Exploring the Factors Affecting Wheat Productivity in Pakistan: An Empirical Analysis

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Abstract

Food security plays a vital role in both economic progress and social harmony, especially in nations such as Pakistan, where the agricultural sector significantly drives the economy. Wheat is the major staple food in Pakistan. This paper aims to explore the effects of major inputs on wheat productivity in Pakistan. For this purpose, data for the period from 1981 to 2021 was empirically analyzed through Autoregressive Distributed Lag (ARDL) model. The results revealed that the major inputs including improved sees, area under cultivation of wheat, water availability, fertilizer, Farm machinery, specifically tractors, play a crucial role in enhancing wheat productivity in Pakistan with a notable and meaningful effect. The study recommends that providing subsidies to small-scale farmers for key agricultural inputs such as tractors, tube-wells, and fertilizers can be an effective way to improve wheat productivity in Pakistan. Moreover, Access to modern agricultural machinery and inputs can also help small-scale farmers to increase their yields and reduce the cost of production, which can improve their profitability and livelihoods.

***Keywords*:** Food security, Wheat productivity, Influencing factors, ARDL Model, Pakistan,

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Introduction

The food security of Pakistan is indeed an important indicator of its overall well-being and the well-being of its citizens. Pakistan's food security situation is indeed fragile, and it faces various challenges in ensuring access to food for all its citizens. Wheat is a staple food in Pakistan, and it has historically catered to around 80 percent of the country's consumption requirements. However, in recent years, Pakistan has faced challenges in meeting its wheat production targets due to various factors such as climate change, water scarcity, and inefficient farming practices. As a result, Pakistan has to rely on imports to meet the shortfall in wheat production which caused of a huge foreign exchange cost (Jalil et al., 2023). Additionally, fluctuations in international wheat prices can also affect Pakistan's food security situation, as it can make imported wheat more expensive and less accessible for the population. In spite of this, Pakistan has indeed made significant progress in agriculture since its independence. The country's agriculture sector accounts for a significant portion of the economy and employs a large proportion of the population (Khan et al., 2022). The Indus Basin has experienced a Green Revolution, which has helped increase agricultural production and yields. However, despite the progress made, the benefits of the Green Revolution have not reached small farmers. Most Pakistan's farmers are smallholders who lack access to the resources necessary to adopt modern agricultural technologies. As a result, they have been left behind in the process of agricultural development. In addition, the productivity of wheat has declined in recent years due to the loss of momentum of Green Revolution technologies. It has been because of no. of factors e.g., a lack of investment in research and development, poor extension services, and inadequate access to credit and other resources (Rana & Malik, 2021).

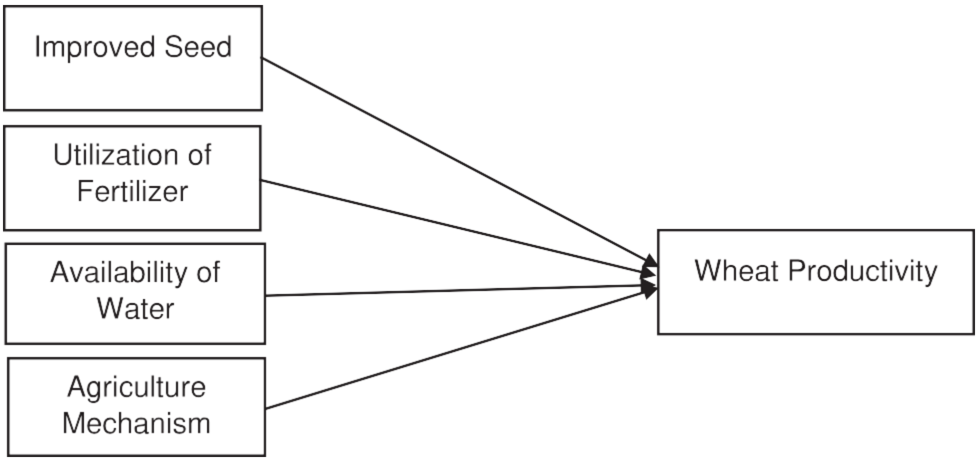
The estimated population of Pakistan in the year 2022 is around 229.22 million, and the country continues to have a significant portion of its population engaged in agricultural operations. According to the Pakistan Bureau of Statistics, in the fiscal year 2022-23, the agriculture sector contributed 22.9% to Gross Domestic product (GDP) of the country. In 2022-23, significant crops made up 18.23% of the agricultural sector's value addition and 4.18% of the GDP. Similarly, other crops also contributed14.49% in the agriculture sector as well as 3.32% to the GDP of the country. Overall, the sum of wheat production in Pakistan during the 2022-23 is covering an area of 9,043 thousand hectares, showing a 0.7 percent increase compared to the previous year's 8,977 thousand hectares. Wheat contributed 8.2% of the value added in agriculture and 1.9% in GDP. Moreover, wheat production reached 27.641million tons, indicating a growth of 5.4 percent compared to last year's 26.208 million tons. This increase in wheat production can be attributed to the government's implementation of the Kissan Package-22, which aimed to address the losses caused by the Flood-2022. The wheat production within the domestic region for the 2022-23 crop year is projected to be approximately 26.8 million tons, cultivated across 9.0 million hectares of land. It represents a growth of 1.6% as compared to the previous year's production i.e. 26.39 million tons. Additionally, the government raised the Minimum Support Price (MSP) to Rs 3900 per 40 kg from Rs 2200 per 40 kg, to get better economic returns and helped to offset higher input cost (Economic Survey of Pakistan, 2022-23). The Punjab province is the largest producer of wheat in Pakistan, followed by Sindh and Khyber Pakhtunkhwa. The government of Pakistan provides various incentives to farmers to increase wheat production, including subsidies on fertilizers, seeds, and irrigation (Shaheen et al., 2022). Additionally, the government also supports research and development in agriculture to promote the use of modern farming techniques and improve crop yields. Despite these efforts, there are still challenges that need to be addressed to improve wheat production in Pakistan. These challenges include climate change, water scarcity, outdated farming practices, procurement issues and the spread of diseases and pests (Kashif et al., 2020). In order to address such challenges, the is a need to require mutual efforts from all stakeholders including government, farmers and others to encourage sustainable farming practices and also improve overall agriculture infrastructure in the country (Zulfiqar et al., 2021).

The productivity of wheat on small farms is low, and this poses a challenge for small and marginal farmers who rely on wheat production for their livelihoods. The increasing input prices and low output prices exacerbate the problem, leading to a cost price squeeze that further reduces the profitability of wheat farming. This situation has made wheat less competitive in the international market, which in turn affects the food security of small farmers who depend on it (Gaydon et al., 2021). The government of Pakistan does engage in a complex wheat procurement, acquisition, transport, storage, and distribution operation. The government's procurement policy is aimed at ensuring food security for the country's population by maintaining adequate stocks of wheat and making it available at affordable prices. Under this system, the government procures wheat from farmers at a support price and then distributes it to registered flour mills at a subsidized rate. Thereafter, flour mills are required to produce flour and other wheat products at a fixed price that is set by the government. This system has a basic feature that the government only covers half of the cost of procuring and handling wheat from the farm. As a result, the registered flour mills, which purchase wheat from both the local market and the government, receive a subsidy on their quota by the provincial food departments. This system has faced various challenges, such as corruption, inefficiencies in the procurement process, and a lack of transparency. These challenges have led to the hoarding of wheat by middlemen and shortages in certain areas, which can lead to food insecurity and price hikes (Rana, 2020).

Factorings Affecting Wheat Productivity

Several studies have found that there are many factors such as improved seed, farming experience, farm size, access to farm machinery, water availability, fertilizer, soil quality, market proximity, extension service, credit facilities, marketing information, household saving significantly affect the productivity of wheat (Abebaw & Belar, 2001; Abubakar et al., 2016; Adedoyin et al., 2016; Al-Hassan & Jatoe, 2002; Ali et al., 2014; Asfaw et al., 2012; Chandio et al., 2018; Hossain et al., 2016; Jalil et al., 2023; Kassie et al., 2011; Kebede et al., 2017; Kumar et al., 2016; Mango et al., 2014; Maruod et al., 2013; Odoemenen & Obinne, 2010; Okello et al., 2016; Ologbon et al., 2012; Rasheed et al., 2021).

Theoretical Framework



Improved Seed

Improved or certified seed is always considered an important agriculture input to increase production of wheat crop. The agricultural productivity system heavily relies on the use of improved seed, as highlighted by Muhsin et al. (2021). Access to better seed is crucial for ensuring farmers' prosperity and food security. According to Nazu et al. (2021) the adoption of improved seed not only enhances the production of food grain crops but also boosts the income of farming families, thereby positively impacting rural development. Developed seed, regarded as a highly innovative advancement, is widely adopted by farmers in emerging nations to improve yield efficiency and increase food production for vulnerable populations. The department of federal seed certification and registration governs the production of certified or improved food grain crops. Enhanced seeds, serving as the key input for crop cultivation, hold considerable importance in promoting sustainable agricultural methods and ensuring the country's food security. As per an economic survey conducted in 2022-23, Pakistan acquired around 143,159 Metric tons of improved seeds for a variety of crops. Furthermore, an import of 39.784 thousand metric tons of seeds took place, encompassing yields like paddy, maize, potato, sunflower, canola, and various food and vegetable crops.

H_1: There is a significant impact of improved seed on wheat productivity.

Utilization of Fertilizer

Fertilizers play a vital role in agriculture, contributing to increase per-acre land yield and rapid returns (Kurmanbayeva et al., 2021). Each kilogram of fertilizer applied results in approximately eight kilograms of rice, wheat, and maize, respectively, in terms of nutrient production. The soil in Pakistan faces significant deficiencies, with nitrogen lacking in over 90% of areas, phosphorus in 80%-90%, and potassium in 30%. However, achieving balanced fertilization, where the optimal amount of fertilizer is applied to meet the crop's nutrient requirements, is crucial for maximizing the utilization of fertilizers and other inputs. During 2022, Pakistan met around 82% of its fertilizer needs through local production, while the excess was met through imports. Fertilizer production in Pakistan increased by 5.9% between July and March of FY2022 compared to the previous year. During that time, the total availability of fertilizer increased by 0.3%, while the supply of fertilizer imported decreased by 20.1%. Hamid and Ahmad (2009) conducted a study using the Cobb-Douglas production function and analyzed time series data from 1980 to 2018 to examine changes in agriculture value added. The results of the research indicated that various factors such as level of agriculture & trade activities, no. of labor force utilized for farming, utilization of other inputs like fertilizer, high quality seed, pesticides, as well as capital stock and HRD played a vital role in the agricultural value added. Additionally, the study emphasized the significant impact of fertilizers on improving agricultural productivity in developing countries. According to Amjadian et al. (2021) fertilizers are considered essential as they played a vital role in the green revolution in Asia and also contributed almost 50% in overall agriculture productivity.

According to Blekking et al. (2021) conducting a need assessment for agricultural inputs is a crucial strategy to enhance crop production, particularly in sub-Saharan Africa. Participation in activities such as adopting modern agricultural technology, utilizing fertilizers, pesticides, and improved food grain crop varieties plays a significant role in increasing agricultural productivity. Food grain crop production is significantly influenced by factors like production capacity, educational attainment, landholding size, and the price levels of fertilizers. Farmers actively employ fertilizers for crop cultivation, while factors such as orientation, age, and family size do not have a significant influence (Amanze et al., 2010). Similarly, Emmanuel et al. (2016) examined the effects of agricultural extension services on fertilizer adoption and rice crop productivity using the PSM (Propensity Score Matching) approach in Ghana. It is found that access to agricultural extension services significantly and positively influences fertilizer used in farming. Moreover, Amanze et al. (2010) demonstrated that farmers' livelihoods are improved and food grain crop yields are increased when fertilizers are used in moderation. Additionally, deficiencies in soil nutrients can be treated and aid in maintaining the soil's fertility. It was seen that without the utilization of composts, crop yields could not, as of now, be expanded. Whereas, Quddus et al. (2008) claimed that when commercial fertilizer was first used in Pakistan in 1952, only 1000 tons of nitrogen were consumed, while 100 tons of phosphorus were added to the initial supply in 1959–60.

H_2: There is a significant impact of utilization of fertilizer on wheat productivity.

Availability of Water

Securing adequate access to water is essential in order to fulfill the increasing food demand of country's rising population. A crucial requirement for the production of sustainable food grain crops is the effective use of water (Lutz et al., 2022). Water availability is closely linked to Pakistan's agricultural sector. According to the Economic Survey of Pakistan (GOP, 2022-23), the water availability for the Kharif season of 2022 reached 68.1 million acre-feet, marking a 9.3% increase as compared to the Kharif season of 2022 and 8.4% increase was observed as compared to the aggregate supplies of 67.3 million per acre-feet. However, for the Rabi season of 2022-23, the water availability remained at 29.4 million acre-feet, which is 12% lower than the availability during the previous Rabi season. However, efficient water use and proper harvesting of food grain crops are crucial. The yields of grain crops for food and food security will decrease as a result of a lack of water. According to Atamurodov et al. (2022) agriculture accounts for approximately 70% of all freshwater extraction worldwide and is the largest user of water. The canal network is used to irrigate more than 70% of Pakistan's land. According to Bhanger and Memon (2008) agriculture now uses nearly 93% of freshwater resources. Research findings indicate that surface water resources in Pakistan are not only limited but also display notable disparities in availability among various regions and over time. Consequently, this circumstance has prompted the establishment of an extensive groundwater system within the Indus basin. During the last five decades, a substantial proportion of farmers have embraced the use of groundwater as a reliable source of irrigation, giving rise to a transformative phenomenon known as the "quiet revolution." Moreover, Qureshi et al. (2010) indicated that the proportion of total irrigated land relying on groundwater has increased by more than 50% since 1960. However, despite the critical role of groundwater resources in crop production (Shah, 2000), these resources face significant challenges and are at risk in Pakistan.

H_3: There is a significant impact of availability of water on wheat productivity.

Agriculture Mechanism

The availability of modern farm machinery is essential to ensure in time cultivation and harvesting of food grain crops. There is a dire need to increase the productivity of food crops in order to meet the future demand of food by rising population (Rahmane et al., 2021). The production of food grain crops extensively relies on the utilization of human labor, animals, and modern machinery. However, in developing economies, farmers often rely on manual labor for various operations such as sowing, weeding, harvesting, and threshing because of some factors such as low income, poor saving, insufficient government subsidies and also lack of credit facilities for small scale farmers. Tillage is the only machine that is used for these tasks (Iqbal et al., 2015). Tractors are currently employed for tillage on both small and large farms in Pakistan. Small farmers continue to use bullock-powered machinery, though. In comparison to other nations that employ contemporary agricultural technologies, Pakistan's average output of food grain crops is extremely low. Crop production in comparison to other countries worldwide varies significantly, ranging from 50 to 83 percent below average (Tewari et al., 2012; Khan et al., 2011). Agricultural mechanization offers numerous advantages throughout the crop production process, such as time savings (20–30%), reduced labor costs (20–30%), savings on fertilizers and seeds (15–20%), increased crop intensity (5–20%), and higher yields (10–15%) (Rakhra et al., 2022; Fountas et al., 2015; Chauhan et al., 2006; Singh & Kohli, 2005). One of the primary benefits of agricultural machinery is its ability to enhance crop yields while minimizing postharvest losses. In 2021, the total manufacturing of tractors reached 39,272, compared to 36,635 in the previous year, indicating a significant increase of 15.21 percent. This surge in demand for farm machinery can be attributed to the reduction in Goods and Services Tax (GST) from 7% to 5% on locally manufactured tractors as well as imported ones (GOP, 2022).

H_4: There is a significant impact of agriculture mechanism on wheat productivity.

Research Methodology

Source of Data

The aim of this study is to explore the factors that impact wheat productivity in Pakistan from 1981 to 2021. The specified Autoregressive Distributed Lag (ARDL) model was constructed using annual data sourced from the Economic Survey of Pakistan, Agriculture Statistics of Pakistan and Pakistan Statistical Year Books. The empirical ARDL model comprises eight variables for our estimations. Wheat productivity is measured in thousands of tons, while land area for wheat cultivation is measured in thousands of hectares. Improved seed distribution is measured in thousands of tons, fertilizer usage in thousands of nitrogen/tons, water availability in million acre-feet (MAF), agricultural machinery, including tractors, is measured in numbers, and the number of tube wells is also considered. In the model, WP represents Wheat Productivity, AREA denotes the area under wheat cultivation, IMSEED refers to improved seed distribution, WA represents water availability, FET signifies fertilizer usage, INS represents insecticide usage, TRAC indicates the number of tractors, TW represents the number of tubewells, whereas, α represents the constant intercept, and e denotes the error term.

$$\ln WPt = \alpha + \beta_1 \ln IMSD_t + \beta_2 \ln AREA_t + \beta_3 \ln WA_t + \beta_4 \ln FET + \beta_5 \ln INS_t + \beta_6 \ln TRACT_t + \beta_7 \ln TW_t + \epsilon \qquad eq-1$$

In this study, Augmented Dickey Fuller (1981) has been used that is a unit root test to check the reliability of our analysis by assessing the stationarity properties of the variables, ensuring accurate and meaningful results. Once the stationarity of the variables was confirmed, we also utilized the ARDL bounds test to study the long-term relationship between agricultural technology factors and wheat productivity. The selection of the ARDL approach was motivated by its efficacy in handling small sample sizes, as our study encompassed 40 observations, as well as its flexibility in accommodating various optimal lag lengths for the variables under investigation. Following the determination of the appropriate lag structure for the model, the ARDL framework facilitated cointegration assessment using the Ordinary Least Squares (OLS) approach, which is proposed by Pesaran et al. (2001). Therefore, in order to examine the long-term relationship between wheat productivity along with seven independent explanatory variables, we employed the bounds test procedure for cointegration, estimating the conditional version of the ARDL approach as follows:

$$\Delta lnWP_t = \alpha + \gamma_1 lnWP_{t-1} + + \gamma_2 lnIMSD_{t-1} + \gamma_3 lnAREA_{t-1} + \gamma_4 lnWA_{t-1} + \gamma_5 lnFET_{t-1} + \gamma_6 lnINS_{t-1} + \gamma_7 lnTRACT_{t-1} + \gamma_8 lnTW_{t-1} + \sum_{i-1}^{q} \psi_{1i} \Delta lnWP_{t-i} + \sum_{j-1}^{q} \psi_{1i} \Delta lnIMSD_{t-i} + \sum_{k-1}^{q} \psi_{1i} \Delta lnAREA_{t-i} + \sum_{l-1}^{q} \psi_{1i} \Delta lnWA_{t-i} + \sum_{m-1}^{q} \psi_{1i} \Delta lnFET_{t-i} + \sum_{n-1}^{q} \psi_{1i} \Delta lnINS_{t-i} + \sum_{r-1}^{q} \psi_{1i} \Delta lnTRACT_{t-i} + \sum_{s-1}^{q} \psi_{1i} \Delta lnTW_{t-i} + \epsilon \quad \ldots\ldots\ldots\ldots eq-2$$

Where ψ denotes the discrepancy in the independent variables, capturing the short-term dynamics that will be estimated using the Error Correction Model (ECM). Meanwhile, γ_1 denotes the long-term multipliers, and α represents the constant intercept, and ϵ represents the error term or random error. The initial step in conducting the ARDL bounds test for co-integration involves testing the presence of a long-term relationship between the variables. This is done by estimating Equation (2) through the Ordinary Least Squares (OLS) method. Afterward, the F-statistic test is calculated to evaluate the joint significance of the lagged levels of the variables. It is hypothesized that

$$H_0: \gamma_1 = \gamma_2 = \gamma_3 = \gamma_4 = \gamma_5 = \gamma_6 = \gamma_7 = 0 \ (Notcointegrated)$$

$$H_1: \gamma_1 = \gamma_2 = \gamma_3 = \gamma_4 = \gamma_5 = \gamma_6 = \gamma_7 = 0$$

The ARDL bounds test was used by Pesaran and Shin (1998); Pesaran et al. (2001), and Chandio et al. (2018), is utilized to explore the long-term relationship and co-integration among variables. This test is applicable irrespective of the underlying series are integrated of order zero (I(0)) or integrated of order one (I(1)). The null hypothesis of no co-integration is rejected when the calculated F-statistic exceeds the upper bound, indicating a significant association between the variables. Similarly, if the computed F-statistic falls below the upper bound, the null hypothesis of no integration cannot be rejected, suggesting the absence of a long-term relationship. Next step is to look at the long-term connection. Following is the ARDL long-run model for wheat productivity:

$$\ln GCP_t = \beta_0 + \sum_{i-1}^{p} \psi_{1i} lnWP_{t-i} + \sum_{i-0}^{q1} \psi_{1i} lnIMSD_{t-i} + \sum_{i-0}^{q2} \psi_{1i} lnAREA_{t-i} + \sum_{i-0}^{q3} \psi_{1i} lnWA_{t-i} + \sum_{i-0}^{q4} \psi_{1i} lnFET_{t-i} + \sum_{i-0}^{q5} \psi_{1i} lnINS_{t-i} + \sum_{i-0}^{q6} \psi_{1i} lnTRACT_{t-i} + \sum_{i-0}^{q7} \psi_{1i} lnTW_{t-i} + \mu_t \;\ldots\ldots\ldots\ldots eq - 3$$

On the basis of Akaike Information Criterion (AIC), the order of the lags has been chosen for ARLD as p_1, q_1, q_2, q_3, q_4, q_5, q_6 and q_7. Now, the final step is to calculate the short term correlation between the wheat productivity and the independent variables. Accordingly, the model is as under:

$$\Delta \ln WP_t = \emptyset_i + \sum_{i-1}^{p} \alpha_{1i} \Delta lnWP_{t-i} + \sum_{j-1}^{q} \alpha_{2j} \Delta lnIMSD_{t-j} + \sum_{k-1}^{q} \alpha_{3k} \Delta lnAREA_{t-k} + \sum_{l-1}^{q} \alpha_{4l} \Delta lnWA_{t-l} + \sum_{m-1}^{q} \alpha_{5m} \Delta lnFET_{t-m} + \sum_{n-1}^{q} \alpha_{6n} \Delta lnINS_{t-n} + \sum_{r-1}^{q} \alpha_{7r} \Delta lnTRACT_{t-r} + \sum_{s-1}^{q} \alpha_{8s} \Delta lnTW_{t-s} + \rho ECM_{t-1} + v_t \;\ldots\ldots\ldots\ldots eq - 4$$

Equation (4) above illustrates the short-term coefficients of the model's equilibrium. The Error Correction Model (ECM) is denoted as ECM_(t-1), with ρ representing the coefficient that estimates the rate at which the short term adjustments converge towards the long-run equilibrium. Therefore, the model for calculation of ECM is as under:

$$ECM_t = lnWP_i - \beta_0 - \sum_{i-1}^{p} \psi_{1i} lnWP_{t-i} - \sum_{j-1}^{q1} \alpha_{2j} lnIMSD_{t-j} - \sum_{k-1}^{q2} \alpha_{3k} lnAREA_{t-k} - \sum_{l-1}^{q3} \alpha_{4l} lnWA_{t-l} - \sum_{m-1}^{q4} \alpha_{5m} lnFET_{t-m} - \sum_{n-1}^{q5} \alpha_{6n} lnINS_{t-n} - \sum_{r-1}^{q6} \alpha_{7r} lnTRACT_{t-r} - \sum_{s-1}^{q7} \alpha_{8s} lnTW_{t-s} \;\ldots\ldots\ldots\ldots eq - 5$$

Results and Discussion

The stationarity status of all variables is examined. Accordingly, prior to investigating the long run correlation between wheat productivity and the independent variables, it is essential to assess the stationarity of the variables. Hence, Table No. 1 shows the ADF unit root test results, including trend and intercept.

Table 1
ADF Unit Root Test

Variables	At level	First Difference
lnWP	-4.7012***	-3.8274***
lnIMSD	-3.4583*	-6.6518***
lnAERA	-3.5126**	-9.6221***
lnWA	-0.3345	-11.8245***
lnFET	-3.8912	-6.7486***
lnINST	-4.7714***	-11.8352***
lnTRACT	-2.9865	-5.4981***
lnTW	-2.0326	-6.9591***

*Note: ***, **, * indicate that the rejection of null hypothesis of non-stationary at 1%, 5% & 10% level of significance. Source: Author's Calculation*

Table 1 presents the stationarity analysis of the variables. It is observed that wheat productivity, the area under cultivation of wheat, improved seed, and insecticide exhibit stationarity at their current levels, suggesting they are integrated of order zero (I(0)). On the other hand, fertilizer, tractors, and tube-wells demonstrate non-stationarity and are integrated of order one (I(1)). Based on these findings, employing the ARDL bounds test specification to estimate the model is a suitable approach.

ARLD Bound Test for Long Run Relationship

After confirming the stationarity of all variables, We utilized the ARDL bounds test to examine whether a long-run relationship exists among the variables. The outcomes of the ARDL bounds test are displayed in Table 2.

Table 2

ARDL Bounds Test for Co-integration Results

F-Statistics	Level of Significance	Lower Bound	Upper Bound	Decision
	10%	2.05	3.89	
5.094570	5%	2.52	3.23	Co-integrated
	1%	2.87	4.56	

Source: Authors' Calculation

The estimated findings from ARDL bounds test validate the presence of a long term relationship between wheat productivity and the independent variables. This is because of the calculated value of F-Statistic surpasses the upper critical value at a significance level of 5%.

Results Of Long-Run Relationship

The following Table 3 describes the long run relationship between wheat productivity and the independent variables.

Table 3

Calculated long-run coefficient using the ARDL Approach

Dependent Variable: LnWP				
Regressors	**Coefficient**	**Std. Error**	**T-Ratio**	**P-value**
lnIMSD	0.131021***	0.035871	4.982541	0.0000
lnAERA	1.020036***	0.275631	3.432111	0.0026
lnWA	-0.758141*	0.358647	-2.278012	0.0401
lnFET	0.480417***	0.120249	3.901337	0.0016
lnINST	-0.027526	0.019950	-1.204447	0.2825
lnTRACT	0.013817	0.025272	0.590719	0.5811
lnTW	-0.493181***	0.004968	-3.401521	0.0038
Constant	0.495269	3.005413	0.167133	0.8235

*Note: *Level of Significance @ 10%; *** Level of Significance @1%*
Source: Authors' Calculation

The findings from Table 3 highlight significant relationships between various factors and wheat productivity. Specifically, the variables including area under cultivation of wheat, improved seed, and fertilizer demonstrate positive correlations with wheat productivity at a significance level of 1. Whereas, in the long run, a percentage increase in the area under cultivation of wheat, adoption of improved seed, and utilization of fertilizer correspond to an approximate increase in wheat productivity in Pakistan by 1.020036%, 0.131021% and 0.480417% respectively. These results emphasize the significance of factors such as the expansion of cultivated area, the adoption of certified/improved seed, and the appropriate use of balanced fertilizer in enhancing grain crop production and improving farmer welfare (Aryal et al., 2021; Chandio et al., 2018; Nordin & Hojgard, 2017; Khonje et al., 2015; Emmanuel et al., 2016).

Similarly, the coefficients of both water availability and insecticide display negative and statistically significant relationships at a 5% significance level. This means that under long run relationship, there were negative relationship found between water availability & insecticides and wheat productivity. It is pertinent to mention that in Pakistan, the majority of control over the irrigation system is held by landlords who own approximately 40% of the arable land, making it difficult to implement a wide range of reforms (Chandio et al., 2018; Koondhar et al., 2016; Buriro et al., 2015;). Moreover, because of Inadequate skills and knowledge, Pakistani small farmers are unaware of the proper application of insecticides during spraying on wheat crops. As a result, small farmers require training and workshops to learn the uses of insecticide on their crops. Furthermore, the use of cutting-edge agricultural technology is critical for timely crop sowing and harvesting. The tractors have a positive relationship with wheat productivity. This indicates that tractors are correlated to wheat productivity in the long run. Whereas, the coefficient of tractor is found 0.022814 which is statistically insignificant. These findings show that a 1% increase in the use of tractor increases wheat production by nearly 0.013817%. On the other side, the coefficient of the tube-well is found negative and significant, indicating a long-term negative relationship between the production of wheat and the tube-well. This is because of the farmers in rural Areas generally use tube wells because of a lack of electricity. They use tube wells as source of water at high cost of diesel which and small-scale farmers cannot afford but they have to operate their tube wells.

Results of Short Run Error Correction

The dynamics of the variables were examined using the short run error correction method. The empirical results are shown in Table 4.

Table 4

Calculated ARDL Short Run Error Correction

Dependent Variable: LnWP				
Regressors	**Coefficient**	**Std. Error**	**T-Ratio**	**P-value**
$\Delta\ ln$IMSD	0.5603	0.0447	1.1524	0.2550
$\Delta\ ln$IMSD-1	-0.0267	0.0401	-0.8124	0.5606
$\Delta\ ln$AREA	1.4867***	0.3046	4.2185	0.0005
$\Delta\ ln$AREA-1	0.2790	0.3122	0.8454	0.4270
$\Delta\ ln$WA	0.0200	0.3972	0.0482	0.9220
$\Delta\ ln$WA-1	0.5743*	0.2956	1.8739	0.0720
$\Delta\ ln$FET	0.3506***	0.1214	2.9958	0.0086
$\Delta\ ln$FET-1	-0.2946**	0.1462	-2.1606	0.0432
$\Delta\ ln$INST	-0.0652*	0.0327	-2.0119	0.0604
$\Delta\ ln$INST-1	-0.0153	0.0279	-0.5895	0.6075
$\Delta\ ln$TRACT	-0.0198	0.0394	-0.0465	0.6761
$\Delta\ ln$TRACT-1	-0.0508	0.0400	-1.4177	0.1824
$\Delta\ ln$TW	-0.0056	0.0062	-0.8495	0.3941
$\Delta\ ln$TW-1	0.0027	0.0070	0.3657	0.7596
ECM (-1)	-1.3919***	0.2484	-5.9137	0.0000
R- Squared: 0.853912			Durbin-Watson Stat: 2.271897	
Adjusted R-Squared: 0.685439			F-Statistics: 4.188327 (0.002976)	

*Note: *Level of Significance @ 10%; ** Level of Significance @ 5%; *** Level of Significance @1%*

Source: Authors' Calculations

The analysis reveals that improved seed is positively correlated with wheat productivity in both short and long run. However, in the short run, this relationship is statistically insignificant, suggesting that the use of improved seed has no immediate impact on wheat productivity. This observation can be attributed to the prevalent adoption of traditional farming methods among the majority of small farmers in Pakistan. The high cost associated with certified / improved seed for wheat, rice, and maize varieties further discourages farmers from embracing this technology, resulting in low per-acre yields of wheat (Rana & Malik, 2021). On the other hand, the area under wheat cultivation exhibits a significant and positive association with wheat productivity both in short and long run. The coefficient of 1.486742 indicates that a 1% increase in the area under wheat cultivation corresponds to a 1.48% increase in wheat productivity. These findings align with previous researches done by Jalil et al. (2023); Chandio et al. (2018); Ahmad (2011). However, in the short term, the relationship is statistically insignificant, suggesting that immediate changes in the area under cultivation do not have a significant impact on wheat productivity. The reliance on traditional farming techniques and the economic constraints faced by farmers regarding the adoption of improved/certified crop varieties contribute to these observations, leading to lower grain crop yields per acre in Pakistan (Rana & Malik, 2021).

Similarly, Fertilizer plays a crucial role in enhancing per-acre wheat production and ensuring favorable returns. A well-balanced and adequate use of fertilizer can result in approximately eight kilograms of wheat for every kilogram of fertilizer applied. The correlation between fertilizers and wheat productivity remains positive in both short and long run. Notably, in short run, fertilizers exhibit a significant positive coefficient of 0.350674 at a 1% level of significance. This finding implies that 1% increase in fertilizer usage leads to an approximate 0.35% increase in wheat productivity in the short term. However, it is important to note that a sustainable and sufficient supply of water for irrigation is a critical requirement for achieving consistent per acre yield productivity.

In short run, availability of water has positive impact on wheat productivity. This is because water is a key input in the agricultural production process and a lack of it can limit crop yields. When water is readily available, farmers can irrigate their crops, which can lead to increased yields (Brunel et al., 2013). Water availability has a positive coefficient of 0.574359 which is statistically significant at 10% level of significance. It implies that 1% increase in availability of water will enhance 57% in wheat productivity. Therefore, farmers need availability of water during sowing time of food grain crops. Without sufficient water, seeds may not germinate, or seedlings may wither and die, leading to reduced crop yields. However, as mentioned earlier, the relationship between water availability and crop production is more complex in the long run, and other factors must also be taken into account to ensure sustainable and resilient agricultural practices (Mishra, 2023).

Similarly, in both short and long run, insecticides, tractors and tube wells were discovered to have a negligible negative impact on wheat productivity. These outcomes align with the findings of previous researches conducted by Jalil et al. (2023); Chandio et al. (2018) and Badar et al., (2007). Finally, at a 1% level of confidence, the projected ECM is found negative i.e. -1.391942 and significant at 1% level of confidence. The ECM coefficient was found to be -1.391942, showing that adjustment tends towards the long-term equilibrium at a rate of 1.39 percent annually. The value of R-squared is found above 85% which indicates that the model is best-fitted.

Conclusion & Policy Implications

Increasing wheat productivity can indeed be an important determinant of economic growth and poverty reduction, particularly in developing countries where agriculture is a key sector of the economy. The study applied Autoregressive Distributed Lag (ARDL) model to explore the impact of major factors on wheat productivity for the period from 1981 to 2021. The results showed that there is correlation between wheat productivity (dependent variables) and other independent variables i.e., improved seed, area under cultivation of wheat, fertilizer, insecticides, water availability, tractors and tube wells. The overall empirical analysis showed that the coefficient of improved seed, area under cultivation of wheat, fertilizer and tractor are found 0.1310, 1.0200, 0.4804 and 0.0138 respectively which have positive impact on wheat productivity in Pakistan both in short and long run. On the other side, water availability, insecticides and tube well have negative impact of wheat productivity.

The study recommends that there is need to provide subsidies to farmers for key agricultural inputs such as tractors, tube-wells, and fertilizers that can be an effective way to improve wheat productivity in Pakistan. Access to modern agricultural machinery and inputs can help farmers to increase their crop production and reduce the cost of production, which can improve their profitability and livelihoods. In addition, the knowledge and awareness of farmers about the appropriate use of fertilizers and pesticides can also have a positive impact on crop productivity. Agricultural extension officers can play a key role in providing technical assistance and training to farmers on best practices for crop management, including the optimal use of inputs such as fertilizers and pesticides. Moreover, small size group meetings and training workshops at the village level can be an effective way to reach out to farmers and provide them with practical knowledge and skills to improve their crop yields. By investing in agricultural education and extension services, policymakers and other stakeholders can help to promote sustainable agricultural practices and improve the livelihoods of farmers in Pakistan.

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