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Roles of Personal, Household, Physical, and Institutional Factors on Farmers' Efficiency of Hybrid Maize Production: Implications for Food Security

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Abstract: This study explored the multifaceted factors influencing the efficiency of hybrid maize production and investigated the possible implications for food security. The study adopted a comprehensive approach, examining personal, household, physical, and institutional factors that affect farmers' productivity. Findings revealed the technical, allocative, and economic efficiencies through a combination of field surveys, data analysis, and econometric modeling. The mean technical, allocative, and economic efficiency scores for the sampled farms were 0.89, 0.66, and 0.59, respectively. Moreover, the result of Tobit regression analysis showed high significance of all three efficiencies. The significant factors associated with technical efficiency were farm size, age of farm household, maize farming experience, maize farming area, distance from the farm to the main market, number of visits by extension workers, credit access, and Okara district. In addition, the number of visits by extension workers, districts (Sahiwal and Okara), age of farmers, maize farming experience, and regional disparity (Sahiwal district) had substantial influences on allocative and economic inefficiencies in the hybrid maize-growing farms. Policymakers and agricultural stakeholders can develop focused strategies to improve farmers' productivity and overall food security by identifying the key factors associated with hybrid maize production. Tailored interventions that address knowledge gaps, improve resource allocation, and provide improved institutional support can help make food systems more sustainable and resilient.

Keywords: productivity; market access; sustainability; information; supply chain

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1. Introduction

Food is an essential building block that is required for the development of a nation. Food security is linked to the stability and sustainability of agricultural production. Maize cultivation is critical to global food production. Due to its high yield potential, it is widely grown throughout the world, including in Pakistan. Maize (*Zea mays* L.) is the third major cereal crop in Pakistan—after wheat and rice. It has the potential to play a vital role in feeding the Pakistani population. It is an alternate food source where the traditional cereal grains, i.e., wheat and rice, are scarce. Maize, being the most promising cereal crop in terms of productivity, has significant importance in developing countries such as Pakistan, where the population is increasing rapidly and a large proportion of the population remains undernourished. Maize contributed 3.4% of the value added in agriculture and 0.6% to the GDP during the 2020–21 farming season. Maize has several different uses in Pakistan; about 60% is used as poultry feed, 28% is used for wet milling, and 6% is used as food. Additionally, maize is a source of scarce foreign exchange and raw material in the food industry. According to one estimate, only two provinces—Punjab and Khyber Pakhtunkhwa—account for up to 98% of the country's total maize production [1].

Maize cultivation offers several advantages to farmers, especially in Punjab province. For instance, it is the best-suited crop for a large number of potato growers as it fits properly in their crop rotation cycles due to the short growth duration of both crops [2,3]. Although maize is cultivated all over the country, significant growing areas are in the districts of Sahiwal, Okaro, Toba Tek Singh, Pakpatan, Chiniot, and Faisalabad [4]. These districts are agroecological domains in central Punjab.

In Punjab, per acre production of maize is still low despite the availability of plenty of irrigation water and fertile soil. Low production in the area may be due to the use of traditional farming practices rather than contemporary technology. Several studies in Pakistan have documented the factors responsible for inefficiency in agriculture [4,5]. Efficiency plays a significant role in improving output, a goal that depends on the efficient allocation of limited resources [6]. On the other hand, ineffective resource management reduces production levels, which has a detrimental effect on farmers' capacity to make ends meet.

The adoption of better agricultural technologies and increasing the effectiveness of maize production can both increase maize productivity. However, in Pakistan, the rate of adoption of advanced technology is low [7–9]. Therefore, productivity gains are possible through the efficient use of available resources, for example, by improving their technicality and efficiency (technical efficiency) in farming.

Recently, the introduction of hybrid maize has doubled maize production in Pakistan. Most farmers in maize-growing areas now cultivate hybrid maize varieties. However, the yield levels remain lower than the potential of the maize varieties. Although many studies in the available literature have focused on assessing the technical, allocative, and economic efficiencies of various crops in Punjab, researchers have ignored the cultivation of hybrid maize in selected districts. Therefore, the efficiency of hybrid maize farming using technology and the available resources remains unknown. Previous research conducted in Punjab, Pakistan, and other countries in the region focused on identifying factors associated with efficiency and proposing policy interventions to enhance the productivity and technical efficiency of maize production [9,10]. However, a systematic investigation into the cost efficiency of hybrid maize farms, specifically in the four selected districts of Punjab (Chiniot, Faisalabad, Okara, and Sahiwal), is lacking, thus having a strategic importance in the maize economy of the country.

Farm Efficiency and Food Security: A Brief Survey of the Literature

Realizing greater efficiency of agricultural production is one of the major factors that ensure food security; hence, greater production/technical efficiency can effectively mediate food security, especially in developing countries where this efficiency remains modest [11–13]. There are ample insights linking increased efficiency in agriculture with a range of implications for food security. Dessale [14], for example, has suggested that food security can be effectively improved and poverty alleviated by increasing agricultural production efficiency. A similar link was shown to exist by [15,16], who portray a viable link between agricultural efficiency and food security. This is a very plausible and conceivable link as agricultural production involves farm and livestock production using natural resources such as water, land, and the environment, in addition to synthetic and biotic inputs. The production of grains, milk, sugar, beans, pulses, fruits, vegetables, meat, fish, and poultry involves combining various forms of inputs, which need ample consideration for proper application—both alone and in combination with other inputs—to ensure a high level of productivity from the fixed level of natural resources. Hence, proper use of an optimum level of inputs, either alone or in combination with other inputs, will greatly influence productivity, which will affect the level of food availability, access, and utilization, as well as the stability of the food supply.

Food security is greatly influenced by the production levels of food items grown on farms and the production level is linked to farmers' decisions on the use of key inputs inter alia land, water, seed, fertilizer, and labor, which can best be evaluated through efficiency measures—technical, economic, and allocative efficiencies [17]. Iheke and Onyendi, [17] further noted, in the case of Nigeria, that food insecurity is widespread within agricultural households and achieving food security will remain challenging without effectively addressing inefficiencies in production and resource allocation. Similarly, refs. [9,18] have examined the relationship between technical efficiency and food security in farming households using the stochastic frontier analysis (SFA) method and the probit model of data from Pakistan. Another aspect associated with gender vis-à-vis efficiency and food security has been studied by [16,19], who highlighted the significant impact of gender on technical efficiency and food security. Female-headed households were found to be vulnerable to maintaining food security in the households. Under the threats of climate change, natural resource degradation, and low coping capacity, food security comes under high risk due to low efficiency of input (production inefficiency), especially in Pakistan [9,20]. An increased level of allocative as well as production efficiency provides a greater cushion for diversification and increased productivity, leading to higher income. Such an increased level of income is a major source of ensuring food security, while diversification can be instrumental in promoting nutritional security—the utilization aspect of food security [21–23].

In addition, there is ample evidence of the promotion of efficiency in agriculture affecting/improving the food security of the masses. Nevertheless, there are a range of challenges that hamper the achievement of both outcomes, i.e., food security and production efficiency. This paradox is more conspicuous in developing countries and the dichotomy was noted by [24] who further highlighted that differences in household characteristics determine variations in the efficiency, food security, and income of households. Farm size, farming experience, and differentiation are other major factors that influence farmers' efficiency, which influence households' livelihoods and ultimately determine the level of food security. One of the major effects of farmers' efficiency on households' food security emanates from the former's role in improving/realizing a comparative advantage that makes the local products more competitive in the global market, thus helping to bring in added income. This increased level of earning strongly mediates the optimum consumption of nutritious food in ample quantities [25–28]. Hence, there is a great scope for linking farm efficiency with food security in Pakistan and other countries with similar contexts in the region, as there exists a major gap in identifying implications for food security through improving farm-level efficiency.

Hybrid maize inefficiency research has been substantial, with numerous studies concentrating on various aspects of maize production. Some studies examined the cost efficiencies, while others have identified the profitability and economic advantages of maize production. Moreover, some scholars have delved into the realm of economic efficiency and the allocation of land for maize cultivation. However, there remains a notable scarcity of studies that examine the role of personal, household, physical, and institutional factors on farmers' efficiency of hybrid maize production and their implications for food security. The significance of this research is that it can lead to concrete policy recommendations by analyzing, at a micro-level, in-depth interviews with farmers. The study area is also significant. Punjab province is the largest agricultural area and is an important region for hybrid maize production in Pakistan. The findings of this study are expected to clarify ways in which the efficiency of maize production can be improved in Punjab, Pakistan, or other regions around the world. Consequently, the primary objective of the current research study is to address this knowledge gap. To address this gap, the core objective of this study is to comprehensively examine the technical, cost, and allocative efficiencies of maize farms in Punjab. The study employs the data envelope approach to analyze the productivity and cost efficiency of maize farms, attempts to discern the significance of several factors linked to this efficiency, and identifies potential cost inefficiencies in maize production. The findings of this study will provide farmers and policymakers with valuable insights into how to enhance maize production by optimizing the utilization of available resources and technology, thereby addressing the food insecurity challenge in Punjab, Pakistan.

2. Materials and Methods

2.1. Study Area Selection and Sampling

In this study, survey-based data were collected from hybrid maize growers in December 2020 using well-structured questionnaires. Non-hybrid maize growers were excluded from the study. A multistage random sampling strategy was used to select the sample households. In the first stage, the Faisalabad and Sahiwal divisions were chosen randomly. In the second stage, two districts were chosen from each division. In the third stage, two tehsils were randomly selected from each district. In the fourth stage, two union councils were purposefully selected from each tehsil, keeping in mind the union council's distance from the main road and the main market. In the fifth stage, five villages were randomly selected from the already-selected union councils. In the last step, five farmers were randomly selected from each village. The 2 divisions selected and the 4 districts in these divisions are the major producers of maize and almost all of the hybrid maize is produced in these districts.

Overall, 400 farmers—100 farmers per district—were randomly selected from the study area using the following formula.

$$n = \frac{N}{(1 + Ne^2)} \quad (1)$$

where n represents the sample size; N is the total number of farming households in the study area; and e is the margin of error, which was set at ±15% (0.15). Map of study area is shown in Figure 1.

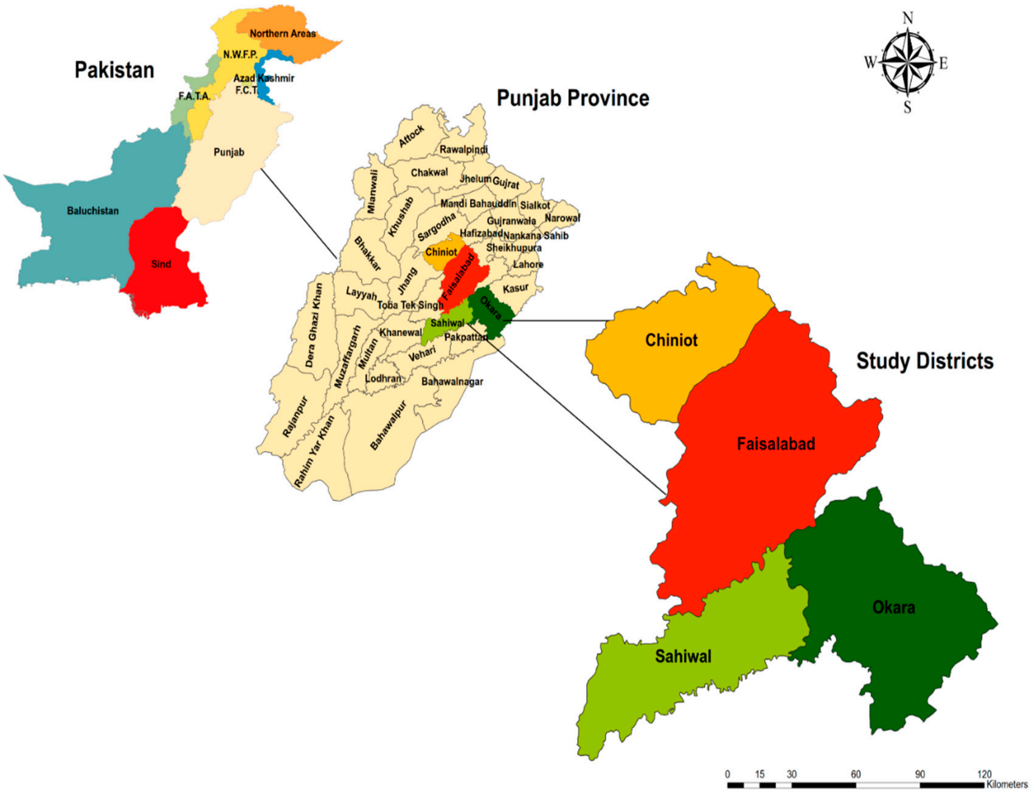

Figure 1. Map of the Study Area.

2.2. Data Envelopment Analysis (DEA) Approach for Estimating Technical Efficiency (TE)

Technical efficiency (TE) can be estimated using parametric and non-parametric techniques. Parametric techniques estimate frontiers and apply econometric methods to provide efficiency measures. An example of this is the stochastic frontier approach. On the other hand, the non-parametric method constructs an efficiency frontier and uses linear programming techniques to measure efficiency relative to the constructed frontiers. Data envelopment analysis is one such linear programming technique. In parametric approaches, several assumptions are made regarding the parametric forms of the function and the distribution of disturbance terms [29]. However, difficulties may arise in the statistical testing and theoretical substantiation of these assumptions and hypotheses. Due to these problems, parametric approaches are sometimes considered weak at estimating technical efficiencies [30].

Data envelopment analysis (DEA) is a non-parametric approach that uses linear programming techniques to estimate efficiency and/or inefficiency. First, a linear piecewise frontier is constructed from the available data. Therefore, any assumption regarding functional form and distribution of error terms is not required. Moreover, the DEA specification about not taking any assumptions counts is its main advantage, which is why it is widely adopted when specifying the relationship between inputs and outputs [31,32].

In the DEA, efficacy calculations are comparative as they relate to the data sample from which they are designed. These comparative rankings can be delicate if the number of farms in the sample is small relative to the number of outputs and inputs being considered [33]. In this study, the sample size of the farms is quite significant compared with the rule-of-thumb benchmark, $M \times N$, where M is the number of outputs and N is the number of inputs. Overall, DEA has the flexibility of accommodating numerous outputs and inputs in diverse units, where any defined relationship among them is termed an advantage.

According to [34], it is necessary to select an orientation from an input-oriented DEA model or an output-adapted DEA model based on which quantities the decision maker has more control over. Smallholder farmers in the study areas have more control over inputs than outputs. Accordingly, an input-oriented DEA model was used in the study. Besides, the constant return to scale DEA model is only appropriate when all firms are operating at optimal scale. However, it is not possible to hold this assumption in agriculture in the study areas since smallholder farmers face constraints. As a result, the variable return-to-scale DEA model was used in this study. The outcomes of the DEA in this study were efficiency scores, which represent performance indicators as 1 = best performance and 0 = worst performance. The best of the efficient decision-making units (DMUs) lie on the frontier, while the inefficient ones lie below. The efficient DMUs can be considered benchmarks for the inefficient DMUs. The inefficient DMUs can improve their performances to reach the efficient frontier by decreasing their current input levels [35]. The efficiency scores can be calculated using a linear programming model as presented in [36]. An input-oriented variable, i.e., the return-to-scale DEA model, was applied for technical efficiency estimation following [34].

min θ, λ θ, subject to:

$$-y_i + Y_\lambda \geq 0,\ \theta x_i - X_\lambda \geq 0,\ \lambda \geq 0 \tag{2}$$

where Y represents the output matrix of N number of hybrid maize farmers; θ is the total technical efficiency; λ represents Nx1 constant; X describes the input matrix for hybrid maize farmers; y_i represents the total revenue in rupees (PKR); x_i is the vector of inputs x_{1i}, x_{2i}, . . . x_{7i} (x_{1i} represents the area under hybrid maize (acres); x_{2i} expresses the total labor (man-days) required for all farm operations; x_{3i} represents the total farm machinery (Number) used in the farm operation; x_{4i} is the total quantity of seeds (Kg); x_{5i} represents total irrigations (number); x_{6i} is the total weight of fertilizers (Kg); and x_{7i} expresses the total pesticides and weedicides (Liter/acre) applied by the ith farmer.

2.3. Estimation of Economic Efficiency (EE)

The cost minimization DEA model is considered the first step in the estimation of economic efficiency and it is simply a ratio of minimum to observed cost as mentioned by Coelli et al. (1998) [34]. The cost minimization DEA model can be expressed as:

$$\begin{gathered} \min \lambda,\ xi^E / w_i xi^E \\ \text{subject to}: -y_i + Y\lambda\ \geq 0,\ xi^E - X\lambda \geq 0,\ N_1\lambda = 1,\ \lambda \geq 0 \end{gathered} \tag{3}$$

where w_i represents the input price vector; W_{i1} W_{i2}, ..., W_{7i}, $x_i{}^E$ represent the vectors of cost-minimizing input quantities; N refers to the total number of hybrid maize farmers in the sample; w_{1i} refers to land rent of the ith farm in Pak Rupees (Rs.); w_{2i} indicates the total cost of labor in Pak Rupees (Rs.); w_{3i} indicates the total amount of money spent on farm machinery in Pak Rupees (Rs.); w_{4i} indicates the total cost of seeds in Rupees (PKR.); w_{5i} indicates the total cost of irrigation in Pak Rupees (Rs.); w_{6i} indicates the total cost of fertilizers in Pak Rupees (Rs.); w_{7i} indicates the total cost of pesticides and weedicides in Pak Rupees (Rs).

Economic efficiency is simply a ratio of the minimum cost and observed cost.

$$\text{Economic Efficiency (EE)} = \text{minimum cost/observed cost} = w_i x_i^E / w_i x_i \tag{4}$$

2.4. Estimation of Allocative Efficiency (AE)

Allocative efficiency (AE) is a ratio of economic efficiency to technical efficiency.

$$AE = EE/TE \tag{5}$$

where AE, EE, and TE represent allocative efficiency, economic efficiency, and technical efficiency, respectively.

2.5. Tobit Regression Model

The technical, allocative, and economic inefficiency scores were separately regressed on socio-economic and farm-specific variables [37,38]. The range of efficiency scores is censored between 0 and 1 using DEA. Therefore, it shows that the dependent variable in the regression model was not normally distributed. This suggests that the potential bias arising from the non-normal distribution of the dependent variable does not allow for the use of the ordinary least squares technique [30,32]. Therefore, this study uses the Tobit regression model proposed by [39].

$$\begin{gathered} E_i = E_i^* = \beta_0 + \beta_1 Z_{i1} + \beta_2 Z_{i2} + \beta_3 Z_{i3} + \beta_4 Z_{i4} + \beta_5 Z_{i5} + \beta_6 Z_{i6} + \beta_7 Z_{i7} + \\ \beta_8 Z_{i8} + \beta_9 Z_{i9} + \beta_{10} Z_{i10} + \beta_{11} Z_{i11} + \mu_i \text{ if } 0\ \leq\ E* \ \leq\ 1 \\ \text{If } E* < 0,\ E = 0, \text{ and if } E* = 1,\ E > 1 \end{gathered} \tag{6}$$

where *i* represents the *i*th farmer in the sample; *Ei* represents the technical, allocative, and economic inefficiencies; Ei* is the latent variable; Z_{1i} represents the age of the farmers in the sample in years; Z_{2i} describes the education of the *i*th farmer in years; Z_{3i} represents the family size in numbers; Z_{4i} represents maize-farming experience in years; Z_{5i} represents the maize area in acres; Z_{6i} represents the distance of the *i*th farm from the main market in kilometers; Z_{7i} is a dummy variable with a value equal to 1 if a farmer has access to extension agent, otherwise it has a value of 0; Z_{8i} is a dummy variable with a value equal to 1 if a farmer has access to credit, otherwise it is equal to 0; Z_{9i} is a dummy variable with a value of 1 if the farm is in the Sahiwal district, otherwise it is equal to 0; Z_{10i} is a dummy variable with a value of 1 if the farm lies in the Faisalabad district, otherwise it has a value of 0; Z_{11i} is a dummy variable with a value of 1 if the farm lies in Okara district, otherwise it has a value of 0; $ß_i$ represents the unknown parameters to be estimated; and μ_i represents the error term. The variables on access to extension agent (Z_{7i}) and agricultural credit (Z_{8i})

are regarded as institutional variables following [40,41]. This is because these factors are beyond the control of farmers and have to be managed and run by relevant institutions.

The statistical software package "Stata 13.00" was used for the estimation of the Tobit regression model.

3. Results and Discussion

3.1. Descriptive Statistics

Table 1 presents the summary statistics of socio-economic variables for farms and farm households used in the regression model. The average age of hybrid maize growers is about 45 years, with a minimum age of 25 years and a maximum age of 70 years. The average education is about 7 years of schooling. The average family size is 6.27 members. Hybrid maize farmers had 12 years of farming experience, though some were new to this farming business. On average, the farming area under hybrid maize is about 33 acres. The average distance from the main road to the farm gate is approximately 5.60 km. We also used extension services, credit access, and region (Sahiwal, Okaro, Faisalabad, and Chiniot) as dummy variables in the Tobit regression.

Table 1. Descriptive Statistics of the study.

Age	Year	44.76	9.93	25.00	70.00
Education	Year	6.68	4.46	0	16.00
Family Size	Person	6.27	1.62	3.00	11.00
Maize experience	Year	12.20	5.45	2.00	26.00
Maize area	Acre	33.31	33.93	2.00	150.00
Distance from Market	Km	15.83	8.78	3.00	36.00
Extension Contact	Binary	0.77	0.43	0	1.00
Agri Credit Access	Binary	0.47	0.50	0	1.00
Faisalabad	Binary	0.25	0.43	0	1.00
Sahiwal	Binary	0.25	0.43	0	1.00
Okara	Binary	0.25	0.43	0	1.00

Note: authors' calculations from survey data, 2020.

3.2. Technical, Allocative, and Economic Efficiency Scores

The frequency distributions of the technical, allocative, and economic efficiencies of hybrid maize farmers are shown in Table 2. Results show that most of the hybrid maize farmers are in the range of 0.60–1.0. Out of 400 sample farms, about 45 percent have technical efficiency levels higher than 0.90, about 37 percent have efficiency levels between 0.80 and 0.90, and about 18 percent operate between 0.70 and 0.80. However, the allocative efficiency levels are lower.

Table 2. Distribution of Technical (TE), Allocative (AE), and Economic Efficiency (EE).

Efficiency Category	TE		AE		EE	
	Frequency	Percentage	Frequency	Percentage	Frequency	Percentage
$0.3 < E \leq 0.4$	-	-	-	-	4	1.00
$0.4 < E \leq 0.5$	-	-	16	4.00	89	22.25
$0.5 < E \leq 0.6$	-	-	113	28.25	144	36.00
$0.6 < E \leq 0.7$	4	1.00	138	34.50	103	25.75
$0.7 < E \leq 0.8$	70	17.50	87	21.75	33	8.25
$0.8 < E \leq 0.9$	148	37.00	33	8.25	17	4.25
$0.9 < E \leq 1.0$	178	44.50	13	3.25	10	2.50
Overall	400	100.00	400	100.00	400	100.00
Mean	0.89		0.66		0.59	
SD	0.09		0.11		0.12	
Min	0.67		0.43		0.36	
Max	1.00		1.00		1.00	

Note: E denotes efficiency.

The results of the DEA model show that the mean technical efficiency in the production of hybrid maize is 0.89, with a maximum of 1.00 and a minimum of 0.67 (Table 1). This implies that approximately 11 percent of excess inputs can be saved/reduced to operate at the existing technical efficiency levels while using the same technology with no effect on the existing output. The mean value of allocative efficiency is 0.66, with a maximum of 1.00 and a minimum of 0.43. The total cost can be reduced by 34 percent while still operating at the existing allocative efficiency levels. The average value of the economic efficiency of the hybrid maize farmers is 0.59, with a range of 0.36–1.00.

Results in Table 2 also indicate the distribution of farmers with respect to various categories of efficiency levels. The majority of farmers fall within the efficiency range of 0.60–1.0. Similarly, around 45 percent of farmers exhibit a technical efficiency of more than 0.90, whereas 37 percent of farmers lie within the 0.80–0.90 range. However, the allocative efficiency levels of these groups are relatively lower. The allocative efficiency (AE) of the hybrid maize farmers falls within the range of 0.50–0.90. Out of the 400 farms sampled, only 3.25 percent have an allocative efficiency between 0.90 and 1, 21.75 percent have an allocative efficiency between 0.70 and 0.80, about 35 percent have an allocative efficiency between 0.60 and 0.70, and about 29 percent have an allocative efficiency between 0.50 and 0.60.

Economic efficiency is more widely distributed, and most of the sample farms fall within the range of 0.40–0.90. Out of 400 farms sampled, only 2.50 percent have economic efficiency levels higher than 0.90, 4.25 percent have economic efficiency between 0.80 and 0.90, 8.25 percent have economic efficiency between 0.70 and 0.80, 25.75 percent have economic efficiency between 0.60 and 0.70, 36 percent have economic efficiency between 0.50 and 0.60, about 22 percent have economic efficiency between 0.40 and 0.50, and only 1% have economic efficiency between 0.30 and 0.40.

Table 3 shows the summary statistics of the DEA model. Results show that input usage varies across farms as it depends on the financial status of the hybrid maize farmers. The average yield on a maize farm is about 132,847 kg. In monetary terms, the average revenue per farm is about PKR 3,132,113 (PKR is an abbreviation for Pakistani rupee). On average, a farmer pays PKR 22,686 for land rent–calculated for six months of hybrid maize production. The average machinery cost is PKR 213,104, the average seed cost is PKR 230,487, the average irrigation cost is PKR 193,320, the average fertilizer cost per farm is PKR 734,873, and the average pesticide and weedicide cost is PKR 58,512 per farm. Farming hybrid maize is a labor-intensive activity, and the average labor cost is PKR 674,068 per farm.

Table 3. Descriptive statistics of the variables used in the DEA and Tobit analysis.

DEA Variables	Units	Mean	SD	Min	Max
Maize yield	Kg	132,847.00	145,347.06	6000.00	770,000.00
Maize area	Acre	33.31	33.93	2.00	150.00
Labor	man-days	527.60	684.35	18.00	3250.00
Farm machinery	Number	273.31	295.60	12.00	1540.00
Seed	Kg	325.19	342.16	20.00	1750.00
Irrigation	Number	401.36	415.28	20.00	1960.00
Fertilizer	Kg	17,732.69	18,784.19	800.00	96,250.00
Pesticides + weedicides	Liter	86.61	97.68	4.00	525.00
Input Cost and Output					
Overall revenue	PKR	3,132,113.25	3,443,187.79	135,000.00	15,840,000.00
Opportunity value of land	PKR	22,686.25	2886.21	15,000.00	27,500.00
Labor cost	PKR	674,067.52	804,331.01	37,660.00	3,861,000.00
Machinery cost	PKR	213,103.55	229,774.51	11,250.00	1,386,000.00
Seed cost	PKR	230,487.75	236,656.37	14,000.00	1,050,000.00
Irrigation cost	PKR	193,320.06	204,676.18	14,000.00	1,293,750.00
Fertilizer cost	PKR	734,873.31	780,834.52	33,200.00	3,297,000.00
Pesticides + weedicides cost	PKR	58,519.99	66,075.13	1700.00	450,000.00

3.3. Determinants of TE, AE, EE Efficiencies

The regression results of the Tobit model are shown in Table 3. Table 4 shows the Tobit regression results. Adnan et al. [15] revealed that the technical efficiency of the maize grower is determined by the farmer and the farm characteristics. Our findings show that the age of the grower is positively and significantly correlated with technical efficiency and allocative efficiency but has a negative impact on cost efficiency. Technical and formal education has a great impact on the farmers' technical efficiency because education increases technical, allocative, and economic efficiencies. Our findings are in agreement with previous studies that showed that educated farmers have more access to new techniques [7,42]. Maize-farming experience increases technical, allocative, and economic efficiencies. However, the effect is not statistically substantial for allocative efficiency. Distance from the main input and output market and agricultural credit facility are statistically significant and positively associated with technical efficiency, allocative, and economic efficiencies. Assuming that the distance from maize input and output market and agricultural credit facility contacts with extension staff as the institutional variable play vital roles in ensuring productivity and efficiency, our findings are in line with [43,44]. The positive sign of credit access shows that efficiency increases with the credit obtained. Perhaps the farmers did not have access to modern technology to enable them to be more efficient at spending money. Many times, credit availed—generally available at subsidized costs from Zarai Taraqqiati Bank Ltd. ZTBL (local name of Agri. Development Bank) at almost zero markup for the farmers—would be used for other things rather than on farming. Rizwan et al. [45] and [46] have explicitly noted the extent of misuse of farm credit in Pakistan, leading to a reduced level of both technical and allocative efficiency. According to [45], around 65 percent of the amount acquired in the form of agricultural credit was utilized for farming purposes while the rest was used for managing livelihoods and other business activities. Thus, when farmers have easy access to money, they can have leisure and go around with little focus on production activities on farms and simply use random inputs with little attention to quality, timing, dose, and requirement. This is the major externality of easily accessible farm credit that can easily promote inefficiency. In another study by [46] involving Khyber Pakhtunkhwa (KPK), the misuse of farm credit was greater than its proper utilization. The untoward uses thereof include expenses on healthcare, education, and marriages of children, as well as domestic needs and businesses.

Table 4. Results of the Tobit Regression analysis.

Independent Variables	Technical Efficiency	Allocative Efficiency	Economic Efficiency
Age	0.0020 ** (0.0009)	0.3880 (0.0012)	−0.0023 ** (0.00129)
Education	0.0010 *** (0.0009)	0.9980 ** (0.0012)	0.0009 * (0.00129)
Maize farming experience	0.0014 *** (0.0010)	0.2210 (0.0013)	0.0025 ** (0.00144)
Distance from market	0.0045 ** (0.0018)	0.5730 (0.0025)	0.0033 * (0.00265)
Agri credit facility	0.0197 ** (0.0082)	0.8850 * (0.0112)	0.0146 (0.01211)
Extension contact	0.0086 (0.0109)	0.0243 * (0.0133)	0.0142 (0.0137)
Faisalabad	0.0103 (0.0115)	0.7850 (0.0157)	0.0112 (0.01691)
Sahiwal	0.0188 * (0.0121)	−0.0080 (0.0165)	−0.0264 (0.01783)
Okara	0.0478 *** (0.0118)	0.1730 * (0.0161)	0.0114 (0.01734)
LR chi2	42.07	16.95	16.31
Prob > chi2	0.0000	0.0323	0.0382
Log-likelihood	436.4432	313.35911	282.923
Total observation		400	

Note: *, **, and *** represent significant levels at 0.10, 0.05, and 0.001, respectively.

The coefficient of extension contact has a positive effect on technical, allocative, and economic efficiencies but has a statistically significant impact on economic efficiency. This implies that access to extension services has positive effects on technical and economic efficiencies. This result further implies that technical and economic efficiencies increase with more meetings with extension staff. However, our results show that this effect is statistically significant. These findings are in line with the results of [33,44]. The dummy variable Sahiwal region is negatively associated with allocative and economic efficiencies; however, the coefficient of the Okara region (dummy) is positive and significantly associated with technical and allocative efficiencies. The coefficient of the Faisalabad region is positive; however, its effect is not statistically significant for any type of efficiency.

4. Conclusions

This study explored the role of farmers' personal, household, physical, and institutional factors on the efficiency of hybrid maize production and documented other prominent issues associated with hybrid maize farmers' efficiency. The results revealed that all factors associated with production enhanced hybrid maize productivity, while fertilizer and labor represented the highest share of the total cost. The overall technical efficiency of the sample farms was 89 percent, while allocative efficiency was 66 percent, and economic efficiency was 59 percent. The results of this study indicate that farmers can reduce production costs by up to 41 percent and still attain the same production level by utilizing optimal proportions and improving technical efficiency. Likewise, the findings also recommend that the current level of production can be potentially increased by 11 percent with the current level of inputs just by improving the technical efficiency of the farms. As the maize crop in Pakistan, especially the hybrid varieties, has demonstrated a great potential for contributing to food security, an improvement in the supply chain and processing at local levels would provide greater impetus for livelihood sustainability in rural settings. Alternatively, as the majority of farmers exhibit more than average levels of efficiencies, post-harvest operations and value-addition options can improve rural incomes, local employment, and food self-sufficiency. Another insight from the analysis is the role of market access. The positive coefficient of distance from the market implies that increased distance from the market would significantly increase the technical inefficiency of hybrid maize farming. Alternatively, the greater the distance of the maize farm from the relevant market—both input and output—the lower the technical efficiency would be. Although the private sector has been quite active in purchasing maize output, the input markets in rural areas are still imperfect, both in terms of conduct and infrastructure.

Moreover, Tobit regression was utilized to understand the sources of technical, allocative, and economic inefficiencies. The Tobit regression model revealed that the technical, allocative, and economic efficiencies were positively and statistically significantly influenced by personal, household, physical, and institutional factors such as education of the family head, agricultural credit facility, extension agent contact, and farming experience but significantly and negatively associated with age. The dummy variable for the Sahiwal region was statistically negative for allocative and economic efficiencies. Credit access at subsidized rates can also increase efficiency and this needs to be addressed both at the Government and farmer levels. Farm credit is meant for increased productivity and efficiency; however, the empirical finding in this study points otherwise. Hence, a thorough revisit is warranted to make this system focused, supervised, and target-oriented instead of just advancing loans and leaving it to the individual. Extension contacts are also positively associated with technical efficiency; therefore, the extension department may improve links with farmers and spread awareness about hybrid maize production. The findings also reveal that those farmers who have better access to the main or tarred roads and the main village market are technically more efficient than those who have no access or poor access to the main market and main road.

5. Policy Implications

The presented research findings have important policy implications for national maize production. To attain a conclusive understanding of hybrid maize farming efficiency and its determinants, the recommendation is to conduct comparative analyses across various provinces or regions in Pakistan. Such an analysis would offer a broader perspective, enabling the identification of regional variations in agricultural practices and levels of efficiencies. This comparative approach would identify the factors that influence hybrid maize farming outcomes in different geographical contexts and contribute to a more nuanced understanding of the subject. The government should upgrade the agricultural socialized service system to help farmers adopt new agricultural technologies in modern farming. Farmers should have easy access to quality hybrid maize seeds, fertilizers, pesticides, and other necessary inputs at reasonable prices. The government should conduct farm training programs on farmers' fields to enhance farmers' skills and knowledge about hybrid maize farming techniques, pest management, soil health, and conservation practices. Policymakers should also provide professional guidance for fertilization and pesticide application, aiming to avoid excessive use of fertilizers and pesticides and improve the efficiency of fertilizer and pesticide use. To improve the productivity and efficiency of maize farming, the government should focus on developing hybrid maize varieties—at local research stations—that are more resistant to the local climatic conditions, diseases, and pests.

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