Improving agricultural productivity in Pakistan's agriculture through ICTs: determinants and impact

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Abstract

This study measures the efficiencies as technical, allocative, and economic of major staple food items as well as to analyze the factors which affects technically inefficiency for grain productivity (rice-wheat farming system) in District Sialkot. Hypothesis testing in this study was done by using primary data gathered from one hundred and twenty landholders. For this purpose, a non-parametric Data envelopment analysis (DEA) method was used for analysis. To examine the factors including information and communication technologies (ICTs) that define the technical efficiency or inefficiency of the system, an appropriate regression analysis was utilized. The Tobit regression results also depicted that years of schooling, visits of extension workers and access to finance, ICTs had negative coefficients, indicating a negative impact on technical inefficiencies of the rice-wheat system, while coefficients of farm size, age of the small landholder has a optimistic influence. It is recommended young and educated people in farming, should be is inculcated by the government with the provision of subsidized information and communication technologies (ICTs) and interest free loans for the farming community. Tackling these inefficiencies has the potential to improve the agrarian sector and promote rural development in the country.

Keywords: Grain productivity. Data envelopment analysis. Information and communication technologies. Rural development.

1. Introduction

Agriculture sector comes at the first priority for Pakistani economic stability and it is the major sector for the growth and expansion. It is the principal supplier of several input goods across various sectors of the economy. Some of the Industries also help feed the agriculture sector by supplying it with specific inputs. The industrial sector has input-output relation with the agriculture sector in other words there are flow of interdependence between agriculture and industrial sector. The demography of most of the population was in the rural areas, and as a result, they base their sources of income on the revenues made from the agricultural sector (Khan et al., 2022). This rural poverty means that improvement of agriculture sector could be of help in its minimization. It has the contribution of 22.9% to the national Gross Domestic Product (GDP), occupies 37.4% of the total workforce in Pakistan (GOP, 2023).

Agriculture sector satisfies the food requirement of the population also supplies the raw material for industries apart from having the surplus export. From above analyzed information, it is seen that agriculture sector has a vast prospect to contribute to the national economy in future in case of proper attention for solving the emerged problems. This is where the agricultural sector transformation is developed with increased efficiency of inputs on attaining higher orders of agricultural output. Grain crops such as wheat, rice and maize stand out as the main staple foods of the reasonably large population in Pakistan. The degree of food security very much depends on the stable cereal supplies. The people in the country also take other food items in order to fulfill their nutritional needs but food cereals can be said to form the backbone of nutritional needs (Abid et al., 2016; Aslam and Li, 2024; Khan et al., 2022).

Wheat is the most widely grown food cereal of the country concerning the extent of cultivation land and yield, tracked by maize and rice. It is also taken as conventional staple food in various countries including France, Canada, Bangladesh, Argentina, India and Australia etc. Wheat is cultivated in various rain-fed and irrigated areas around the globe. Of course, as the population is growing day by day, there is a need to increase the production of wheat in order to meet food requirement. Wheat contributes 13.2 percent for the value added products in agriculture and 2.9% of the total Gross Domestic Product commonly abbreviated as GDP (Khan et al., 2022; Aslam et al., 2024).

As Pakistan is a agro-based economy and rice plays a special role as the primary cash crop. By providing more than 2 million tons of food to the nation, it significantly contributes to the growth of the economy. For rural residents, the rice business is a major source of revenue and employment opportunities that contribute to their financial well-being. Additionally, it is the main source of earnings in foreign currency. The fact that rice accounts for 1.3% of GDP and 5.9% of value-added agriculture in Pakistan's economy further highlights the significance of rice to the country's economy (GDP). Pakistan produces enough high-quality rice to meet the needs of the domestic and global markets (Aslam *et al.*, 2024). Pakistan has two major types of rice. Long, fragrant grains with high yielding cultivars of basmati rice have an IRRI. The world-famous basmati rice species enjoys a monopoly in international markets thanks to its distinctive qualities, which include a potent fragrance and a high degree of cooking elongation (Ghafoor and Aslam, 2012). Two provinces like Sindh and Punjab are the primary producers of food crops. The government is extremely concerned about the above-mentioned crops' output given the country's food security problems (Ali et al., 2016; Habib et al., 2007; Aslam *et al.*, 2024).

Pakistan is an emerging economy and although agriculture has proven to be significant in strengthening and maintaining the national economy, its full potential has yet to be reached. Subsequently, the productivity growth of the primary cereal crops received less attention, productivity enhancement continued to be a neglected field. After independence, a number of administrations implemented initiatives to boost the agricultural industry, especially in the areas of major crop marketing and area expansion. The fact that this sector has received minimal funding during the last five years and other growth plans demonstrates the true situation (GOP, 2022). Furthermore, Pakistan's low productivity of its main food crops is caused by the country's small farmers being exploited and the inefficient management of agricultural output after harvest, which results in both quantitative and qualitative losses (Aslam and Li, 2024; Khan et al. 2022).

A yield gap has been identified by a number of research on the efficiency of agricultural production, mostly for rice and wheat. This disparity accounts for the differences in production between farms using best practices in agriculture and other farms operating under similar conditions but with different resource endowments (Kebede, 2011; Wadud, 1999 and Villano, 2015). The discrepancy between the technically feasible and actual production for the majority of the crops suggested that there was enormous potential to accelerate agricultural production through productivity gains even in the absence of additional technological advancements or improvements and the distribution of other resources, such as labor, land, and water. Generally speaking, it is believed that resources in the agricultural sector—which are mostly found in emerging and underdeveloped nations—are not being distributed and used effectively. The productivity and income generated by agricultural operations, which either directly or indirectly depend on resource use efficiency, are the primary concerns of the farming community. In Pakistan, not much work has been done in this regard with the wheat and rice crops (Habib et al., 2007, Abid et al., 2016).

Agriculture technology, efficiency, or both can be improved to increase productivity or output in Pakistan. The rate of progress and the application of improved agriculture technology are far behind in my country. Therefore, increasing efficiency is the best course of action to raise the nation's agricultural production in the near future. The technical effectiveness and allocative efficiency are the two primary components of a firm's efficiency (Farrell, 1957; Zheng et al., 2022; Zhu et al., 2021; Zheng et al., 2021). An organization's technical efficiency may be defined as its ability to harvest a particular point of output with a particular set of resources or as its capacity to use the technology available to produce a specific amount of output with a restricted number of components of production (Habib, 2007). The capacity of an organization to allocate resources as efficiently as feasible in light of market input and output prices is known as allocative efficiency. According to Zhu et al. (2021), the product of both allocative and technical effectiveness is economic efficiency.

The current food crises involving wheat and rice, as well as periodic surpluses and dearths of agricultural commodities, highlight the necessity for the government to act to enhance the efficiency of the agricultural production system. The government must address several significant challenges, including poor land quality, high interest rates on farm credits, inappropriate irrigation systems, weed and illness outbreaks, extraordinary input prices, capital constraints, low levels of education among farmers, and a lack of extension services, and prioritize them in national plans. Although the system for agricultural production in Pakistan has undergone significant advances, previous food crises have shown that it still wants to be enhanced and rehabilitated in order to address new issues related to the availability of food in the years to come (Aslam et al., 2024).

The primary causes of low wheat and rice productivity are the following: inability to obtain certified seed; absurd fertilizer use; weed infestation; improper planting time; poor irrigation system; crop varieties and acquired instability of new cultivars; lack of appropriate price incentives; inadequate approval of advances in machinery to acquire genetic capacities; and utilization of the rotation of both wheat and cotton. The Pakistani government wants to see increased production, self-sufficiency, and food security in order to achieve wheat self-independency. The key to changing the situations at the global level is self-sufficiency. The primary goal is to increase wheat and rice production in order to reduce importations and provide food safety to meet the needs of the world's rapidly growing population (Habib, 2007; Abbas, 2007; Quandt et al., 2020; Kelemu, 2016). In light of this, the current study aims to investigate the effects of the primary factors influencing low grain productivity in the research region in order to help decision-makers to locate relevant data for efficient policy formulation.

2. Literature Review

Abid et al. (2016) and Ali et al. (2016) computed the technical and allocative efficiencies of wheat and rice producers using the trans-log production function. The major drivers affecting the efficiency were the landholder agricultural experience, their status of qualification, their orientation and understanding of better and advanced innovative technologies and their accessibility, the provision of extension services, provision of ICTs, the training and outreach activities of peasants regarding the judicious use of inputs, ICTs, including the frequency with which the peasants used YouTube and AI tools for agro-based programs which mainly emphasized on productivity enhancement, and improving the subjective well-being of the small landholders.

Habib et al. (2007) employed the Cobb-Douglas frontier technique to measure the technical efficiency in sugarcane production. The study's conclusions identified that farmers of sugarcane were mainly technically efficient. Abid et al. (2016), in their study, safely concluded that though environmental determinants have a big influence on agricultural productivity. they are mainly in their research observed agricultural productivity and efficiency, which provided biased findings. In their investigation, they revealed how several environmental elements impacted wheat output and efficiency. The outcomes depicted that technical efficiency and production function estimates are highly triggered by the environmental variations. Javed et al. (2010) and Javed et al. (2011) determined the technical efficiency of the rice-wheat system in agriculture and figured out the major factors affecting its inefficiency. For this work, a non-parametric method was used. Tobit form of regression analysis was adopted to explore the sources driving the system's of technical inefficiency. The effect of landholding on the technical and economic efficiency of small landholders in the rice-wheat system also indentified in this work. The data envelopment analysis was also performed (Issahakuet al., 2018; Quandt et al., 2020; Kelemu, 2016). According to Khan et al. (2022), landholders in Punjab's rain-fed zones could enhance wheat productivity by improving overall efficiency while sustaining the same level of farm inputs and innovative technologies. They used the stochastic Cobb-Douglas production frontier model to examine the overall technical efficiency of wheat production in the barani agricultural zone of Punjab province. According to Aslam and Li (2024), the country's agricultural industry yielded more returns than any other sector. Agriculture was the second-largest sector and played an unavoidable role since it supplied food for people, raw materials for industry, and serving as the primary trade source. When people lacked safe, secure food that was out of their reach financially and physically, there was food security (Jaleta et al., 2009; Lio et al., 2006; Ogutu et al., 2013). Furthermore, he said that given that our nation was agrarian and that rice was the second-largest food crop after wheat, the state of food security was startling. The problem of food accessibility is mitigated during the whole season by abundant food production, especially of wheat, rice, and maize (Aslam et al., 2015).

3. Material and Methods

In the district of Sialkot, 120 producers of wheat and rice were selected in the primary data collection purposes to determine the factors influencing the efficiencies as (technical, allocative, and economic efficiency) of the rice-wheat system in Pakistan's agriculture. The study's location was chosen to be Sialkot. This region is part of Punjab's rice-wheat belt, where various kinds of wheat and rice are cultivated. This district is among Pakistan's top ten districts for basmati rice production. The study was limited to Punjab, Pakistan's Sialkot area. The union council and tehsil of the district were chosen using a random selection procedure. From each union council, two villages were chosen at random in order to gather information as mentioned in Table 1.

Table 1: Classification of Farmers on the Basis of Farm Size

Size of Farm	Frequency	%
Small Farm	73	60.83
Medium Farm	30	25.00
Large Farm	15	12.50
Total	120	100.0

Village that was chosen at random for data collection was located in a different direction and at a different distance from the market. Eight communities in all were chosen to collect data. Fifteen respondents were chosen from each community. To get pertinent information about numerous farm-specific characteristics and the various farm-level activities that individual farmers use, a well-designed and pre-tested questionnaire was employed. The chosen respondents were then given this schedule, which they completed through in-person interviews. Efficiency, according to Farrell (1957), is a company's current productivity divided by its maximum productivity. The production frontier defines maximal productivity, often known as best practice (Bravo-Ureta and Pinherio, 1997).

A constant returns to scale was used to calculate technical efficiency (Coelli, et al. 1998). According to Coelli et al. (1998), a continuous return to scale The DEA model is only effective in situations where every company is functioning at its ideal scale, which is impossible in agriculture because of several restrictions. The fraction of the least price to the experimental cost is known as economic efficiency. The least cost was estimated using a cost minimization DEA model, in accordance with Coelli, et al. (1998). By splitting financial effectiveness by technical efficiency: allocative efficiency was calculated as Allocative efficiency is equal to the product of technological and economic efficiency.

There are two methods for examining the connections between different socioeconomic and farm-specific characteristics and inefficiencies on farms.

One approach is to perform a basic nonparametric analysis or calculate correlation coefficients. The second approach involves quantifying inefficiency and applying a regression model that expresses it as an indicator of socioeconomic and farm-specific variables. The study encompassed many socio-economic and farm-specific characteristics, such as the age of the small landholder, the years of education, interaction with extension agents, distance from the farm to the market, loan availability, and linkages/contacts by farmers to the extension office.

We employ the following Tobit regression model to investigate how these socioeconomic and farm-specific factors affect estimates of inefficiency:

$$E = E^* = \beta 0+\beta_1 Z_1+\beta_2 Z_2+\beta_3 Z_3+\beta_4 Z_4+\beta_1 D_1+\beta_2 D_1$$

$$E = 0 \qquad \text{if } E \leq 0$$

Where

i refers to the i^{th} farm in the sample.

Ei depicts technical inefficiency of the i^{th} farm.

Ei* is the latent variable.

Z_1 reflects the age of the small landholders (years).

Z_2 shows the qualification of the small landholders (years of schooling).

Z_3 portrays the number of visits of extension agents (numbers).

Z_4 presents the distance of farm from output market (kilometers).

D_1 is a dummy factor.

1 if farmer has adopted ICTs otherwise 0.

D_2 is a dummy factor.

1 if farmer has access to finance otherwise 0.

4. Results and Discussion

There are two sections in this chapter. Descriptive data based on farm size are presented in the first section, while the findings and comments based on the DEA technique and the explanation of inefficiency impacts are presented in this section.

4.1. Types of farms

There are three classifications for farm sizes: small, medium, and big farms. The small group of farms accounted for 60.83 percent of the overall farm size, while the medium and large categories contributed 25.0 percent and 12.50 percent, correspondingly, as Table 1 illustrates.

4.2 Age and farming experience

Productivity can also be impacted by the farmers' level of experience (Aslam and Li, 2024). Farmers' average age and experience are displayed in Table 2. Respondents in the small group averaged 49.17 years old and had 29.51 years of farming experience, whereas farmers in the medium category were 48.37 years old and had around 28.34 years of experience. Large farmers, they had been farming for 25.70 years and were 45.49 years old. This demonstrates that as one gets older, one has more agricultural experience.

Table 2: Average Age and Farming Experience of Small Landholders

Farm size	Average age(years)	Average experience(years)
Small Farm	49.17	29.51
Medium Farm	48.37	28.34
Large Farm	45.49	25.70
Total	47.68	27.86

Source: Authors own illustrations

4.3. Rice farmers' estimates of efficiency in pakistan's agriculture

Table 3 displays the rice's overall technical, allocative, and economic efficiency estimates. The study's findings show that the sample farms' overall technical efficiency has an average of 0.87 and a range of 0.73 to 1.0.

Table 3: Technical Efficiency of Small Landholder w.r.t. Rice Crop

Level of Efficiency	Frequency	%
70-80	63	52.0
81-90	42	35.0
91-100	16	13.0
Total	120	100.0
Efficiency (Overall)		
Average	0.87	
Maximum Value	1	

Minimum Value	0.73

Source: Authors own illustrations

These findings suggest that targeted farms might lower their input consumption by 13% on average while maintaining similar degree of output and technology if they were operating at maximum efficiency. The sampled farms' average allocative efficiency is assessed to be 0.70, with a high of 1 and a low of 0.40. The sample farms had an average economic efficiency of 0.65, with a range of 0.30 to 1.0. The study's findings also show that, using current technology, sampled rice farmers could cut their production costs by 35% while maintaining similar level of output if they worked at maximum efficiency.

Since farmers able to operate at 100% efficiency, the farmers in this group were doing so at that level. A technical efficiency score of at least 70 percent is required. Out of the 120 farms that were chosen, 63 landholders had efficiency levels between 70 to 80 percent. Therefore, 52.0 percent of landholders are up to 80 percent efficient. There are 42 farms in the 81–90 efficiency range. 35.0% of the landholders possessed up to 90% technological efficiency. Only 16 landholders are classified as having an efficiency level between 91 and 100. This can be explained by the fact that 13.0% of landholders have 100% technical efficiency. These findings concur with the studies of Karim et al. (2010), Abid et al. (2016), Ali et al. (2016), Habib et al. (2007) and Aslam et al. (2024).

Table 4 illustrates that the majority of the sampled farms had allocative efficiencies between 51 and 70. Among the 120 sample farms, a mere 3.33 percent exhibit an allocative efficiency greater than 0.90, 13.0 percent fall between 71 and 80, 47 percent fall between 61 to 70, 48 percent fall between 51 to 60, 1.7 percent fall between 41 to 50, and 4.2 percent farms fall among 30 to 40 in their allocative efficiencies respectively.

Table 4: Allocative Efficiency of Small Landholders w.r.t. Rice Crop

Level of Efficiency	Frequency	Percent
30-40	5	4.2
41-50	2	1.7
51-60	48	40.0

61-70	47	39.2
71-80	13	10.8
81-90	1	0.83
91-100	4	3.33
Total	120	100.0
Allocative Efficiency of Rice Farmers (Over all)		
Average	0.70	
Maximum Value	1.00	
Minimum Value	0.40	

Source: Authors own illustrations

Table 5 makes it clear that the majority of the sampled farms had economic efficiencies between 41 and 60. Out of 120 sampled farmers, only 1.67 percent have an economic efficiency of more than 71 to 80, 3.32 percent fall between 91 to 100 respectively as their economic efficiency.

Table 5: Economic Efficiency of Small Landholders w.r.t. Rice Crop

Level of Efficiency	Frequency	Percent
30-40	13	10.8
41-50	46	38.3
51-60	50	41.8
61-70	5	4.17
71-80	2	1.67
81-90	0	0
91-100	4	3.32
Total	120	100.0
Overall Rice Farmers' Economic Efficiency		
Average	0.65	
Maximum Value	1.00	
Minimum Value	0.30	

Source: Authors own illustrations

The degree of technical, allocative, and economic inefficiencies among small landholders are probably influenced by socioeconomic and farm oriented determinants. To identify the causes of these inefficiencies, the Tobit regression analysis is employed to individually regress the delineate the influence of socioeconomic and farm oriented determinants on these inefficiencies. When determining possible policy implications and comprehending the differences in inefficiency among farmers, the values of the slope coefficients of latent determinants in Tobit regression analysis are especially relevant. When a parameter has a negative value, it indicates that inefficiency is being reduced; when it has a positive sign, inefficiency is being increased.

4.4 Rice farmers' technical inefficiencies in Pakistan's agriculture:

Sources of inefficiency in technology shows that the technical inefficiency of farms in the rice-wheat system is positively correlated with the age of the small landholder, although the years of education, linkages with the extension workers, and access to financing are negatively correlated. The years of schooling variable's parameter is impacting negatively. This recommends that landholders with higher qualification are, on paper, less inefficient than the landholders with minimum or no education. It was also observed in the past work of Aslam et al. (2024), Habib et al. (2007), Zhu et al. (2021), Issahaku et al. (2018), Jaleta et al. (2009) and Aslam and Li (2024). Table 6 enlists the causes of the rice-wheat system's technological inefficiency.

Table 6: Determinants of Technical Inefficiencies of Farmer w.r.t. Rice Crop

Driver	Coefficients	Standard Error
Constant	0.3679	0.609
Age of farmers	0.832*	0.106
Education of farmers	-0.326*	0.539
ICTs Adoption	-0.427*	0.165
No. of Farmer Visit to Extension Agent	-0.505*	0.9079
Farm to Market Distance	0.547*	0.316
Credit Access	-0.443*	0.593

Source: Authors own illustrations
**Shows the significance level at 0.01 whereas **represents the significance level at 0.10.*

Better educated people are more likely to accept and employ technological inputs more optimally and efficiently, according to Aslam and Li (2024). The farmers with higher levels of education often have greater access to knowledge on the status of the newest technology and how to apply it. Longer schooling increases farmers' awareness, which improves productivity for educated farmers. The farmers with higher levels of education are probably more adept at interacting with financial institutions. The technical inefficiency of farmers is positively and considerably linked with the age of the small landholder, suggesting that young peasants are inherently less inefficient than the older folks. The results of the research work are supported by the studies of Aslam and Li (2024), Khan et al. (2022), Abid et al. (2016), Ali et al. (2016) and Aslam et al. (2024). Aged farmers could be reluctant to take chances and steer clear of frequent technological experimentation. Aged landholders are less likely to interact with information and communication technologies, advisory and extension workers and are less inclined to embrace innovative techniques along with contemporary inputs, according to Ali et al. (2016). According to Aslam and Li (2024), younger farmers may be better at acquiring knowledge and comprehending novel methods since they are more likely to have some formal schooling.

Strengthening the relationship is the negative and significant coefficient of contact with the variable of extension agents. This suggests that farmers who interact with extension agents more frequently than their colleagues who interact with them less frequently or not at all are, on paper, less inefficient. The study's conclusions are consistent by the research work of by Aslam et al. (2024). The apparent explanation for this link might be that farmers who interact with extension agents more frequently capable to learn the latest developments in authorized agricultural technology as well as its applications (Lio et al., 2006; Ogutu et al., 2013, Quandt et al., 2020).

A negative correlation exists between technical inefficiency and the quantity of farmer visits to extension agents. This demonstrates that farmers who receive more visits are, on the whole, less inefficient than others. They may use the advice of extension agents in the field, which is a clear explanation for their relationship.

The purpose of the accessibility to credit dummy variable is to examine how farmers' technological inefficiencies are affected by loan availability. The dummy variable for parameter estimates of access to finance had a negative relationship. The study's findings suggest in theory that farmers with more access to loaning facilities are more efficient than those with low or no access to credit facilities. The results of the study align with the studies of by Habib et al. (2007), Aslam et al. (2024), Aslam and Li (2024). The most obvious explanation for this link might be that having access to credit increases liquidity and makes it easier to buy inputs during peak seasons, such as better seeds, fertilizers, and insecticides. The availability of finance incentivize farmers to adopt high-yielding technologies in order to increase production per acre.

The technological inefficiency of farms is positively and strongly correlated with the farm to market distance variable. The parameter's positive sign for this variable matches the study's presumptive predictions. According to the study's findings, when market and transportation infrastructure improved, sampled farms' technical inefficiencies would dramatically decline. Price incentives alone, will not be sufficient to increase the supply of agricultural commodities unless they are combined with ongoing investments in rural infrastructure (Aslam and Li, 2024).

4.5 Wheat Farmers' Estimates of Efficiency in Pakistan's Agriculture

Estimates of total technical, allocative, and economic efficiency are shown in 9. The data clearly show that sample farms' overall technical efficiency ranges from 0.70 to 1.0, with an average of 0.85. These findings suggest that the sampled farms might lower their input consumption by 15 percent on average while maintaining the same level of production if they were operating at maximum efficiency.

The sampled farms have an average allocative efficiency of 0.88, ranging from a minimum value of 0.75 to maximum of 1. The sampled farms' mean economic efficiency is 0.82, with a range of 0.63 to 1.0, as shown by the joint impact of technical and allocative efficiencies. According to the study's findings, the sampled landholders in the rice-wheat system in the region exhibit significant allocative and economic inefficiencies. The study's conclusions also show that sample farms could cut their production costs by 27% while maintaining the same level of output and using the current equipment if they ran at maximum efficiency.

Table 7 demonstrates that most of the sampled farms' technical efficiencies are between 81 and 100. Out of the 120 sampled farms, 45.8 percent had technical efficiency between 91 to 100, 35.8 percent between 81 and 90, 15.0 percent between 71 and 80, and 3.33 percent up to 70. Very few farms have technical efficiency below 70.

Table 7: Technical Efficiency of Farmer w.r.t. Wheat Crop

Level of Efficiency	Frequency	%
60-70	4	3.33
71-80	18	15.0
81-90	43	35.8
91-100	55	45.8
Total	120	100.0
Technical Efficiency Overall		
Average	0.85	
Maximum Value	1.00	
Minimum Value	0.70	

Source: Authors own illustrations

Table 8 illustrates the majority of the sampled farms had allocative efficiencies between 60 and 80. Just 5.0% of the 120 sampled landholders had an allocative efficiency between 91 to 100, 5% have an allocative efficiency between 81 and 90, 44.1% have an allocative efficiency between 71 to 80, and 45.9% have an allocative efficiency between 60 to 70.

Table 8: Allocative Efficiency of Farmers w.r.t. Wheat Crop

Level of Efficiency	Frequency	%
60-70	55	45.9
71-80	53	44.1
81-90	6	5.0
91-100	6	5.0
Total	120	100.0
Allocative Efficiency Overall		
Average	0.88	
Maximum Value	1.00	
Minimum Value	0.75	

Source: Authors own illustrations

Table 9 makes it clear that the majority of the sampled farms' economic efficiency is between 61 to 80. Just 2.5% of the 120 samples landholders have an economic efficiency between 91 to 100, 5.83% have an economic efficiency exist between 81 to 90, 41.7% have an economic efficiency prevail between 71 to 80, 45.8 percent have an economic efficiency in between 61 to 70, and 4.17 percent having an economic efficiency between 50 to 60.

Table 9: Economic Efficiency of Farmers w.r.t. Wheat Crop

Level of Efficiency	Frequency	%
50-60	5	4.17
61-70	55	45.8
71-80	50	41.7
81-90	7	5.83
91-100	3	2.50
Total	120	100.0
Economic Efficiency (Overall)		
Average	0.82	
Maximum Value	1.00	
Minimum Value	0.63	

Source: Authors own illustrations

4.6 Technical inefficiency sources for wheat crop

Table 9 portrays that the qualification coefficient is negatively and profoundly correlated with farms' technical inefficiencies. This suggests that farmers with more years of schooling are, on the whole, less inefficient than those with lesser or no education. The most apparent explanation for their association in comparison to their less educated or uneducated fellow farmers, more qualified landholders had greater exposure to knowledge, accessibility of ICTs, and access to credit availability (Aslam and Li, 2024; Zheng et al., 2022; Zhu et al., 2021).

Table 9: Determinants of Technical Inefficiencies of Farmer w.r.t. Wheat Crop

Determinant	Coefficient	Standard Error
Constant	0.179	0.517
Age	0.196*	0.159
Education	-0.158*	0.515
ICTs Adoption	-0.241*	0.192
Farm to Marker Distance	0.369*	0.005
Number of Farm Visits by Extension Workers	-0.275*	.0105
Finance Availability	-.942**	.0114

Source: Authors own illustrations
**Shows the significance level at 0.01 whereas **represents the significance level at 0.10.*

The age variable's estimate is substantial and has a positive sign. The study's findings suggest that, in theory, young small landholders are less inefficient than their older folk. The younger farmers' greater access to information and communication technologies and extension services, together with their likelihood of having some schooling, may be the apparent explanation for this association. They could be less reticent and more receptive to adopting cutting-edge farming technologies. When it comes to farming, they could be more aggressive, nimble, and active than their elder counterparts.

There is a negative and noteworthy coefficient of ICTs variable. The study's findings show that farmers who interact with ICTs more frequently are, on the whole, less inefficient than their peers who interact with them less or not at all. Similar outcomes were mentioned in the studies of Kelemu (2016) and Aslam and Li (2024). One likely explanation for the association might be that growers who adopts ICTs more frequently are able to obtain knowledge about market trends, insect pest control, production practices, the most recent developments in agricultural technology, and the appropriate and timely use of inputs.

A negative correlation exists between technical inefficiency and the number of extension agents visit to farms. This demonstrates that farmers who receive more visits are, on the whole, less inefficient than others. The apparent explanation for this association is that they use the advice of extension agents for their farming practices. Technical inefficiency is negatively impacted by the availability to finance accessibility dummy variable. It suggests that, in the sampled region, landholders with better accessibility to finance are theoretically lesser inefficient than the landholders having low or no access to finance. This relationship's apparent cause might be because farmers' ability to organize inputs during peak seasons is facilitated by their access to financing.

The technological inefficiency of farms has a positive and substantial correlation with the production origin to output market distance. According to the study's findings, production origin nearer to the market had lower levels of technical inefficiency than farms farther away from it. The link may be explained by the evident fact that better infrastructure led to an improvement in the supply chain and input utilization, including fuel, fertilizer, insecticides, and authorized seeds Aslam and Li (2024), Khan et al (2022), Quandt et al. (2020), Abid et al. (2016), Ali et al. (2016), Issahaku et al. (2018), Jaleta et al. (2009), Lio et al. (2006).

5. Conclusions and Implications

The main objective of the current research assessed the technical, allocative, and economic efficiency estimates of major grains Pakistan's rice-wheat system, as well as to look into the factors that contribute towards technical inefficiency. One hundred and twenty respondents were selected to figure out the reasons of technical inefficiency in the region. The average technical, allocative, and economic efficiencies of the small landholders in the study region is 0.87, 0.70, and 0.65, accordingly, as per outcomes from DEA models used with rice crop. A wheat farmer's average technical, allocative, and economic efficiencies of the small landholders in the study area was 0.85, 0.88, and 0.82 accordingly. The findings of the Tobit regression techniques directed that the technical inefficiency of farms in the rice-wheat system is positively impacted by the age of the small landholders, but negatively impacted by the number of years of education, accessibility of ICTs, interactions with extension agents, and finance availability.

The study's most evident conclusion is that, in order to increase efficiency over an extended period of time, rural families need to be encouraged to adopt information and communication technologies (ICTs) and participate in formal education through decisive policies. This will help small landholders to allocate inputs more judiciously and allow them to make improvised and informed technical decisions. Access to advisory services and informal extension education may be beneficial for the farming community, particularly for individuals with less formal education. The study's findings reflected that small landholders who interact with extension service providers more frequent are less inefficient than the fellow farmers who have no or less interaction with these service providers. Therefore, it is suggested that policymakers concentrate on improving farmers' access to knowledge by offering higher-quality extension services including the provision of ICTs or promote the use/adoption of ICT tools. The study's findings showed that farmers with higher loan availability are more productive than those with less credit accessibility. It is also recommended that policymakers should devise policies that concentrate on improving the road and market infrastructure in the country. Addressing these inefficiencies could potentially strengthen the agricultural sector and would foster the rural development in the country.

6. References

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