Research Article

Technical Efficiency of Wheat Production in District Peshawar, Khyber Pakhtunkhwa, Pakistan

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Abstract | This study was designed to determine technical efficiency of wheat production in district Peshawar of Khyber Pakhtunkhwa, Pakistan. Data from 100 wheat growers were collected through multistage stratified random sampling technique during 2009-10. Stochastic frontier analysis was employed for the estimation of technical efficiency levels and its determinants. Maximum likelihood estimation (MLE) technique was applied to estimate stochastic frontier Cobb-Douglas production function to ascertain the level of technical efficiency. The econometric computer software STATA was applied for the estimation. The estimated value of technical efficiency ranges from 34 to 88 per cent for the farms in the sample, with an average of 62 per cent. This means that if the average farmer in the sample was to achieve the technical efficiency level of its most efficient counterpart, then the average farmer could increase wheat yield by 30 per cent. Similarly the most technically inefficient farmer could enhance wheat yield by 61 per cent. Results further showed that one percent increase in value of land under wheat crop, labour, chemical fertilizer and tractor plough would raise the wheat yield by 0.052, 0.566, 0.130 and 0.438 percent, respectively and were found statistically significant. Farmers' education was found to be major determinant of technical efficiency/inefficiency. The estimated coefficient of farmers' education was negative and statistically significant, implies that technical inefficiency decreases with the increase in farmers' education. The use of more labour and tractor plough hours would increase wheat production in the country. The analysis revealed that the technical efficiency increases with the increase in the level of education. Government of Pakistan should focus on formal as well as informal education in the country. Government should also need to provide better educational opportunities to the rural population and extension education to wheat producers.

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Introduction

Wheat is a main cereal crop and is the staple food of many countries including Pakistan. It is grown almost all over the world. Wheat is one of the most abundant sources of energy and protein for the world population. Wheat is adapted to many soil types, has a short growing season, offers good yield, and grows well in fairly dry and mild climates, although the highest yielding crops require more optimal growing conditions. The total area under wheat in world was 223.56 million hectares in 2008, ranging between 207.66 to 226.85 million hectares during 1991- 2008. Out of the total area under wheat crop, 43.60% area under wheat crop was in Asia followed by Europe (27.6%), America (18.5%), Oceania (6.1%) and Africa (4.2%). Production of wheat in world increased from 546.88 MMT in 1991 to 689.95 MMT

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in 2008. Thus during the stated period total world wheat production increased significantly. The average annual increase was 1.51% with the strongest average annual growth in Oceania (15.29%) followed by Africa (3.86%), Europe (2.24%), Asia (1.89%) and America (1.42%). Out of total wheat production, 40.6% of world wheat is produced in Asia followed by Europe (36.0%), America (17.2%), Oceania (3.2%) and Africa (3.1%) in 2008 (FAO, 2009).

It appears that Germany is the world top wheat yielder, with the yield ranging between 5961 to 8087 kilograms per hectare (kg ha^{-1}), followed by France (6250 to 7606 kg ha^{-1}), China (3100 to 4762 kg ha^{-1}), US (2304 to3018 kg ha^{-1}), Canada (1832 to 2852 kg ha^{-1}), India (2281 to 2802 kg ha^{-1}), Pakistan (1841 to 2716 kg ha^{-1}), Russian Federation (1360 to 2446 kg ha^{-1}), Turkey (1787 to 2359 kg ha^{-1}), Australia (907 to 2167 kg ha^{-1}) during 1991-2008 (FAO, 2009).

Despite of the fact that Pakistan is the 9th largest wheat producing country in the world, it has remained net importer of wheat in the world market. Pakistan imported, on average, 1.453 million tons (239.221million $) of wheat each year during 1991-2007. During the same period in only three years, Pakistan's export of wheat has exceeded than imports but the amount was very meagre while in the remaining fourteen years exports were greater than imports (FAO, 2009). Wheat has been imported to meet the minimum food need of the country, over greater period of Pakistan's existence. Wheat imports in some years went over 2 million tons. In the current year, wheat deficit has further widened.

Wheat is a major source for food security in Pakistan. It provides livelihoods and income to millions of farmers in the country. Wheat has a unique position among the cultivated crops. It covers the largest area as compared to other crops in the country. Its value addition in agriculture, on average, is 13.20 % and it contributed 3.03% to Pakistan's GDP during 2001-2008 (GoP, 2008).

The importance of wheat crop is relatively more in Khyber Pakhtunkhwa compared to other provinces. In Khyber Pakhtunkhwa total wheat requirement was 2686.0 thousand tons, while its production was 1071.8 thousand tons during the year 2007-08. This is due to the fact that the productivity of wheat was very low in even the irrigated area (1968 kilograms per hectare) as compared to the national average yield (2451 kilograms per hectare) during 2007-08 (Govt. of Khyber Pakhtunkhwa, 2008).

The aforementioned discussion unveils that Pakistan is far behind in wheat production due to low productivity. The national strategic importance of food is evident in its consideration as a key variable in matter relating to national security and in planning against food requirements. However, a major indicator of depressed performance of the Pakistan wheat crop is the food crisis experienced in the country in the past years (Byerlee and Siddiq, 1994; Rajaram et al., 1998; Ahmad et al. (2002).

According to Nishimizu and Page (1982) and Srinivasan (2001) growth in productivity can be divided into two components, first one is innovations that create new and/or improved inputs and techniques of production and new uses for existing products, and second is growth in the efficiency of the use of these technologies. The latter requires technological capability like technical, managerial and institutional skills and building such capabilities in harmony with the dynamism of changing technologies (Kalirajan, 1991; Lall, 1993).

The analysis of efficiency dates back to Knight (1933), Debreu (1951) and Koopmans (1951). Koopmans (1951) provided a definition of technical efficiency while Debreu (1951) introduced its first measure of the 'coefficient or resource utilization'. Following Debrew in a seminal paper Farrell (1957) provided a definition of frontier production functions, which embodied the idea of maximization (Shuwu, 2006).

The term 'technical efficiency' was first introduced by Farrell (1957). According to Farrell, technical efficiency (TE) is associated with the ability of a firm to produce on the isoquant frontier. Technical efficiency can be measured in a relative sense. It is the departure of a firm from the best performance in a representative peer group.

Results of this study are expected to be helpful for those are engaged in decision making process at farm level and at national level as well. Reliable estimates of technical efficiency level and inefficiency factors are of great importance. Results of this study would provide information to wheat growers regarding better farm management practices. Planners and policy makers would also take help from the findings of this study in formulating appropriate measures to increase wheat production in Khyber Pakhtunkhwa in particular and in Pakistan in general. The objectives of present study are, therefore, to estimate technical efficiency in production across wheat growers and to identify technical inefficiency factors, if any, in wheat production.

Data and Methodology

This study was carried out in Khyber Pakhtunkhwa Province [(formerly known as North West Frontier Province (NWFP)] of Pakistan. The population for this study consisted of total number of wheat growers in Khyber Paktunkhwa Province. Multistage sampling technique was used for selection of the sample. In the first stage district Peshawar was purposively selected, since this is one of the major wheat producing and highly irrigated districts of Khyber Pakhtunkhwa Province (Government of Khyber Paktunkhwa, 2008). District Peshawar has 92% irrigated area under wheat during 2008-09 (Govt. of Khyber Pakhtunkhwa, 2010). In the stage second, one tehsil was randomly selected. In stage third from the selected tehsil two union councils were selected randomly. In stage four from each selected union council one village was randomly selected. 100 respondents were selected through proportional allocation sampling technique as follows (Cochran, 1977):

$$n_i = n/N \times N_i \quad \text{-----------------------} \quad (1)$$

Where;
n_i = Number of sample respondents in ith village
n = Total sample size
N_i = Total number of wheat growers in ith village
N = Total number of wheat growers

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 100 wheat growers.

Analytical framework

Review of literature shows that estimation of technical efficiency has been performed by two approaches namely parametric and non-parametric. Parametric approach makes use of econometric method whereas non-parametric approach is based on mathematical method (Data Envelopment Analysis). Battese (1992), Bravo-Ureta and Pinheiro (1997) and Coelli and Perelman (1999) have discussed advantages and disadvantages over each other.

- The econometric method is stochastic and it separates the effect of random error (noise) from the effect of inefficiency. The non-parametric method is nonstochastic and lumps noise and inefficiency and is referred to as combination inefficiency.
- The econometric method is parametric and restricts the effects of misspecification of functional form (of both inefficiency and technology) with inefficiency. The non-parametric method is non-parametric and less susceptible to this specification error.

However literature review reveals that econometric method is widely used to estimate technical efficiency of firms (Bravo-Ureta and Reiger, 1991; Kalirajin, 1991; Battese and Hassan, 1999; Hassan and Ahmad, 2005; Idiong, 2007; Feng, 2008; Kamruzzaman and Islam, 2008; Tchale, 2009; Theophilus, 2011). According to econometric method stochastic frontier analysis (SFA) was carried out.

Slochostic frontier analysis

Aigner et al. (1977) and Meeusen and van den broeck (1977) independently developed stochostic frontier analysis (SFA) also called composed error model. Their work was based upon the measure of technical efficiency by Farrell in 1957. Assuming a suitable production function, we define the stochastic production frontier as follows:

$$Y_i = f(X_i\ \beta_i) \qquad (i = 1,2,\text{------}n) \quad (2)$$
$$Y_i = \beta_i X_i + \varepsilon_i \ (i = 1,2,\text{--------}n) \quad (3)$$

Where;
Y_i = output obtained by *ith* farmer
X_i = inputs for *ith* farmer
β_i = parameters
ϵ_i = composed random error

$$\epsilon_i = v_i - \mu_i$$

Where;
v_i is symmetric ($-\infty < v_i < \infty$) and covers the random (stochastic) effects which are beyond the control of farmers i.e., weather, breakdowns and natural dis-

asters etc. It is assumed that v_i is independently and identically distributed as N (0, σ^2_{v}) (Gujarati and Porter, 2009).

Farm specific technical inefficiency was depicted by μ_i. In other words it estimates the shortfall of output (Y_i) from its maximum possible output given the stochastic frontier [$f(X_{ij}, \beta) + v_i$] (Aigner et al. 1977). u_i comes from a N (0, σ^2_u) is half normally distributed below 0. u_i and v_i are independent of each other (Gujarati and Porter, 2009). The term v_i and μ_i are also assumed to be independent of physical inputs X_i.

In the study at hand the stochastic frontier production function approach was used to study the effect of socioeconomic variables on the technical efficiency/inefficiency.

Model specification

Stochastic frontier production model was employed to estimate the technical efficiency in wheat production. This method separates technical inefficiency effects from effects of those factors, which cannot be controlled by the farmers. The first problem encountered with specification of stochastic frontier production model is the choice of functional form. It is desirable to choose that functional form, which meet the economically reasonable restrictions and does not present unreasonably complex estimation problems (Fuss and Mundlak, 1978). In the present study technical efficiency was estimated 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. Moreover, flexible functional form imposes the problem of multicollinearity. Cobb-Douglas stochastic frontier production function for this study is expressed as follows:

$$\text{In } Yi = \Sigma^n_{i=1} \beta i \text{ In } x i + \varepsilon i \text{----------------} (4)$$

Where;

Y_i = Output of wheat in kilograms per hectare

X_1 = Land under wheat crop in hectares (As most of the area under study is irrigated, therefore, land is assumed to be of homogeneous quality)

X_2 = Number of labour 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

ϵ_i = Composed error term

ln = Natural log

β_0 = Intercept

β_i = Parameters to be estimated

Estimation of SFA model

Maximum likelihood estimation (MLE) technique was employed for estimation of SFA (Green, 1980). 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.

$$\ln L = n/2 \text{ In } [\pi/2] - n/2 \ln \sigma^2 + \Sigma^n_{i=1} \ln [1- F [\varepsilon_i \sqrt{\gamma} / \sigma \sqrt{(1-\gamma)}]] - 1/ 2 \sigma^2 \Sigma^n_{i-1} \epsilon^2_i \text{ ----------} \quad (5)$$

$$\epsilon i = Yi - Xi \beta \qquad (6)$$

Where;

σ^2_v and σ^2_u are variances of v and u respectively,

$\sigma^2_\varepsilon = \sigma^2_v + \sigma^2_{u,}$

$\gamma = \sigma_{u/} \sigma_v$

F = Cumulative density function (cdf), estimated at ($\lambda \epsilon / \sigma_{u,}$)

The MLE of β, γ and σ^2_ε at which the value of the likelihood function is the maximum are obtained by setting the first order partial derivatives with respect to β, γ and σ^2_ε equal to zero and solving these non-linear equations simultaneously. Equation (3.8) can be estimated by using a non-linear optimization algorithm to find the optimal values of the parameters.

Estimation of technical inefficiency

For the estimation of technical efficiency it is assumed that v_i is distributed as N (0, σ^2_v) and u_i is half normally distributed as N (0, σ^2_u).

Technical inefficiency model is expressed as follows:

$$\mu_i = \delta_0 + \delta_1 Z_{1i} + \delta_2 Z_{2i} + \delta_3 Z_{3i} + \delta_4 Z_{4i} + \omega_i \text{-------} (7)$$

Where;

μ_i = Farm specific technical inefficiency

Z_{1i} = Age of the ith farmer in years

Z_{2i} = Farming experiences of the ith farmer in years

Z_{3i} = Education of the ith farmer in years

Z_{4i} = Land under wheat crop of the ith farmer in hectares

ω_i = Random error term normally distributed with 0 mean and constant σ^2

δ_0 and δ_i are the parameters to be estimated

Estimation of technical efficiency/inefficiency of individual farms

Table 1. *Summary statistics of survey variables in technical efficiency model*

Variables	Unit	Mean	Std. Dev.	Minimum	Maximum
Yield	kg	2424.15	321.20	1927.46	3113.59
Land under wheat	ha	1.45	1.06	0.10	5.46
Labor	MD	37.62	2.11	34.35	43.24
Chemical fertilizer	kg	267.19	44.76	185.33	398.12
Tractor plough	Hrs	10.00	1.40	7.41	12.36
FYM	kg	3080.79	1172.96	0.00	4497.40
Farmers' age	Years	47.89	8.24	24.00	68.00
Farming experience	Years	26.96	9.51	8.00	50.00
Farmers' education	Years	5.83	5.47	0.00	16.00

Source: Survey Data, 2009-10

For the estimation of technical efficiency of individual wheat farms, the following formula was applied.

$$TE_i = Y_i / Y_i^* \quad \text{-----------} \ (8)$$

Where
Y_i = Observed output of ith farm
Y_i^* =frontiers output of ith farm that can be achieved
TE_i = Technical efficiency of ith farm that ranges between 0 and 1.

For the estimation of technical inefficiency of individual wheat farms, the following formula was applied.

$$TI_i = 1 - TE_i \quad \text{------------} \ (9)$$
$$TI_i = 1 - [Y_i / Y_i^*]$$

Where
TI_i = Technical inefficiency of ith farm that ranges between 0 and 1.

Normality test (Jarque-Bera test of normality)

The Jarque-Bera (JB) test of normality is an asymptotic (large sample) test. It uses the formula as:

$$JB = n\,[(S^2 / 6) + (K-3)^2 / 24]$$

Where
n is sample size, S is Skewness coefficient and K is kurtosis coefficient. Under the null hypothesis that the residuals are normally distributed, JB statistic follows the chi-square distribution (Gujarati and Porter, 2009).

As the estimated p-value (0.124) is insignificant, suggesting that we cannot reject the hypothesis that data is normally distributed.

Results and Discussion

Summary statistics of survey variables in technical efficiency model

Table 1 indicates summary statistics of survey variables in technical efficiency model for District Peshawar. The average yield of wheat in district Peshawar was 2424.15 kilograms per hectare (kg ha^{-1}) ranging from 1927.46 to 3113.59 kg ha^{-1} with the standard deviation of 321.20 kg ha^{-1}. Average land under wheat crop was 1.45 ha ranging from 0.10 to 5.46 ha with the standard deviation of 1.06 ha. Average numbers of labour were 37.62 man days ranging from 34.35 to 43.24 man days with the standard deviation of 2.11 man days. Average application of chemical fertilizer was 267.19 kg ha^{-1} ranging from 185.33 to 398.12 kg ha^{-1} with the standard deviation of 44.76 kg ha^{-1}. Average tractor plough Hrs ha^{-1} was 10.00 ranging from 7.41 to 12.36 Hrs ha^{-1} with the standard deviation of 1.40 Hrs ha^{-1}. Average application of FYM was 3080.79 kg ha^{-1} ranging from 0 to 4497.40 kg ha^{-1} with the standard deviation of 1172.96 kg ha^{-1}.

Log Likelihood Ratio test for selection of functional form

The formula for the LR test statistic is as under.

$$\text{LR statistic} = 2\,[\ln H_0 / \ln H_1]$$
$$= -2\,[\ln H_0 - \ln H_1] \quad \text{------} \ (10)$$

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. Our calculated LR statistic (15.59) is greater than the

Table 2. *MLE results of the sampled farmers*

Variables	Unit	Parameters	Coefficients	Std. errors	t ratio
Constant		β_0	3.950	0.333	11.861**
Ln Land under wheat	ha	β_1	0.052	0.019	2.736**
Ln Labor	MD	β_2	0.566	0.108	5.242**
Ln Chemical fertilizer	kg	β_3	0.130	0.055	2.363*
Ln Tractor plough	Hrs	β_4	0.438	0.054	8.111**
Ln FYM	kg	β_5	-0.0035	0.0016	-2.188*
Technical inefficiency model					
Constant		δ_0	-55.401	39.053	-1.418
Farmers' age	Years	δ_1	0.921	0.754	1.221
Farming experience	Years	δ_2	-0.318	0.291	-1.092
Farmers' education	Years	δ_3	-0.359	0.164	-2.189*
Land under wheat	ha	δ_4	3.918	2.800	1.400
Sigma-U		σ_u	0.049		
Sigma-V		σ_v	0.026		
Gamma		.γ	0.780		
Mean TE		X_{mean}	0.620		
Minimum TE		X_{min}	0.340		
Maximum TE		X_{max}	0.880		

*** and * indicates significance at 0.01 and 0.05 probability respectively; Source: Survey Data, 2009-10*

Table 3. *Distribution of individual farmers according to technical efficiencies*

Efficiency level	Number
≤ 0.50	13
0.51-0.60	20
0.61-0.70	42
0.71-0.80	15
0.81-0.90	10
≥ 0.91	00
Mean TE	0.62

Source: Survey Data, 2009-10

critical value (12.59), so we reject the null hypothesis in favour of presence of inefficiency.

MLE results of the sampled farmers

Table 2 represents MLE results of technical efficiency of the sampled farmer in Peshawar district. The analysis depicted that explanatory variables i.e., land under wheat crop, labor, chemical fertilizer and tractor plough had positive relationship with wheat production and are found statistically significant. The estimated elasticity for these variables revealed that one percent increase in land under wheat crop, labour, chemical fertilizer and tractor plough would raise the wheat yield by 0.052, 0.566, 0.130 and 0.438 percent respectively and were found statistically significant. The coefficient of farm yard manure (FYM) was -0.0035 but is not according to our expected positive sign with almost negligible magnitude. This negative coefficient may be due to over use of FYM and farmer is operating in stage III of production in the application of FYM (Debertin, 2012). These findings are in line with the findings of Hassan and Ahmad (2005), Kolawole and Ojo (2007), Singh (2007), Hasan and Islam (2010), Nwaru et al. (2011) and Shaheen et al. (2011).

The estimated value of technical efficiency ranges from 34 to 88 per cent for the farms in the sample, with an average of 62 percent. This means that if the average farmer in the sample was to achieve the technical efficiency level of its most efficient counterpart, then the average farmer could increase wheat yield by 30 per cent [i.e., 1– (62/88) = 0.2955]. Similarly the most technically inefficient farmer could enhance wheat yield by 61 per cent [i.e., 1– (34/88) = 0.6136]. Comparing the mean technical efficiency from this study with other studies revealed that the mean technical efficiency is not far from the findings of Ahmad

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et al. (2002), Ahmad et al. (2005), Dolisca and Jolly (2008), Ghaderzadeh and Rahimi (2008) and Sadiq et al. (2009) with the mean technical efficiency of 68, 67, 63, 67 and 68% respectively. The average technical efficiency recorded from this study is higher than the one recorded by Ahmad (2003), Gul et al. (2009), Tchale (2009) and Shaheen et al. (2011) with an average technical efficiency of 43, 20, 53 and 51% respectively. Similarly the average technical efficiency recorded from this study is higher than the one recorded by Villano and Fleming (2004), Abedullah et al. (2006), Kolawole and Ojo (2007), Nchare (2007), Hossain et al. (2008), Ogundari (2008) and Hasan and Islam (2010) with an average technical efficiency of 79, 84, 73, 89, 75, 75 and 84%, respectively.

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 but statistically insignificant implied that farmers' age has no significant effect on technical efficiency in district Peshawar. The coefficient of farming experience was negative and statistically insignificant. The coefficient of farmers' education was negative and statistically significant. The relationship between technical inefficiency and land under wheat crop was positive but statistically insignificant.

Distribution of individual farmers according to technical efficiencies

Table 3 shows the frequency distribution of individual farmers of District Peshawar. Average technical efficiency of wheat producers were 0.62. The lowest efficiency ratio for Peshawar was 0.34 and highest efficiency ratio was 0.88. Results further revealed that 42 percent of District Peshawar farmers lied between 0.61-0.70 in the efficiency ratio.

Conclusions and Recommendations

Land under wheat crop, labour, chemical fertilizer and tractor plough and FYM were found to be the major determinants of wheat productivity. Results indicated that one percent increase in value of land under wheat crop, labour, chemical fertilizer, tractor plough and FYM would raise the wheat yield by 0.052, 0.566, 0.130, 0.438 and -0.0035 percent respectively and were found statistically significant.

The estimated coefficient of farmers' age and technical inefficiency was positive and statistically insignificant implied that farmers' age was not significantly affecting technical efficiency of wheat producers. 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 but statistically insignificant.

These results suggest that yield of wheat may be achieved from existing resources and techniques of farming. More use of labour in different activities would increase the wheat production. 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 study area. The analysis revealed that the technical efficiency increases with the increase in the level of education. Therefore Government of Pakistan should focus on formal as well as informal education in the country. Government should also need to provide better educational opportunities to the rural population and extension education to wheat producers.

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