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ESTIMATION OF TECHNICAL EFFICIENCY OF WHEAT FARMING IN KHYBER PAKHTUNKHWA, PAKISTAN: A STOCHASTIC FRONTIER APPROACH

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ABSTRACT: This study determined technical efficiency of wheat farmers in Khyber Pakhtunkhwa, Pakistan. Data from 300 wheat growers were collected through multistage stratified random sampling technique. Maximum likelihood estimation technique was applied to estimate stochastic frontier Cobb-Douglas production function to estimate the level of technical efficiency in wheat farming. Results showed that explanatory variables i.e., land under wheat crop, labor, chemical fertilizer, and tractor plough were statistically significant. The estimated elasticity for these variables indicated that a one percent increase in land under wheat crop, labor, chemical fertilizer and tractor plough would raise the wheat yield by 0.126, 0.248, 0.081, 0.226 and 0.066 percent respectively. The coefficient of farm yard manure was found insignificant. The estimated value of technical efficiency ranges from 39 to 94 per cent, with an average of 64 per cent. This means that if an average farmer opts to attain the technical efficiency level of its most efficient counterpart, then wheat yield could be increased by 32 per cent. Similarly the most technically inefficient farmer could enhance wheat yield by 58 per cent. Farmers' age, farming experience, farmer' education and land under wheat crop were major determinants of technical inefficiency. The relationship between farmers' age and technical inefficiency was positive and statistically significant implied that technical efficiency decreases with the increase in the farmers' age. The coefficient of farming experience was negative but statistically insignificant. The coefficient of farmers' education was negative and statistically significant which implied that inefficiency decreases with increase in the farmers' education in the study area. The relationship between technical inefficiency and land under wheat crop was positive suggesting that those farmers with relatively large farm size under wheat crop are technically inefficient but the coefficient is insignificant. It is suggested the use of more labor and tractor plough hours would increase wheat production in the country. Government of Pakistan should focus on formal as well as informal education in the country. Government should also encourage educated and young people to participate in agriculture particularly wheat growing.

KEYWORDS: Wheat, technical efficiency, stochastic frontier production function, Khyber Pakhtunkhwa, Pakistan.

1 INTRODUCTION

Wheat (Triticum aestivum L.) is the major food crop of larger part of Pakistan's population. Self-sufficiency in wheat is of immense important for sustainable food security since it is the key component of Pakistanis' diet. It contributes 3.1 per cent to GDP and 15 per cent to value added in food products [1]. Wheat production in Pakistan was 25.2138 million tons in 2010-11. The productivity of wheat which was 2553 kg/hectare in 2009-10 has increased to 2833 kg/hectare in 2010-11. In Khyber Pakhtunkhwa, the third ranked wheat producer province after Punjab and Sindh, in the year 2010-11 area under wheat was 724.500 thousand hectares, production 1155.800 thousand tons and productivity 1595 kg/hectare [2].

It is evident that food production in Pakistan grows at slower rate as compared to demand for food because population of Pakistan grows at the higher rate of 1.9 per cent. Through increasing productivity, especially of small farmers who are majority in Pakistan and putting emphasis on major wheat growing districts, food availability can be secured [3].

Productivity of agriculture sector can be accelerated by improving efficiency or introducing new technology or both. Improvement in efficiency is an appropriate option to increase the agriculture productivity in short run because adoption rate of new technology in Pakistan is very low [4]. In order to achieve sustained growth in agriculture, efficiency and productivity differentials have to be reduced by improving the management skills of the farming communities, knowledge, education and development of infrastructure [5][6]. In this backdrop, efficiency measurement of agricultural production is an important scenario in developing countries.

Farrell (1957) [7] proposed that economic efficiency can be divided in to two components, technical and allocative efficiencies. The term technical efficiency of a farm is its ability to produce the largest possible potential output from existing set of inputs and existing technology while allocative efficiency refers to the ability of a firm to produce at a given level of output using the least cost combination of inputs. A measure of producer's performance is one of the important tools for policy purposes and the concept of economic efficiency provides a theoretical base for such measure. Growth in agricultural sector and promoting productivity are effective tools for economic development. Wheat productivity growth is one of the important determinants of long-term economic growth and real per capita income growth which in turn are crucial factors of living standard and well being of the society. Enhanced productivity leads to improved returns to the producers as well as to labor and enables larger consumption of goods and services per person including health, education and other community services.

Very little analytic research has been carried out on technical efficiency of Pakistan's wheat crop e.g., [8][9][10][11][4]. Thus there is an intense need to carry out a comprehensive study on technical efficiency of Pakistan's wheat crop. It is anticipated that this study will help farmers to identify factors that affect wheat growers' technical efficiency and determining the opportunity for increasing output. The present investigation aims to estimate and examine technical efficiency of various resources used in the production process of wheat crop in Khyber Pakhtunkhwa, Pakistan.

2 DATA AND METHODOLOGY

This study was carried out in Khyber Pakhtunkhwa Province of Pakistan. The population for this study consisted of total number of wheat growers in Khyber Pakhtunkhwa Province. Data from 300 wheat growers were collected through multistage stratified random sampling technique. In the first stage Peshawar, Charsadda and Mardan districts were purposively selected, since these are major wheat producing and highly irrigated districts of Khyber Pakhtunkhwa Province. Peshawar, Charsadda and Mardan have 92%, 88% and 71% irrigated area under wheat, respectively, during 2008-09. Similarly, these districts produced 83.55 thousand tons, 86.38 thousand tons and 99.01 thousand tons of wheat, respectively, during 2008-09 [12]. In the stage second out of these three districts, one tehsil from each district was randomly selected. In 3rd stage, from each selected tehsil two union councils were selected randomly. In stage four from each selected union council one village was randomly selected. A pilot survey was carried out for collection of data on yield of wheat (kilogram per hectare) from 60 respondents, 10 respondents from each village. Using the following formula, the required sample size was determined [13]:

$$n = (S * Z_{\alpha/2} / e)^2 \tag{1}$$

Where;

n	=	Sample size
S	=	Std. Dev. of wheat yield (kilograms per hectare)
	=	441
Z (α/2)	=	1.96; the value of standard normal variate at 95% confidence level
e	=	Sampling error
e	=	50
n	=	298.84 ≈ 300

100 respondents from each district were selected applying proportional allocation sampling technique. List of wheat growers in each village were prepared with the help of halqa patwari of that village [13]:

$$n_i = n/N \times N_i \tag{2}$$

Where;

n_i = Sample growers in each village
n = Total sampled growers
N_i = Population of wheat growers in each village
N = Population of wheat growers in each District

Primary data for the current study were collected through well structured questionnaire during 2009-10, while secondary data were collected from various published and unpublished sources. An interview schedule was prepared in the light of study objectives. The primary data regarding wheat yield, inputs used in the production process and other factors involved in the production process were collected from 300 randomly selected wheat growers.

Literature reveals that econometric method is widely used to estimate technical efficiency of firms e.g., [14]-[18]. According to econometric method stochastic frontier production model is estimated. Stochastic frontier analysis was developed by Aigner, Lovell and Schemidt (1977) [19] and Meeusen and Van Den broeck (1977) [20] also called composed error model. Their work was independently based upon the measure of technical efficiency by Farrell in 1957 [7]. For the present study, assuming a suitable production function, we define the stochastic production frontier as follows:

$$Y_i = f (X_i, \beta_i) \quad (i = 1,2 ,---------- n) \tag{3}$$

$$Y_i = \beta_i X_i + \epsilon_i \quad (i = 1,2 ,---------- n) \tag{4}$$

Where Y_i is the output obtained by ith grower, X_i is the inputs applied by ith grower, β_i are the parameters and ϵ_i is the composed error term for ith grower consisting of ν_i and μ_i. ν_i is symmetric ($-\infty < \nu_i < \infty$) and covers the random (stochastic) effects which are beyond the control of farmers i.e., weather, breakdowns and natural disasters etc. ν_i is assumed to be independently and identically distributed as $N (0, \sigma^2_v)$ [21]. μ_i depicts farm specific technical inefficiency. It estimates the shortfall of output (Y_i) from its maximum possible output given the stochastic frontier $[f (X_{ij}, \beta) + \nu_i]$ [19]. u_i is independently and half normally distributed i.e. u_i - $[N (0, \sigma^2_u)]$. The disturbance ν_i and μ_i are assumed to be independent of each other. The term ν_i and μ_i are also assumed to be independent of physical inputs X_i. Stochastic frontier production model separates technical inefficiency effects from effects of those factors, which cannot be controlled by the farmers.

Present study estimated technical efficiency within the framework of Cobb-Douglas stochastic frontier production function. Cobb-Douglas production functional form has been utilized because of its ease of interpretation and estimation as follows:

$$\ln Y_i = \beta_0 + \sum_{i=1}^{n=7} \beta_i \ln X_i + \epsilon_i \tag{5}$$

Where;

Y_i = Yield of wheat grains in kilograms per hectare
X_1 = Land under wheat crop in hectares
X_2 = Number of labor days (man days) per hectare
X_3 = Chemical fertilizers in kilograms per hectare
X_4 = Number of tractor plough hours per hectare
X_5 = Farm yard manure in kilograms per hectare
X_6 = Dummy for Peshawar District i.e., 1 if Peshawar District, 0 otherwise
X_7 = Dummy for Charsadda District i.e., 1 if Charsadda District, 0 otherwise
ϵ_i = Composed error term
ln = Natural log
β_0 = Intercept
β_i = Parameters to be estimated

The stochastic frontier model was estimated by using maximum likelihood estimation (MLE) method. The basic idea of the ML principle is to choose the parameter estimates (β, σ^2_ε) to maximize the probability of obtaining the data. Therefore maximum likelihood estimation technique was used to estimate the stochastic frontier production model given as under:

$$\ln L = n/2 \ln [\pi/2] - n/2 \ln \sigma^2 + \sum^n_{i=1} \ln [1- F [\varepsilon_i \sqrt{\gamma} / \sigma \sqrt{(1-\gamma)}]] - 1/ 2 \sigma^2 \sum^n_{i-1} \epsilon^2_i \tag{6}$$

Where;

$\epsilon_i = Y_i - X_i \beta$ (7)
σ^2_v and σ^2_u are variances of v and u respectively,
$\sigma^2_\varepsilon = \sigma^2_v + \sigma^2_u$ (8)
$\gamma = \sigma_u^2/(\sigma_u^2 + \sigma_v^2)$ (9)
F = Cumulative density function

Technical inefficiency model is expressed as follows:

$\mu_i = \delta_0 + \delta_1 Z_{1i} + \delta_2 Z_{2i} + \delta_3 Z_{3i} + \delta_4 Z_{4i} + \omega_i$ (10)

Where;

μ_i = Farm specific technical inefficiency
Z_{1i} = Age of ith grower (years)
Z_{2i} = Farming experiences of grower (years)
Z_{3i} = Education of ith grower (years)
Z_{4i} = Land under wheat crop of ith grower (hectares)
ω_i = Random error normally distributed with mean 0 and constant σ^2
δ_0 and δ_i are the parameters to be estimated

For estimating individual farmers' technical efficiency the following formula was applied:

$T E_i = Y_i / Y_i^*$ (11)

Where;

Y_i = Output obtained by ith wheat grower
Y_i^* = Output obtained by wheat grower operating at frontier
$T E_i$ = Technical efficiency of ith grower (ranges between 0 and 1)

For estimating individual farmers' technical efficiency the following formula was applied:

$T I_i = 1 - T E_i$ (12)

$T I_i = 1 - [Y_i / Y_i^*]$

Where;

$T I_i$ = Technical inefficiency of ith wheat grower (ranges between 0 and 1)

3 Results And Discussion

The management practices and input use are likely to be influenced by various socio-agro-economic factors such as age of the farmer, educational level of the farmer, farming experience, access to information etc. These factors influence farmers to adopt any technology fully or partially. It is possible to attain a higher yield of different crops by adopting modern practices and the yield gaps can be minimized in this way [22]. Socioeconomic characteristics of farmers provide useful information to the researchers. The salient features of the wheat growers of the research area pertaining to their age, educational level, farming experience, and land under wheat crop are given in table 1.

Table 1 Socio-economic characteristics of the sampled respondents in the study area

Variables	Mean	Std. Dev.	Minimum	Maximum
Age	45.61	9.47	20.00	68.00
Farming Experience	24.11	9.26	5.00	50.00
Farmers' Education	5.61	5.44	0.00	16.00
Area (hectares)	1.67	1.09	0.10	6.07

Source: Survey Data; 2009-10

Table 2 Maximum likelihood estimates of the stochastic frontier production function in the study area

Variables	Parameters	Coefficients	Std. errors	t-ratios
Constant	β_0	5.820	0.187	31.122**
Ln Land under wheat	β_1	0.126	0.029	4.344**
Ln Labor	β_2	0.248	0.040	6.200**
Ln Chemical fertilizer	β_3	0.081	0.034	2.382*
Ln Tractor plough	β_4	0.226	0.043	5.256**
Ln FYM	β_5	-0.001	0.0012	-0.833
Technical inefficiency model				
Constant	δ_0	-9.822	2.244	-4.377**
Farmers' age	δ_1	0.090	0.049	1.836*
Farming experience	δ_2	-0.010	0.044	-0.227
Farmers' education	δ_3	-0.198	0.067	-2.955*
Land under wheat	δ_4	0.116	0.933	0.124
Peshawar dummy	δ_5	-4.526	2.083	-2.170*
Charsadda dummy	δ_6	-2.312	0.941	-2.460*
Sigma-U	σ_u	0.087		
Sigma-V	σ_v	0.041		
Gamma ($\sigma_u^2/\sigma_u^2 + \sigma_v^2$)	.γ	0.820		
Mean T E	X_{mean}	0.640		
Minimum T E	X_{min}	0.380		
Maximum T E	X_{max}	0.940		

*** and * indicates significance at 0.01 and 0.05 probability respectively,*
Source: Author's estimates from survey data, 2009-10.

Farmers' age is an important socioeconomic factor for adopting or rejecting a new technique or practice. Average age of farmers in the study area was 45.61 years ranging from 20 to 68 years with standard deviation of 9.47. Farming experience is also considered as one of the socioeconomic characteristics that affect farmers' decision regarding input use and other farm practices. Average experience of farmers in all the study area was 24.11 years ranging from 5 to 50 years with standard deviation of 9.26. Education plays an important role in the behavior formation, improving specific skills, rational use of scarce resources amicable to production [23]. Average level of education in all the study area was 5.61 years ranging from 0 to 16 years with the standard deviation of 5.44. Land under wheat crop operated by the farmers affects technical efficiency of the farmers. Average land under wheat crop in all the three districts was 1.67 hectares ranging from 0.10 to 6.07 hectares with standard deviation of 1.09 hectares.

According to the Log Likelihood Ratio (LR) test two models were estimated and then these models were compared. The formula for the LR test statistic is as follows:

$$\text{LR statistic} = 2\ [\ \ln H_0 / \ln H_1\ ] = -\ 2\ [\ \ln H_0 - \ln H_1\ ] \tag{13}$$

Where $\ln H_0$ denotes the log likelihood of the model when it is assumed that inefficiency is absent. And $\ln H_1$ the log likelihood of the model when it is assumed that inefficiency is present. If LR statistic is significant, then we reject the null hypothesis of no technical inefficiency. As our calculated LR statistic (40.46) is greater than tabulated χ^2 (12.59), so reject the null hypothesis of no technical inefficiency.

The estimated elasticities for the explanatory variables and efficiency levels of wheat growers are presented in table 2. Results show that explanatory variables i.e., land under wheat crop, labor, chemical fertilizer, and tractor plough were statistically significant. The estimated elasticity for these variables indicated that one percent increase in value of land under wheat crop, labor, chemical fertilizer and tractor plough would raise the wheat yield by 0.126, 0.248, 0.081, 0.226 and 0.066 percent respectively. The coefficient of farm yard manure (FYM) was found insignificant. The estimated value of technical efficiency ranges from 39 to 94 per cent. with an average of 64 per cent implies that if an average farmer opts to attain the technical efficiency level of its most efficient counterpart, then wheat yield could be increased by 32 per cent. Similarly the most technically inefficient farmer could enhance wheat yield by 58 per cent. Estimated value of γ (0.82) implies that 82 per cent of the total variation in wheat productivity was due to technical inefficiency of wheat growers.

Estimated value of LR test (40.76) was statistically significant, which follows Chi-square distribution. The estimated dummy variables for both, Peshawar and Charsadda, districts were found to be statistically significant at 5 per cent α; implies that technical efficiencies of the sample farmers are different from each others and also from the sample farmers of district Mardan.

The estimated coefficients of the explanatory variables for the technical inefficiency function are represented in the lower part of table 2. The relationship between farmers' age and technical inefficiency was positive and statistically significant implied that technical efficiency decreases with the increase in the farmers' age. The coefficient of farming experience was negative but statistically insignificant at all level of significance. The coefficient of farmers' education was negative and statistically significant. This means that inefficiency decreases with increase in the farmers' education in the study area. The relationship between technical inefficiency and land under wheat crop was positive suggesting that those farmers with relatively large farm size under wheat crop are technically inefficient but the coefficient is insignificant.

Comparing the mean technical efficiency of this study with other studies revealed that the mean technical efficiency is not far from the findings of [8][24][25] with the mean technical efficiency of 68, 67, and 67 % respectively. The average technical efficiency recorded from this study is higher than the one recorded by [9][26][27] with an average technical efficiency of 43, 53 and 51% respectively. Similarly the average technical efficiency recorded from this study is higher than the one recorded by [28][29][30][22] with an average technical efficiency of 84, 73, 89, and 84% respectively.

Figure 1 shows the frequency distribution of individual farmers of District Peshawar, Charsadda and Mardan and all three Districts. Average technical efficiency of wheat producers of District Peshawar, Charsadda and Mardan were 0.62, 0.64 and 0.67 respectively. The lowest efficiency ratio for Peshawar, Charsadda and Mardan Districts were 0.34, 0.39 and 0.42 respectively. Results further revealed that 42 percent of District Peshawar farmers lied between 0.61-0.70 in the efficiency ratio, while 39 percent of District Charsadda farmers lied between 0.61-0.70 in efficiency rating and Mardan (37%) farmers efficiency rating ratio ranging from 0.61-0.70.

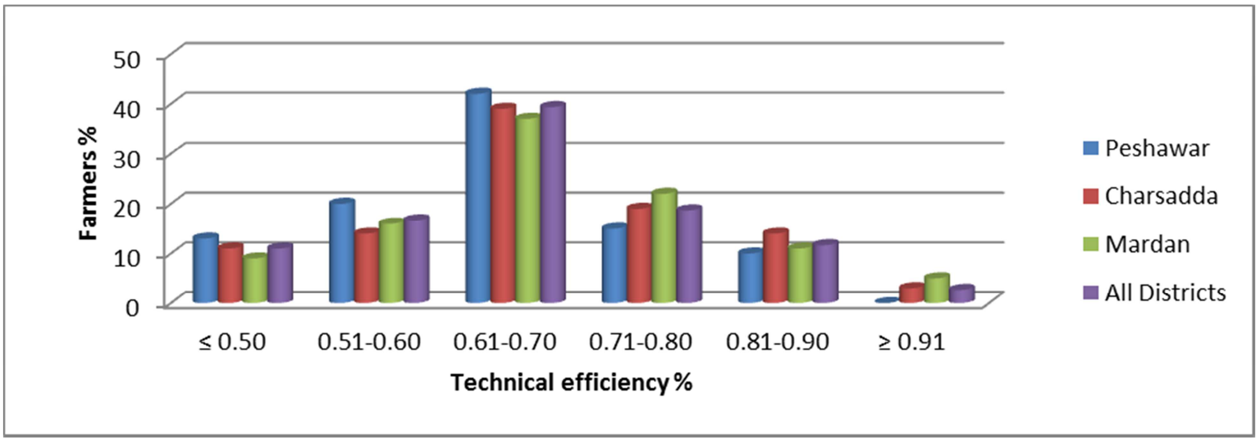

Figure 1 Frequency distribution of technical efficiency of wheat growers in the study area

4 CONCLUSION AND RECOMMENDATIONS

Stochastic frontier CDPF was used to estimate the level of technical efficiency in the study area. Major determinants of efficiency are land under wheat crop, labor, chemical fertilizer and tractor plough and FYM. Results indicated that one percent increase in value of land under wheat crop, labor, chemical fertilizer and tractor plough would raise the wheat yield by 0.126, 0.248, 0.081, 0.226 and 0.066 percent respectively. The coefficient of farm yard manure was found insignificant. The estimated value of technical efficiency ranges from 39 to 94 per cent. with an average of 64 per cent implies that if an average farmer opts to attain the technical efficiency level of its most efficient counterpart, then wheat yield could be increased by 32 per cent. Similarly the most technically inefficient farmer could enhance wheat yield by 58 per cent. Estimated value of γ (0.82) implies that 82 per cent of the total variation in wheat productivity was due to technical inefficiency of wheat growers. Major determinants of technical inefficiency were farmers' age, farming experience, farmer' education and land under wheat crop in hectares The estimated coefficient of farmers' age and technical inefficiency was positive and statistically significant implied that technical efficiency decreases with the increase in the farmers' age. The coefficient of farming experience was negative and statistically insignificant at all levels of significance. The coefficient of farmers' education was negative and statistically significant. This means that inefficiency decreases with increase in the farmers' education in the study area. The relationship between technical inefficiency and land under wheat crop was positive suggesting that those farmers with relatively large farm size under wheat crop are technically inefficient but the coefficient is insignificant. This concludes that wheat output in the study area may be increased considerably from available inputs and techniques of production. An increase in the employment of labor would increase the production of wheat. Tractor plough increased wheat production implying that wheat producers should apply more tractor hours to fully prepare the soil for wheat cultivation. This would increase wheat production in the country. As technical efficiency increases with the increase in the level of education, therefore, government needs to focus on formal as well informal education in the country. Encouragement of educated and young people to participate in agriculture is also a good policy option for boosting up wheat productivity in the country.

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