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# TECHNICAL EFFICIENCY OF WHEAT PRODUCTION IN RAIN-FED AREAS: A CASE STUDY OF PUNJAB, PAKISTAN

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This study has analysed the technical efficiency in wheat production in the rain-fed cropping zone of Punjab through stochastic Cobb-Douglas production frontier. It is based on the cross sectional data of the wheat crop for the crop year 2009-10, collected from a random sample of seventy farm households. The mean technical efficiency of wheat production was 47.1 percent in the study area. The results signify that farmers of the rain-fed zone of Punjab have a scope to increase productivity of wheat through technical efficiency improvements under the existing conditions of input-use and technology. The yield of wheat can be doubled through adoption of better practices of technology. Seed rate has contributed negatively and significantly to wheat production, indicating that there is possibility to increase wheat production by decreasing seed rate. Irrigation application to the crop has significant positive contribution to wheat production indicating that there is scope for increasing wheat production by improvement in moisture availability through better conservation of rain water or investment in water sources. The inefficiency in wheat production was due to sowing of poor quality crop produce as seed year after year and large operational farm size in *Rabi* season. On the other hand, tractor ownership was a technical inefficiency decreasing farm characteristic

**Keywords:** Wheat productivity, food security, rain-fed, Stochastic Cobb-Douglas production frontier

## INTRODUCTION

Food insecurity is one of the major challenges faced by world. As many international organizations including Food and Agriculture Organization (FAO) and the World Food Program of the United Nations have warned of the impending onslaught of food security, at the global level (Niaz, 2008). Wheat is a major crop to address the food insecurity in Pakistan as it provides seventy two percent of the total protein and forty eight percent of calories in the daily diets of people in the country (Ministry of Finance, 2008). Over last three decades, production of wheat increased by 109 percent (from 11.5 million tones in 1981-82 to 24.0 million tones in 2008-09). However, the country has been importing significant quantities of wheat to meet the needs of its fast growing population. The fiscal year 2007-08 witnessed the worst ever wheat crisis in the history of Pakistan. The country imported 1.82 million tones (8.54% of the total requirement) and 3.19 million tones (15.91% of the total requirement) of wheat in years 2007 and 2008, respectively.

Though, wheat yield has increased over time by 69 percent; from 15.9 mounds per acre in 1986-87 to 26.9 mounds per acres in 2008-09 (Pakistan Bureau of Statistics, 1991 and 2011). However, improved semi-dwarf wheat cultivars available in Pakistan have genetic yield potential of 60 to 80 mounds per acre (PARC, 2012). Thus, there is a yield gap of about 55 to 65 percent. Yield gap for the wheat crop accounts about 40 percent in irrigated areas of Punjab and even more in the rainfed areas as the yield potential of the varieties recommended for these areas is almost equal to that for irrigated areas but yield obtained by the farmers even in the years with better rainfall is almost half of what is obtained in irrigated zones (Hussain *et al.*, 2011).

Punjab is classified into five agro-ecological zones viz. cotton-wheat, mixed, rice-wheat, low intensity and rain-fed. It is a major wheat producing province, with more than 75 percent contribution to the total wheat produced during 2010-11 in the country (Pakistan Bureau of Statistics, 2012). Rain-fed/*Pothwar* zone is comprised of five districts viz. Attock, Chakwal, Rawalpindi, Jhelum and Islamabad. Rain-fed zone is the smallest zone as per both area under wheat cultivation and production is concerned. In the crop year 2008-09, area under wheat cultivation and total production in this zone were 466.8 thousand hectares and 772.1 thousand tonnes respectively and it accounted for 6.8 percent of the provincial wheat area and 4.2 percent of the wheat production, respectively (Pakistan Bureau of Statistics, 2010).

A very small proportion of farms mostly in irrigated areas are experiencing fast growing modernization, while majority of the farmers both in irrigated as well as rain-fed areas are resource poor and loosing out even the existing potential. Either they are unaware of proper production technology or can not afford to adopt new technologies. Therefore, reducing polarization within the agriculture sector by helping the inefficient farmers to approach the frontier is very important. In the same context, identification of factors responsible behind yield gaps and finding solution to resolve stagnating productivity in different production systems is of vital importance. By addressing technical efficiency issues of the wheat farmers, we can increase wheat productivity and handle food insecurity challenge in the best possible way.

Citing few studies [e.g., Fan (1991); Lin (1992); Thirtle *et al.* (1995); Kalirajan *et al.* (1996), Ahmad and Ahmad (1998); Pingali and Heisey (1999) and Ahmad *et al.* (2002) etc.] it is argued that the existence of higher technical inefficiencies could fully offset the potential gains of highly superior technologies. Since technological development is a slow process, the increase in agriculture growth in future will depend on the stock of existing knowledge and how fast this knowledge is disseminated to the farmers. This will help in improving the technical efficiency of the growers. In this reference, so far more or less forty studies have been undertaken specifically for Pakistan, out of these eleven pertained to wheat crop. Five studies have been conducted in Punjab. Out of these two studies were pertained to rainfed areas of the province. The study conducted by Ahmad and Ahmad (1998) used time series data for the period of 1970-71 to 1996-97 for four districts of the rain-fed Punjab and applied fixed effects technique to the data. The results reported that mean efficiencies of Attock, Rawalpindi, Jehlum and Chakwal districts were reported at 89, 84, 88 and 88 percent respectively. Qasim and Knerr (2010) analyzed technical efficiency of wheat farmers in rain-fed zone of the province based on farm level data. Though in this study, an attempt has been made to find out determinants of wheat productivity under rain-fed conditions but important information about wheat yield and technical efficiency levels of the farmers are not given. Thus, there is an information gap about determination of technical efficiency level of wheat farmers in the rain-fed areas of the province. Furthermore, in view of increasing input prices (especially of fuel and fertilizers) and higher support prices announced by the government for wheat produce in the year 2008-09 and 2011-12, it is anticipated that over time changes in technical efficiency level of wheat farmers have occurred. Keeping all this in context, this study has been designed to analyze technical efficiency of wheat farmers in the rain-fed zone of Punjab by finding out determinants of wheat production and studying the effects of farm and farmer specific attributes associated with technical inefficiency on wheat production.

## MATERIALS AND METHODS

***Data collection and sample size*:** Multistage purposive random sampling technique was applied to collect the data for the study. First stage units were districts within cropping zone. Rawalpindi district was selected as it is one of the major wheat producing districts in the zone. Rawalpindi district is ranked third by area, after Attock and Chakwal districts in the zone with area allocation to wheat crop of 115.0 thousand hectares in the crop year 2008-09 and is ranked second by wheat production in the zone, after Attock district with a total production of 207.8 thousand tones (Pakistan Bureau of Statistics, 2010). Second and third stage units were tehsils and villages respectively. There are eight tehsils in Rawalpindi district viz. Rawalpindi town, Pothohar, Murree, Gujar Khan, Taxila, Kahuta, Kotli Suttian and Kalar Syedann (Wikipedia, 2012). Selection of tehsil and villages was made in consultation with agriculture extension department of the district. Tehsil Gujar Khan was selected for the field survey. Nine villages of the tehsil viz. Aadara, Chak Bhahadur, Chhokar, Daultala, Dhonika, Dokhra, Lodhay, Nata Mora and Nitha were visited to interview farmers. As the topographical and geographical characteristics are same across the study area, thus 6-8 farmers were interviewed from each of the villages of the selected tehsil. The farm level cross sectional data was collected for the crop year 2009-10. A total of seventy farmers were randomly interviewed by using a comprehensive questionnaire. The collected data were rechecked, edited and coded accordingly.

***Model specification and estimation*:** The technical efficiency of wheat farms was estimated using the stochastic frontier production function proposed by Aigner *et al*. (1977) and Meeuesn and Van den Brock (1977). The general from of the stochastic frontier function is:

$$\sum \ln Y_i = \alpha_o + \alpha_k \sum X_{ki} + V_i - \mu_i \qquad (1)$$

Where $Y_i$ is the dependent variable in the production function showing the per acre yield (kg) for the i-th farmer. $X_{ki}$s indicates input variables used by the i-th farmer. The $\alpha_o$ and $\alpha_k$ are unknown parameters to be estimated. Vi is usual error term which may result due to weather conditions, economic advertises or plain luck. While μi is non negative (one-sided) error term that captures inefficiency such as faults in management. For the inefficient farm, the actual yield is less than (or equal to) the potential yield. Therefore, the ratio of actual and potential output can be treated as a measure of technical efficiency. Using equation (1), technical efficiency (TE) of the i-th farm is derived as:

$$TE_i = \exp(-\mu_i) = Y_i / Y_i^* \qquad (2)$$

Where $Y_i$* is the maximum possible yield and Yi is the actual yield obtained by a sampled farmers. To study the effect of socioeconomic factors on inefficiency, it was observed that it is better done in a single-step rather than in two-step procedures (Wilson and Hadley, 1998; Battese and Coelli, 1995). The error term associated with technical inefficiency of the production of wheat farmers is assumed to be independently distributed, such that the technical inefficiency effect for the i-th farmer is obtained by traction (at zero) of the normal distribution with mean $\mu_i$ and variance $\sigma^2$, such that

$$\mu_i = \delta_o + \delta_m \sum Z_{mi} + \omega_i \quad (3)$$

Where $Z_i$s are socioeconomic characteristics of the farmers. The δs are unknown parameters to be estimated and are $\omega_i$s are unobservable random variables which are assumed to be independently distributed and obtained by truncation of the normal distribution with zero mean and constant variance ($\sigma^2$). Review of literature revealed that stochastic frontier production functions of Cobb-Douglas and translog specifications of stochastic frontier production model are most commonly used in analyzing technical efficiency in crop sector. The Cobb-Douglas form have advantage over the translog specification, as inclusion of square and interaction terms of the input variables in the production model results into multicollinearity problem, especially when the sample size is comparatively small. Therefore, the Cobb-Douglas functional form was used to estimate the individual technical efficiency and to examine the factors affecting it (equation 4).

$$\mathrm{Ln}\, Y_i = \alpha_0 + \alpha_k \sum_{k=1}^{5} \ln X_i + dD_x + V_i - \mu_i \quad (4)$$

Where,

$Y_i$ = Yield of the i-th farmer (kg)

$X_{ki}$ = Use of the k-th input by the ith farmer

$D_X$ = Dummy variable for a input use

$V_i$ = Random-error assumed to be identically and independently distributed N (0, $\sigma^2_v$)

$\mu_i$ = Firm specific inefficiency effect assumed to follow a truncated (at zero) normal distribution N ($\mu_i$ , $\sigma^2_u$).

The form of inefficiency model used for the study is as under.

$$\mu_i = \delta_o + \delta_m \sum_{m=1}^{4} Z_{mi} + dD_z + \omega_i \quad (5)$$

$Z_{mi}$ = Socioeconomic characteristics of farmers

$D_z$ = Dummy variable for a farm characteristic

The model (equation 3 and 4) were estimated using the computer programme Frontier 4.1 (Coelli, 1996) to estimate simultaneously the parameters of the stochastic production frontier and the technical inefficiency effects.

***Specification of the variables*:** Specification of the variables of production function is as under:

$Y_i$ = Yield of wheat on the i-th farm (kg per acre)

$X_1$ = Ploughings for seed bed preparation (number per acre),

$X_2$ = Seed use (kg/acre),

$X_3$ = Expenditures on weeds control (Rs./acre),

$X_4$ = NPK fertilizer nutrients application (kg/acre)

$X_5$ = Farm yard manure use (tons/acre)

$D_X$ = Dummy variable for irrigation application (value is one if crop was irrigated at least once during crop season, otherwise zero).

Specification of the variables of inefficiency model is as below:

$Z_1$ = Experience of the farmer in crop production (years)

$Z_2$ = Family size of the farmer (number)

$Z_3$ = Sowing period/ age of the main variety at farm (years)

$Z_4$ = Operational farm size in the Rabi season (acres)

$D_z$ = Dummy for tractor ownership (value is one if a farmer owns a tractor, otherwise zero)

## RESULTS AND DISCUSSION

***Sample characteristics*:** The mean and standard deviations of the variables used in the estimation of technical efficiency and its determinants are presented in Table 1. Rainfall in the Rabi season of crop year 2009-10 was comparatively poor in the study area. Thus, there was moisture stress condition in the Rabi season 2009-10 and mean crop yield was very low; 277 kg per acre. In the rain-fed areas, farmers plough land several times to conserve *monsoon* moisture and then prepare seed bed for wheat crop sowing. In the study area, mean number of cultivations for moisture conservation and seed bed preparation was around seven. Average seed rate for the crop was 45.1 kg per acre. Most of the farmer (70.0 percent) reported to apply weedicides to control weeds infestation of the crop. Mean expenditures on weeds control were Rs.377 per acre. Mean use of NPK fertilizer nutrients was 45.5 kg per acre. Majority of the farmers (58.3 percent) reported to use farmyard manure for the crop. Mean use of farmyard manure was 0.8 tons per acre. In the study area, one-fifth of farmers (19.4 percent) reported to have dug wells at their farms. These farmers reported to irrigated limited area of the crop two to three times during whole crop season.

Survey results revealed that in the study area, most of the farmers (90 percent) were very experienced and had been involved in this business since more than 10 years. Mean farming experience of the sampled respondents was 31.1 years (Table 1). Most of the farmers (70 percent) reported to live in joint family system, thus average family size was high in the study area (7.6 members per household). Majority of the farmers (60 percent) reported to sow seed of same variety since three or more years. Recommended varieties for rain-fed areas are; Chakwal-97, Wafaq-2001, NARC-09, GA-2002, Chakwal-50 and Horse-2009 (PARC, 2012). Only 8.6 per cent of the farmers in this zone reported to sow Chakwal-97 variety of wheat. Most of the farmers (52.9 percent) reported to sow seed of Inqlab-91 variety, followed by seed of Saher-2006, Uqab-2000 (17.1 percent each) varieties. Remaining farmers (4.3%) reported to sow seed of other non-recommended wheat varieties. Average

**Table 1. Mean, standard deviation and percentage of key variables**

| Crop Specific Variables | Mean | Standard Deviation | Minimum | Maximum |
|---|---|---|---|---|
| Yield (kg/acre) | 277.3 | 217.1 | 60.0 | 1200.0 |
| Ploughings for seed bed preparation (No./acre) | 6.7 | 1.8 | 4.0 | 11.0 |
| Seed use (kg/acre) | 45.1 | 4.2 | 40.0 | 56.0 |
| Expenditures on weeds control (Rs./acre) | 377.2 | 318.7 | 0.0 | 1200.0 |
| NPK fertilizer nutrients (kg/acre) | 45.5 | 14.5 | 27.6 | 66.5 |
| Farm yard manure use (tons/acre) | 0.8 | 1.6 | 0.0 | 8.0 |
| Irrigation application to the crop (% farms) | | 20.0 | | |
| **Farmer, Household and Farm-specific Variables** | | | | |
| Experience of the farmer in crop production (years) | 31.1 | 15.8 | 2.0 | 65.0 |
| Family size of the farmer (No.) | 7.6 | 4.5 | 2.0 | 26.0 |
| Sowing period/ age of the main variety at farm (years) | 4.1 | 3.1 | 1.0 | 15.0 |
| Operational farm size in *Rabi* season (acres) | 9.7 | 8.8 | 1.0 | 42.0 |
| Wheat area (acres) | 4.6 | 3.6 | 1.0 | 18.0 |
| Tractor ownership (% farmers) | | 41.6 | | |

age or sowing period of main wheat variety at the farm was about four years. Mean operational farm size of the sampled farmers in the Rabi season was 9.7 acres with area allocation to wheat crop of 4.6 acres. Most of the farmers in the area are resource poor and lacks in ownership of farm machinery. Similarly, tractor ownership was reported by less than half of the farmers (41.6 percent).

***Estimation of Frontier Production Function*:** Technical efficiency and factors influencing technical efficiency were examined by fitting frontier production function model including the explanatory factors of technical inefficiency. The results obtained are presented in Table 2. The maximum likelihood estimates of stochastic frontier production model revealed that coefficient of seed rate had a negative sign and was significantly different from zero at one per cent level, i.e. it is contributing negatively towards wheat production. This implies that farmers in the rain-fed zone sow higher than recommended seed rate for wheat crop. Recommended seed rate for rain-fed areas is 40 to 45 kg per acre (PARC, 2012), while considerably large number of the sampled farmers (43.3 per cent) reported to sow more than recommended seed quantity for the crop. Similarly, Bettese and Hassan (1999) and Hassan and Ahmad (2005) also reported that wheat farmers used more than recommended seed rate in cotton-wheat and mixed cropping zones of the Punjab province respectively. So, there is a need to teach farmers to use recommended seed rate for the wheat crop in the study area as well as in the whole province. Negative coefficient of seed rate also imply that farmers use poor quality farm produce as seed which results into germination of more than recommended number of plants per unit area with low vigor to bear the adverse arid climatic conditions, which ultimately results into low crop production. Moreover, most of the farmers in the study area sow seed of the crop varieties recommended for irrigation areas. The variables for irrigation were significant at one per cent level and implies

**Table 2. Maximum likelihood estimates of Stochastic Frontier Production model**

| | Parameter | Standard Error | t-value |
|---|---|---|---|
| $B_0$ | 21.3527 | 4.0318 | 5.2960*** |
| Ln cultivations (No.) | -0.4013 | 0.3828 | -1.0484 |
| Ln seed use (kg) | -3.7435 | 1.0068 | -3.7180*** |
| Ln weeds control cost (Rs.) | 0.0380 | 0.0273 | 1.3913 |
| Ln NPK nutrients (kg) | -0.0600 | 0.0622 | -0.9649 |
| Ln FYM (tons) | 0.0090 | 0.0294 | 0.3079 |
| Irrigation (dummy) | 0.2718 | 0.2226 | 2.0150** |
| **Variance Parameters** | | | |
| Sigma square | 0.3258 | 0.0993 | 3.2780*** |
| Gamma | 0.6803 | 0.4173 | 1.6802* |
| Log likelihood function | | -42.1296 | |

*Note: ***, ** and * indicated significance at 1 and 5 and 10 percent levels, respectively.*

that irrigation application to the crop would add 0.27 percent to the wheat yield. Most of the other variables had expected signs but were statistically insignificant. The signs of the variables of cultivations for the wheat crop production and fertilizer nutrients use were negative, which means that farmers had to excessively plough the land for moisture conservation in drought conditions in anticipation of rainfall. The positive impact of the fertilizer nutrients on crop production is linked with availability of sufficient water availability. The negative signs of these variables show that there is severe water (moisture) shortage in the study area which results into negative impact of fertilizer on the crop productivity. The findings about negative contribution of fertilizer nutrients to wheat production are similar to Qasim and Knerr (2010) who studied the technical efficiency of wheat farmers in the rain-fed zone of Punjab province of Pakistan and Ghaderzadeh and Rahimi (2008) who analyzed the technical efficiency of wheat farms in rain-fed areas of Kurdistan province of Iran. The signs of weeds control cost and farmyard manure use were positive but insignificant.

Mean technical efficiency of the sampled farmers was 47.1 percent, implying that on an average 52.9 percent of their technical potentials in wheat production are not being realized (Table 3). In other words, indicating possibility of improving wheat yield by more than fifty percent by following efficient crop management practices. The technical efficiency level of wheat and other crops' farmer in the study area was low than the wheat and crop farmers of arid areas in the neighboring countries. Ghaderzadeh and Rahimi (2008) reported that mean technical efficiency level of the wheat farmers in rain-fed areas of Kurdistan province of Iran was 65.5 percent. Coelli and Battese (1996) reported that mean technical efficiency scroes of crop farmers at village level in different arid zones of India were ranged from 71.0 to 74.0 percent. Similarly, a decrease in the technical efficiency level of the wheat farmers can be conceived over time by comparing results of present study with the finding of the study conducted by Ahamd and Qureshi (1999) in rain-fed zone of the Punjab province of Pakistan. They reported that mean technically efficiency score of the crop farmers was 62.0 percent. Table 3 shows the frequency distribution of estimated technical efficiency for the sampled farmers. It is observed that most of the wheat farmers were really inefficient in wheat production, as 70 percent farmers had technical efficiency scores equal to less than 60 percent. About one-fifth of the farmers (23.2 percent) had efficiency scores in the range of 61-80 percent and just seven percent farmers had efficiency scores above 80 percent level.

The inefficiency could be due to personal, household and farm specific factors (Table 4). Sowing period or age of the main variety at the farm and operational size had positive signs and were statistically significant. It means that these farm specific factors are causing inefficiency in wheat production in the rain-fed zone. Coelli and Battese (1996) also reported that farm size was inversely related to technical efficiency scores of the crop farmers in rain-fed zones of India. On the other hand, dummy variable of tractor had a negative sign and was statistically significant, which means that tractor ownership had a positive impact on wheat

**Table 3. Technical efficiency levels and distribution of the sample farms into categories by efficiency levels**

| **Efficiency Levels** | **Percent** |
|---|---|
| Maximum | 86.4 |
| Minimum | 9.3 |
| Mean | 47.1 |
| Standard deviation | 25.6 |
| **Efficiency Categories** | **Percent Farmers** |
| ≤20 | 10.8 |
| 21-40 | 32.1 |
| 41-60 | 26.8 |
| 61-80 | 23.2 |
| 81 and above | 7.1 |

**Table 4. Estimates of the influence of farm-specific factors on technical efficiency**

| | **Parameter** | **Standard Error** | **t-value** |
|---|---|---|---|
| $\delta_\circ$ | 0.5941 | 0.6358 | 0.9344 |
| Experience (year) | -0.0104 | 0.0074 | -1.3956 |
| Family size (No.) | 0.0284 | 0.0262 | 1.0819 |
| Age of main variety at farm (years) | 0.1107 | 0.0453 | 2.4463*** |
| Rabi season operational farm size (acre) | 0.0349 | 0.0175 | 1.9917** |
| Tractor ownership (Dummy) | -1.0287 | 0.4996 | -2.0591** |

*Note: *** and **indicates significance at 1 and 5 percent levels, respectively.*

production in rain-fed areas. Farming experience and family size were insignificant while had expected signs.

***Conclusion and Recommendations*****:** Seed rate, moisture or irrigation water availability are significant determinants of wheat yield in the rain-fed cropping zone of Punjab. The mean technical efficiency of wheat production has been found to 47.1 percent. Thus there is a scope to increase wheat yield through technical efficiency improvement under the existing conditions of input use and technology. If the efficiency could be improved, farmers will gain considerably in terms of higher production. Furthermore; technical inefficiencies are significantly and positively related to age of the main variety at farm and Rabi season operational farm size, while, tractor ownership have a significant negative impact on technical inefficiency of the wheat farmers. Keeping in view the results of this study it is suggested that farmers should be taught to use appropriate seed rate. The use of poor quality crop produce as seed should be discouraged and farmers should be taught to use certified seed of wheat varieties approved by the agricultural department for rain-fed areas. Improved extension services can play effective role in this regard. Moreover, efficient moisture conservation practices or increase in irrigation water availability could also have a very positive impact on wheat production. Rain-fed farming is very risky in nature, thus resource poor farmers are diverted to different farm and non-farm activities hence efficiency for the crops is reduced. This is also evident from negative and significant relationship of technical inefficiency with Rabi season operation farm size. Farmers are unwilling to avail institutional credit due to risky nature of rain-fed farming; therefore, public sector should come forward with some policy to provide farm machinery on rental basis to the area farmers.

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