Priyadarsini and Nayak, 2018). Therefore, technological change may double the productivity of the same land, labor, and capital and expand economic growth (Solow, 1956).

Agricultural productivity is affected by environmental change (Koondhar et al., 2020). A wide variety of pollutants are released into the environment by human activities. Many of these pollutants directly affect plants, including carbon dioxide, the photosynthesis substrate, ozone (O), a harmful oxidant, and air pollution (Ainsworth et al., 2020). Therefore, environmental change cannot be separated from the agricultural sector (Adegbeye et al., 2020). Moreover, weather fluctuations have affected agricultural productivity through changes in rainfall and temperature (Misra, 2014). Farmers adopt new agricultural innovations due to financial development and institutions (Ademola, 2019), which help increase agricultural productivity (Anik et al., 2017). It does this by providing loans to financially constrained farmers, allowing them to purchase inputs that increase agricultural output, such as seeds, fertilizers, and agrochemicals (Chandio et al., 2016, 2019). As a result, low-cost and readily available financial services are required to boost agricultural productivity (Zakaria et al., 2019).

Indicators of agricultural productivity help governments and farmers make investment decisions and formulate better economic policies to improve productivity (Kiani et al., 2019). Farmers must evaluate expected benefits and output (Shahraki et al., 2016), namely income and costs, including productivity risk (Shahraki et al., 2018). Variation in agricultural productivity allows us to examine how inputs in the agricultural sector increase output. This study provides an empirical assessment of the factors determining agricultural production in Pakistan. These components include climatic and environmental factors, agricultural credit, and total factor productivity. It is imperative to scrutinize the influence of these variables, which will help in decision-making and the efficient measurement of agricultural productivity in Pakistan. This study helps explain which factors affect agricultural productivity in Pakistan. This study will explain how environmental and climate factors affect Pakistan's agricultural productivity.

The study consists of the following sections: A review of previous studies is given in Section 2. The theoretical background, the study model, and the description of variables are discussed in Section 3. Section 4 contains the research design, data type, data sources, and estimation techniques. The study's results, model interpretation, and discussion are presented in Section 5. The last section presents the conclusion based on the results. Finally, policy recommendations based on the results are presented in the final section.

Literature Review

Several studies have examined the factors that affect agricultural productivity and their direct and indirect contribution to agricultural productivity in Pakistan. For example, Koondhar et al. (2020) empirically found that new agro-based technologies were used to meet food demand. Furthermore, climate fluctuations adversely affect Pakistan's cotton crop by increasing minimum and maximum temperatures, as empirically highlighted by Rashid et al. (2020) and Shahraki et al. (2018). Liu et al. (2020), through experimental research, explained the correlation between greenhouse gas emissions and mono-rice straw management by considering soil quality and crop productivity. They found that the combination of rice straw and green manure effectively stabilizes greenhouse gas emissions and crop quality. Shah et al. (2020) found that rice productivity remained unaffected by variations in rainfall, temperature, and humidity. They concluded that rainfall, temperature, and humidity did not significantly affect rice crop output. Lachaud and Ureta (2020) estimated the influence of climatic factors on productivity and indicated that climatic factors had a negative influence on agricultural output and productivity, while time-invariant environmental factors at the national level had diverse effects across countries. Amponsah et al. (2015) concluded that, in developing countries, a high concentration of carbon dioxide reduced agricultural productivity. This can act as a driving force behind rising prices of goods and services in the economy.

Bahsi and Cetin (2020) revealed that agricultural credit does not directly relate to agricultural output. However, it is a significant source of inputs for agricultural productivity and for increasing agricultural investment. Abbas et al. (2020) highlighted efforts to increase agricultural productivity in Lamongan District from 2010 to 2018. Using multiple linear regression models, Zahoor et al. (2022) found that land, labor, and irrigation had a positive effect on agricultural productivity. They further concluded that higher land and labor productivity promoted economic growth. Brown and Iyabode (2020) analyzed how credit facilities for the agricultural sector, exchange rate fluctuations, investment, and funding in agriculture have led to a notable increase in agricultural productivity. This study suggested that agricultural growth will allow the economy to diversify its production and export base. Rehman et al. (2019) stated that credit distribution and fertilizer consumption had boosted agricultural productivity. Ademola (2019) examined the influence of agricultural loans and production and concluded that credit size and agricultural output harmed agricultural growth. The industrial and agricultural sectors depend on foreign economies for the procurement of raw materials. Sheng and Chancellor (2019) elucidated the correlation between farm size and total factor productivity growth. They found that an increase in farm size increases agricultural productivity (Shahraki and Aliahmadi, 2021). In addition, the study revealed that capital outsourcing is likely to assist farms in increasing total factor productivity and closing the productivity gap between small and large farms in the grain industry.

Shita et al. (2018) showed that fertilizer consumption directly and substantially affected agricultural productivity. Mekonnen (2017) concluded that adopting modern agricultural technology increased smallholder crop productivity and improved the livelihoods of rural Ethiopian families. Therefore, governments and non-governmental organizations should encourage the use of agricultural technology on a larger scale to enhance productivity. Land, labor, temperature, and livestock directly affected agricultural productivity (Ghafarimoghadam et al., 2021; Shahraki et al., 2019), whereas precipitation, fertilizer, and machinery had adverse effects and reduced agricultural productivity, as confirmed by Nwachukwu and Shisanya (2017). Kakar et al. (2016) used the ARDL model to examine the impact of agricultural productivity indicators and concluded that rainfall, agricultural credit, and area under cultivation increase agricultural productivity in the long run. In contrast, agricultural employment and the use of pesticides harmed production in the long run. Gilal et al. (2016) concluded that the government should concentrate on variables that boost productivity growth. Chebil et al. (2015) used the total factor productivity index to examine agricultural productivity growth. The authors found that variations in total factor productivity were caused mainly by delays in R&D spending and drought. In addition, the drought-period dummy variable negatively influences TFP.

Ahmad and Heng (2012) empirically studied the factors affecting agricultural productivity in Pakistan from 1965 to 2009 and found that agricultural credit boosts agricultural productivity. Singh and Singh (2012) found that total factor productivity growth depended on inputs. High-quality inputs increase agricultural productivity and vice versa. However, efficient technological change diminished agricultural productivity because of a lack of investment in research and development. Kassie et al. (2011) used cross-sectional data from 927 households in seven Ugandan regions in 2006 to examine the impact of technology on crop productivity. Based on farm size and educational level, they found interesting effects of technology adoption. The study found that using technology on small household farms had increased agricultural productivity. However, the study noted that unequal availability of improved seeds, a lack of market infrastructure, and limited access to information and agricultural extension services all limit technology adoption. Ahmed and Schmitz (2011) investigated the impact of rainfall, temperature, fertilizers, agricultural credit, and tractors on productivity growth in the agricultural sector of Punjab, Sindh, NWFP, and Baluchistan from

1987 to 2004. A panel model was used to estimate the data. Empirical evidence suggests that rainfall and temperature fluctuations negatively influence crop yield and agricultural expansion. In addition, climate change has continuously diminished agricultural productivity, posing a danger to long-term food security. Kiani et al. (2008) aimed to establish a correlation between agricultural research expenditure and total factor productivity in the Punjab region of Pakistan. The research spanned 34 years, from 1970 to 2004. Using outputs and inputs, they used the Tornqvist-Theil index (TTI) as the measure of total factor productivity for 24 fields and crops. The results showed that all factors directly affected total factor productivity growth in agriculture. The study also concluded that agricultural research had a significant role in increasing productivity. Mechanization and the expansion of road infrastructure had a beneficial impact on TFP.

Previous studies analyzed agricultural productivity (Shahraki et al., 2023) using different variables. However, hardly any literature examines the effects of environmental and climate change. Godfray and Garnett (2014) argue that climate and environmental change cannot be separated from agricultural output. These indicators have probably not been jointly included to examine their effect on agricultural productivity in the existing literature. In the existing literature, these indicators are presumably not grouped as determinants of agricultural output. Determining the impact of climate and environmental change on Pakistan's agricultural output necessitates conducting this recent study. This study addresses this gap by examining the selected variables in relation to Pakistan's agricultural output. This study investigates agricultural productivity by incorporating these variables. The study is unique because it incorporates multiple indicators to assess agricultural productivity.

Theoretical Background

The theoretical considerations show how agricultural productivity moderates the relationship among agricultural credit, total factor productivity, rainfall, temperature, and environmental change. Adam Smith identified several elements that contribute to economic growth, such as capital, labor, land, and technology. He emphasized the importance of agriculture, claiming that it is the only industry capable of making a country prosperous. He stated that land is the mother and labor is the father. For him, the land was the only means by which he could pay for his labor and reap the benefits of this stock (Smith, 1791). Adam Smith argued that the size of the market limits the division of labor, which is useful for understanding wealth creation. As the market grows, so does the need for innovation. Large capital investments are required to develop a specialized labor force. Adam Smith argued that this can boost labor productivity, savings, and investment. Due to the ever-increasing division of labor, any increase in a country's capital stock usually results in a more than proportionate increase in output.

Classical economists such as Stuart Mill, Ricardo, and Malthus also studied the challenges of economic progress (Ricardo, 1817). In his work, Ricardo pointed out that agricultural productivity growth relies on labor. Therefore, Ricardo recommended that technology be utilized and that capital be accumulated to achieve success. As a result of this accumulation, labor productivity increased. Neoclassical growth theory, especially the Solow growth model, explains variations in output over time due to changes in population growth, savings rates, and technological progress. Therefore, technological progress is one of the most important factors in an economy's long-term growth rate. In the Solow model (Solow, 1956), agricultural productivity growth is identified as a shift in the production function, representing technical change within the framework of total factor productivity.

Methods and Materials

This research adopts a quantitative empirical research design. The collection and analysis of numerical data are termed quantitative research methods (Goertzen, 2017). This study employs secondary data to assess the effects of rainfall, temperature, agricultural credit, total factor productivity, and environmental change on agricultural productivity, and the data were collected from different sources in Pakistan. As a result, agricultural productivity in this research comprises several different crop combinations in the country.

Before conducting regression analysis, data analysis plays a crucial role in understanding the research (Steynberg, 2020). Data analysis uses different statistical tools to analyze data. It further helps explain the econometric analysis of the specified study model.

Table 1. Variables Used in the Study

Abbreviations	Indicators	Source
AP	Agriculture Productivity	WDI
AC	Agriculture Credit (US $ Millions)	FAO
TFP	Total Factor Production Index	USDA, ERS
RF	Rainfall (mm)	WDI
TEMP	Temperature (C^o)	WSI
EC	Environmental Performance Index	CIESIN

The ARDL model equation used is as follows.

$$AP_t = \beta_o + \beta_1 AP_{t-1} + \beta_2 AC_t + \beta_3 AC_{t-1} + \beta_4 TFP_t + \beta_5 TFP_{t-1} + \beta_6 RF_t + \beta_7 RF_{t-1} + \beta_8 TEMP_t + \beta_9 TEMP_{t-1} + \beta_{10} EC_t + \beta_{11} EC_{t-1} + \varepsilon_t$$

According to the hypothesis presented by Pesaran et al., (2001) an ARLD bound test provides unbiased long-run estimates and acceptable t-ratios.

$$\Delta AP_t = \beta_0 + \sum_{i=t}^{n} \Delta\beta_1 AP_{t-1} + \sum_{i=t}^{n} \Delta\beta_2 AC_{t-1} + \sum_{i=t}^{n} \Delta\beta_3 TFPI_{t-1} + \sum_{i=t}^{n} \Delta\beta_4 RF_{t-1} + \sum_{i=t}^{n} \Delta\beta_5 TEMP_{t-1} + \sum_{i=t}^{n} \Delta\beta_6 EPI_{t-1} + \beta_7 AP_{t-1} + \beta_8 AC_{t-1} + \beta_9 TFP_{t-1} + \beta_{10} RF_{t-1} + \beta_{11} TEMP_{t-1} + \beta_{12} EPI_{t-1} + \varepsilon_t$$

The long-run connection is relevant and can be determined through the ARDL equation, which yields the long-run coefficient.

$$AP_t = \beta_0 + \sum_{i=t}^{n} \beta_1 AP_{t-1} + \sum_{i=t}^{n} \beta_2 AC_{t-1} + \sum_{i=t}^{n} \beta_3 TFP_{t-1} + \sum_{i=t}^{n} \beta_4 RF_{t-1} + \sum_{i=t}^{n} \beta_5 TEMP_{t-1} + \sum_{i=t}^{n} \beta_6 EC_{t-1} + \varepsilon_t$$

Once a long-run relationship among the variables is identified, short-run associations among the variables are estimated using the Error Correction Model (ECM). In such a situation, the ECM demonstrates how rapidly the adjustment process causes shocks to converge from the short run to the long run.

The short-run coefficients may be calculated using the equation below:

$$AP_t = \beta_0 + \sum_{i=t}^{n} \Delta\beta_1 AP_{t-1} + \sum_{i=t}^{n} \Delta\beta_2 AC_{t-1} + \sum_{i=t}^{n} \Delta\beta_3 TFP_{t-1} + \sum_{i=t}^{n} \Delta\beta_4 RF_{t-1} + \sum_{i=t}^{n} \Delta\beta_5 TEMP_{t-1} + \sum_{i=t}^{n} \Delta\beta_6 EC_{t-1} + ECM_{t-1} + \varepsilon_t$$

ECMt-1 showed the short-term impact and quickness of correction.

Finding and Discussion

According to the descriptive statistics, the data are normally distributed, and there are no outliers (Kaliyadan and Kulkarni, 2019; Mishra et al., 2019). However, there is slight variance in the data. The correlation matrix ("What Is a Correlation Matrix?", 2018) is shown in Table 3. A positive correlation exists among agricultural credit, total factor productivity, temperature, and total agricultural productivity. In data analysis, it is imperative to assess the unit root (i.e., order of integration) of the indicators as a prerequisite for subsequent estimation procedures.

According to Table 4, the results of the ADF (Dickey and Fuller, 1979) unit root test show that total agricultural productivity, rainfall, and temperature are stationary at level, $I(0)$. Agricultural credit, total factor productivity, and environmental change, on the other hand, are stationary at the first difference, $I(1)$ (Kim and Choi, 2017). All variables used in this study have different orders of integration, as observed. None of the variables are integrated of second order, $I(2)$.

Before employing the ARDL model, the lag length criteria must be evaluated. Table 5 displays the results of several selection criteria, and the appropriate lag length is determined using the Akaike information criterion (AIC). The results presented in Table 6 indicate that the calculated F-statistic exceeds the upper critical value at the 5% level of significance. It is determined that the model's TAP, AC, RF, TEMP, and EC variables have a long-run relationship. Thus, we present and analyze the ARDL long-run results.

Table 2. Descriptive Statistics

DS	AP	AC	TFP	RF	TEMP	EC
Mean	94.96712	2138.532	101.5681	25.71407	20.57129	-44625.53
Median	98.80000	2081.359	101.2388	25.48808	20.65272	-45934.13
Maxi	120.6700	2959.449	107.1860	35.27298	21.41462	-32351.72
Mini	67.67000	1536.879	95.91819	15.98308	19.44474	-54108.28
SD	17.11013	406.5070	3.168246	4.872088	0.505126	5866.751
Sk	-0.080553	0.520091	0.237916	0.032281	-0.525559	0.544060
Kurt	1.690193	2.233093	2.260036	2.208130	2.595925	2.446984
JB	2.176939	2.087657	0.967454	0.789032	1.585157	1.862288
Prob.	0.336732	0.352104	0.616481	0.674006	0.452676	0.394103
Observations	30	30	30	30	30	30

Source: Research finding.

Table 3. Correlation Matrix

Correlation	AP	AC	TFP	RF	TEMP	EC
AP	1.000000					
AC	0.824328	1.000000				
TFP	0.620188	0.472758	1.000000			
RF	-0.046237	0.202021	0.034081	1.000000		
TEMP	0.147498	0.006508	0.118407	-0.122365	1.000000	
EC	-0.926720	-0.693912	-0.573022	0.034502	-0.189494	1.000000

Source: Research finding.

Table 4. Augmented Dicky–Fuller (ADF) test

Indicators	1(0)		1(1)		order
	Inter	Trend & inter	Inter	Trend & inter	
AP	0.7353	0.0055	0.0030	0.0050	1(0)
AC	0.3993	0.1583	0.0084	0.0343	1(1)
TFP	0.8974	0.3752	0.0018	0.0055	1(1)
RF	0.0002	0.0015	0.0000	0.0000	1(0)
TEMP	0.0038	0.0439	0.0016	0.0010	1(0)
EC	0.5272	0.1488	0.0000	0.0000	1(1)

Source: Research finding.

Table 5. The Outcome of the Lag Length Criterion

Lag	LogL	LR	FPE	AIC	SC	HQ
0	-603.5439	87.76223	8.34e+15	62.36632	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*

Source: Research finding.

Table 6. ARDL Bound Test

Test	Value	K	Signi.	I (0)	I (1)
F-test	9.2076645	5	10%	2.08	3.00
			5%	2.39	3.38
			2.5%	2.7	3.73
			1%	3.06	4.15

Source: Research finding.

Table 7, Part I, presents the long-run results of the ARDL model. As the population increases, significant changes occur in the consumption and production patterns of rural and urban areas. High demand for goods causes productivity to rise in the agricultural sector. AC is a significant driver of agricultural production. AC does not directly contribute to agricultural production. However, it is an essential source for acquiring inputs used to boost agricultural production and make new investments to promote the growth of the agricultural sector. On average, a one-unit (US million) increase in AC increases to 0.020 units in AP by holding the other variables constant. The funding of this study is similar to the study of (Bahsi and Cetin, 2020; Kakar et al., 2016). We talk about the TFP, agriculture productivity increases by using technology, high-quality seeds and fertilizers, supply of water, and good-quality pesticides (Chandio et al., 2016; Rehman et al., 2019). In the long term, the TFP in this research extends and boosts agricultural production, representing a helpful, statistically significant, and positive impact with a probability value of 0.0012. Furthermore, if we increase total factor productivity, the output in return also increases. The result of the research is similar to (Ahmad et al., 2008; Chebil et al., 2015), who stated that TFP positivity affects the AP.

Unfavorable weather patterns, heavy rainfall, floods, and droughts have negatively influenced agricultural output. Increased rainfall reduces agricultural production. Agricultural productivity in Pakistan declines by 20% due to the harsh climatic conditions prevailing in the region (Aslam, 2016; Sattar, 2012). On average, a one-unit increase in RF (US$ million) leads to a decrease of 0.322 units in AP, holding the other variables constant. The result is consistent with Chandio et al. (2020) and Njuki et al. (2020). There is a significant and positive correlation between temperature and productivity. The taproot system of crops gives them a remarkable ability to withstand high temperatures. Therefore, temperature plays a crucial role in crop ripening and serves as a fundamental determinant of agricultural productivity. The findings indicated that there is a correlation between temperature and agricultural productivity. Specifically, an increase in temperature is associated with an increase in agricultural productivity. The findings of this research are consistent with those of Mahmood et al. (2012), Ahmad et al. (2014), and Rahim and Puay (2017).

Agricultural productivity is affected by environmental changes. A wide variety of pollutants are released into the environment by human activities. Many of these pollutants directly affect plants, including excess carbon dioxide, the photosynthesis substrate, ozone (O), a harmful oxidant, and air pollution (Ainsworth et al., 2020). Environmental changes have an inverse relationship with agricultural productivity and greenhouse gas emissions, including 14–20% of CO2, 53–70% of CH4, and 60% of N2O (Rehman et al., 2019; Robertson, 2014). It destroys crops and lowers agricultural productivity. This empirical result is consistent with the study of Ainsworth et al. (2020).

Table 7. Long-Run and Short-Run

Dependent	Co-efficient	Standard error	t-test	Probability
Long-Run Results (Part I)				
AC	0.020772	0.001657	12.53946	0.0000
TFP	0.723894	0.162901	4.443759	0.0012
RF	-0.322995	0.079370	-4.069495	0.0023
TEMP	6.900508	1.395204	4.945876	0.0006
EC	-0.001482	0.000118	-12.58631	0.0000
C	-220.7326	30.98235	-7.124462	0.0000
Short-run Results (Part II)				

ΔAC	0.014890	0.002251	6.614526	0.0001
ΔTFP	0.828852	0.177804	4.661599	0.0009
ΔRF	-0.251291	0.089596	-2.804713	0.0186
ΔTEMP	3.309980	0.862969	3.835572	0.0033
ΔEC	-0.000831	0.000221	-3.764527	0.0037
ECM_{t-1}	-0.136815	0.118646	-9.581602	0.0000
Diagnostic Test (Part III)				
R^2	0.907475			
Adjusted R^2	0.843864			
DW	1.850793			
Serial	0.666109	0.5400		
Glejser	0.821657	0.652		
RESET	0.624802	0.449		

Source: Research finding.

Table 7 (part II) presents the error correction model short-run of the ARDL model with bound testing cointegration approach. Agricultural credit increases resource allocation and profitability by removing financial restrictions related to cash inputs, increasing farmers' technical efficiency, and removing financial constraints related to cash inputs (Sial et al., 2011). According to (Koc et al., 2019; Nnamocha and Eke, 2015; Ogbuabor and Nwosu, 2017), agricultural credits have been found to have a positive impact on agricultural productivity, as evidenced by statistically significant results. Previous studies proved the influence of credit on total agricultural productivity (Bahsi and Cetin, 2020; Kakar et al., 2016). The short-run result of this research also confirmed that easy and on-time availability of agriculture credit help to buy seeds, fertilizers, and other equipment that improves productivity in the agriculture sector. Over the last few decades, pest attacks, traditional cultivation methods, and climate changes declined the agriculture productivity share. The result of the study confirmed that in the short run, the total factor of production affects agriculture productivity. It became negative in the lag term in the short run. Because in the short run, one factor is fixed. We cannot change because agriculture productivity decreased instead of increased. The TFP is a statistically significant determinant of agriculture productivity with a probability value 0.0009. This study's empirical finding contradicts (Ahmad et al., 2008; Chebil et al., 2015).

Increased rainfall levels have been found to have a detrimental impact on crop yield, ultimately reducing overall agricultural productivity. The rain has a significant and detrimental effect on the short. On average, a one-millimeter (US million) increase in RF leads to a decrease of 0.25 units in AP by holding the other variables constant. The findings are consistent with prior research by Chandio et al. (2020), Magsi et al. (2020), and Njuki et al. (2020). Agricultural productivity is influenced by temperature. This refers to the immediate impact on productivity and the subsequent change in productivity. On average, a one-degree Celsius increase in TEMP leads to a decrease of 3.30 units in AP, holding the other variables constant. The study outcomes are consistent with those of Mahmood et al. (2012), Ahmad et al. (2014), and Rahim and Puay (2017). Environmental changes have a negative relationship with agricultural productivity. Agricultural productivity is both a contributor to and a victim of greenhouse gas emissions and significantly affects the sustainability of agricultural production systems (Valasai et al., 2005). Several human activities cause a rise in the emissions of carbon dioxide (CO2), sulfur dioxide (SO2), and nitrogen oxides (NOx) because of excessive land use mainly for urbanization, industrialization, and infrastructure construction (Adegbeye et al., 2020). As the concentrations of greenhouse gases and sulfur dioxide increase in the atmosphere, the atmosphere and water become more acidic, slowing crop growth and damaging agricultural productivity (Field and Field, 2017). This result is consistent with the study by Ainsworth et al. (2020).

The ECM_{t-1} is a term used to indicate the rate at which the system adjusts toward long-term equilibrium following a short-term shock in the regressors. The estimated coefficient of the error correction term at time t-1 is negative and highly statistically significant. The diagnostic test results of the ARDL model, as presented in Table 7, Part III, indicate that the model has passed the serial correlation and heteroscedasticity diagnostic tests. In addition, the CUSUMSQ graphs remain between the upper and lower critical bounds, indicating that the model is stable. Similarly, the model is stable, and the recursive residuals graph remains within the 2 SE bands, as shown in Figures 1 and 2.

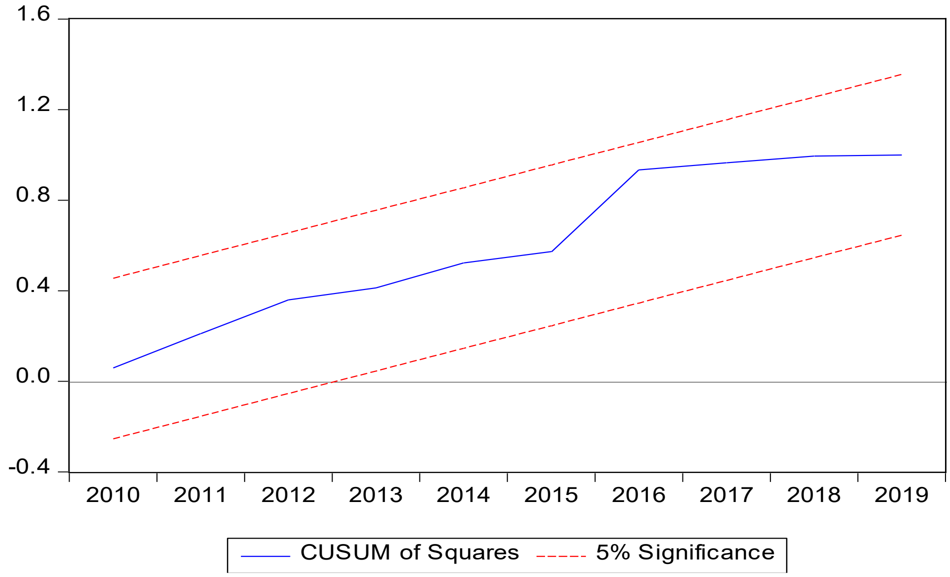

Figure 1. The Graph of CUSUMSQ
Source: Research finding.

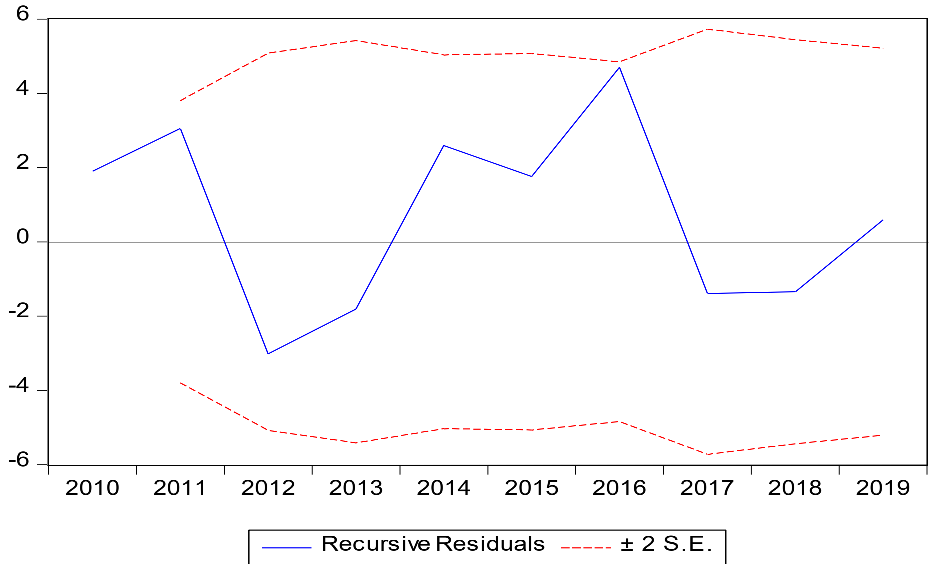

Figure 2. The Graph of Recursive Residuals
Source: Research finding.

Conclusion and Policy Recommendation

This study has found that agricultural credit, total factor productivity, rainfall, temperature, and environmental changes affect agricultural productivity in Pakistan and suggests policies to increase agricultural output. The data used in this study were taken from different sources such as WDI, FAO, and ERS. The study results revealed that agricultural credit, total factor productivity, and temperature boost productivity and have a statistically significant effect on agricultural production in both the long and short run. However, rainfall and environmental changes significantly and negatively reduce agricultural productivity in both the long and short run.

Access to financing for farmers at the time of cultivation could boost production by providing sufficient inputs such as seeds, land preparation, contemporary technologies, and fertilizers. In addition, the study's results suggested that agricultural productivity could be increased through the use of technology, high-quality seeds and fertilizers, water supply, and good-quality pesticides. Agricultural productivity has the potential to be a game changer in stimulating economic growth. However, this sector has remained vulnerable to several challenges, including environmental change and precipitation patterns. Environmental changes and rainfall affect air quality through pollution and increasing concentrations of greenhouse gases, which negatively reduce agricultural productivity. Around 30% of greenhouse gas emissions come from agriculture, primarily due to chemical fertilizers, pesticides, and animal manure.

This study has conducted an empirical analysis and, based on the findings, has formulated policy recommendations to enhance agricultural productivity in Pakistan.

• This empirical evidence suggests that agricultural productivity could be improved and increased by high-quality inputs, seeds, equipment, and fertilizers. In addition, agricultural credit should be managed and provided to small-scale farmers on time, at low cost, and be readily available.

• The area under agricultural cultivation should be increased. As the area under cultivation increases, agricultural productivity also increases, which raises overall output and meets the demands of the growing population.

• The use of modern technology and agricultural education helps enhance productivity. It is essential to offer short training programs for farmers to help them use modern technology properly. Through this, the labor force will become aware of technical agricultural education. This can help overcome cultivation problems and challenges.

• Moreover, total factor productivity is a basic requirement for agricultural productivity. Therefore, as the production factor increases, agricultural production will also increase. Therefore, this study suggests that to increase agricultural productivity, the factors of production should be managed in a timely manner.

• Agricultural infrastructure has to be improved. Furthermore, the Pakistani government needs to establish new legislation and sophisticated weather forecasting systems to deal with climate change.

• Agronomists have developed adaptation measures to address the adverse effects of future environmental changes on agriculture. New crop varieties adapted to environmental conditions are seen as a practical approach to dealing with these changes.

• It is time to develop rainfall- and environmental change-tolerant seed and crop varieties. Research and development must be promoted.

This investigation is centered solely on the impact of several factors on agricultural productivity, namely agricultural credit, total factor productivity, environmental changes, rainfall, and temperature. However, future research should explore the relationship between light, air, soil, and input prices, as well as other variables affecting agricultural productivity.

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