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RESEARCH ARTICLE

Technical Efficiency of Wheat Production in Punjab (Pakistan): A Cropping Zone Wise Analysis

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ABSTRACT

The study was conducted to analyze the technical efficiency in wheat production across major cropping zones of the Punjab (Pakistan) through Cobb-Douglas production frontier. It was based on the cross sectional data of the wheat crop for the year 2009-10, collected from a random sample of seventy households each from mixed, cotton-wheat, rice-wheat and rain-fed zones. The mean technical efficiency of wheat production was 76.2, 83.5, 76.9 and 57.4 per cent in mixed, cotton-wheat, rice-wheat and rain-fed zone, respectively. The results signify that there is a scope to increase wheat productivity through technical efficiency improvements under existing conditions of input use and technology. In the irrigated zones, use of farm yard manure contributed positively to wheat production; the coefficients were significant (15% level) for cotton-wheat and rice-wheat (1% level) zones. Number of irrigations applied to wheat crop also contributed positively to wheat production and the coefficient was significant (5% level) for cotton-wheat zone. In the rain-fed zone, moisture availability (1% level), farm yard manure use (15% level) and balanced use of fertilizer at 10% level (Nitrogen-Phosphorus ratio) contributed significantly to wheat production. On the other hand, seed rate contributed negatively to the crop production in the mixed and cotton-wheat and rain-fed zones and the coefficients were significant for mixed and rain-fed zones. However, seed rate had a positive and significant contribution to wheat production in rice-wheat zone. The inefficiency in wheat production was due to incidences of technical or financial problems, age of the main wheat variety at the farms in irrigated areas and due to wheat crop acreage at the farms in the both irrigated as well as rain-fed zones.

INTRODUCTION

Food security is a major issue in the world today. Many international organizations including United Nations are very pessimistic about the world food situation (Niaz, 2008). The situation is also very serious in Pakistan. Prices of wheat and other edible food items are sky rocketing. Moreover, increasing energy prices, transportation charges, housing, health and education costs are also spoiling the situation and making living unaffordable for the poorest segments of the society (Mahmood, 2008). The fiscal year 2007-08 witnessed the worst ever wheat crisis in the history of Pakistan (Subohi, 2010). Though we are surplus in wheat production for last few years; however, vertical increase is low. Wheat crop is considered as a main pillar of food security as it provides forty eight percent of calories in the daily diets of people in the country (Anonymous, 2008). The production of wheat crop which was 11.5 million tones in 1981-82 increased to 24.0 million tones in 2008-09 (increased by 109%). Inspite of an increase of more than double in the wheat production over last three decades, the country has been importing significant quantities of wheat to meet the needs of its fast growing population. In years 2007 and 2008, Pakistan imported 8.5 and 15.9 percent of the total requirements of wheat respectively (Ahmad and Farooq, 2010). Trend of area under wheat crop during last couple of decades shows the potential of increase in area under this crop has almost been exhausted. As regard per acre yield of wheat, it has increased over time, from 15.9 mounds per acre in 1986-87 to 26.9 mounds per acre in 2008-09 (Anonymous, 1991, 2010). According to officials of National Coordinated Wheat Programme of National Agricultural Research Centre, Islamabad genetic yield potential of wheat cultivars in the country is 6-8 tons per hectare (Anonymous, 2011). Thus, observed average wheat yield per hectare in Pakistan is well below the potential yield by about 60 percent. Hussain et al. (2011) reported that yield gap for wheat crop was 40 percent in the irrigated areas of Punjab. Non-adoption of recommended technologies and production practices by the farmers is declared one of the main reasons of low wheat yield (Mahmood et al., 2006).

Wheat yield may also differ on the farmers' fields having the similar topographic characteristics and access to various input resources. The differences in management practices adopted at these farms are perceived as main sources of yield variation, which in turn contributes to 'technical efficiency gap'. Citing few studies such as Pingali and Ahmad et al. (2002); Heisey (2001); Ahmad and Ahmad (1998); Kalirajan et al. (1996); Thirtle et al. (1995); Lin (1992); Fan (1991); it is argued that the existence of higher technical inefficiencies could fully offset the potential gains of highly superior technologies. Moreover, determination of technical efficiency levels of the wheat farmers and identification of significant factors of wheat production both are very important as majority of the farmers are resource poor; either they are incognizant of proper production technology or can not afford to follow improved production practices.

In context of farm sector, technological development is a slow process, thus it is considered that future agricultural growth will hinge on stock of exiting knowledge and speed with which it is diffused to the farmers. The process will result into an improvement in managerial efficiency of the farmers. In this context extensive review of literature revealed that about forty studies have been undertaken about crop and other sectors of Pakistan up till now. Out of these ten studies are about wheat crop. Five studies have been conducted in Punjab. Out of these two studies were conducted in mix cropping zone of the province based on primary data obtained from Faisalabad tehsil, one was based on secondary data of ten tehsils of Punjab and two studies were pertained to rain-fed areas of the province. So, far no study has been undertaken in all the major wheat growing cropping zones of Punjab. Determination of technical efficiency of wheat farmers across major cropping zones of the province is very important to increase wheat productivity and deal with the food security issue in a better way.

Though findings of the studies conducted in mixed cropping zone of Punjab indicate that farmers in the zone are efficient in wheat production e.g. Hassan and Ahmad (2005) reported that mean technical efficiency of wheat farmers was 93.0 percent and Abbass (2005) reported that technical efficiency of majority of the wheat farmers was ranged from 76.0 to 96.0 percent. Similarly, 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. They reported that mean efficiencies of Attock, Rawalpindi, Jehlum and Chakwal districts were 89, 84, 88 and 88 percent, respectively. However, keeping in view increase in input prices, particularly fuel and chemical fertilizers and higher support prices for wheat produce of the year 2008-09 change in technical efficiency level of the farmers is expected. As high input prices cause delayed, low or imbalanced use of inputs and poor crop management, while high output prices may have an opposite impact. This study has been designed to test the hypothesis that 'A decrease is technical efficiency of wheat farmers in Punjab is likely due to financial stress which not only impinge on their access to sources of information but also intrude on their managerial capacity of the farmers'. This study was undertaken to analyze technical efficiency of wheat farmers across the major cropping zones of the Punjab (Pakistan) to find out determinants of wheat production; and to study the effects of farm and farmers specific attributes associated with technical inefficiency in wheat production.

MATERIALS AND METHODS

Sampling Technique and Data Collection

The information was collected from the field by using a five stage sampling technique. Cropping zones were the first stage units, which were selected to analyze the technical efficiency of the farmers by cropping zones. Punjab province is divided into five cropping zones namely, rain-fed zone, rice-wheat zone, mixed cropping zone, cotton-wheat zone and low intensity zone (Pickney, 1989). This study was carried out in four cropping zones. Low intensity zone was excluded due to subsistence nature of farming in the area and due to time and financial constraints on the part of researchers. Second stage units were districts within each cropping zones. Districts were selected as one of the major ones in wheat production in the cropping zones. One of the top four districts on the basis of total wheat area in the respective cropping zones was selected. Third stage units were tehsils, one tehsil from each district was selected. Villages were fourth stage units, tehsils and villages were selected in consultation with agricultural extension departments of the respective districts. Fifth units were farmers, a purposive sample of farmers was drawn to give representation to all farm size categories. So as a whole, multistage purposive sampling technique was applied.

Farm level cross sectional data was collected for the crop year 2009-10. Wheat farmers were interviewed personally by the researchers at their farms during July to December, 2010. A comprehensive questionnaire was used as data collection tool. Although, total agricultural area and total population of farmers vary across zones in the Punjab province; however, to make the findings comparable across zones, seventy farmers from each zone were interviewed randomly for data collection for this study. In total 280 farmers were interviewed for the study. The operational holdings were categorized into small (<12.5 acre), medium (12.5 to <25 acre) and large (≥25) farm size categories. Number of farmers by different farm size categories across selected zones is given in Table 1. 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 Meeusen and Van den Brock (1977). The general form of the stochastic frontier production function is:

$$\Sigma \ln Y_i = \alpha_0 + \alpha_k \Sigma X_{ki} + V_i - \mu_i \quad (1)$$

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 indicate input variables used by the i-th farmer. The α_0 and α_k are unknown parameters to be estimated. V_i is usual error term which may result due to weather conditions, economic advertises or plain luck. While μ_i is non negative (one-sided) error term that captures inefficinecy such as faults in crop managment. For the inefficient farmer, the actual yield is less than (or equal to) the potential yield. Therfore, the ratio of actual and potential yield can be treated as a measure of technical efficiency. Using equation (1), technical efficiency (TE) of the i-th wheat farmer is derived as:

$$TEi = \exp(-\mu_i) = Y_i/Y_i^* \quad (2)$$

Where Y_i^* is the maximum possible yield and Y_i is the actual yield obtained by the sampled farmers. To study the effect of socioeconomic factors on inefficiency, it was observed that is better done in a single-step rather than in two-step procedures (Wilson et al., 2001; 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 μi and variance σ^2, such that

$$\mu_i = \delta_0 + \delta_m \Sigma Z_{mi} + \omega_i \quad (3)$$

Where Z_is are socioeconomic characteristics of the farmers. The δs are unknown parameters to be estimated and are ωis 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 (σ^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 and 5).

$$\ln Y_i = \alpha_\circ + \alpha_k \Sigma \ln X_{ki} + V_i - \mu_i \quad (4) \quad k=1$$

$$\mu i = \delta_\circ + \delta_m \Sigma Z_{mi} + d_j \Sigma D_{ji} \quad (5) \quad m=1\ j=1$$

Where,

Y_i = Output of the ith farmer (kgs)

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

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

μ_i = Firm specific inefficiency effect assumed to follow a truncated (at zero) normal distribution N (μ_i , σ^2_u)

Zmi = Socioeconomic characteristics of farmers

Dji = Dummy variables

The model (equation 3) was estimated using the computer programme

Specification of Variables

Y = Yield of wheat on the i-th farmer (kg/acre)

X_1 = Area under wheat crop (acres)

X_2 = Ploughings for seed bed preparation No.)

X_3 = Seed use (kgs/acre)

X_4 = Expenditures on weeds control (Rs./acre)

X_5 = Number of irrigations in irrigated zone and a composite variable for number of irrigations by dug-wells on limited area and rain fall in millimeters in wheat crop season (from November to March) in the rain-fed zone.

X_6 = NPK fertilizer nutrients application (kg/acre)

X_7 = Ratio of nitrogenous nutrients to phosphorus nutrients

X_8 = Farm yard manure use (tons/acre)

Z_1 = Age of the farmer (years)

Z_2 = Education of the farmer (number of schooling years)

Z_3=Experience of the farmer in crop production (years)

Z_4=Sowing period/ age of the main variety at farm (years)

Z_5 = Operational Size (acres)

D_1 = Dummy for incidence of technical/financial problem (value is one if farmer faced technical or financial problem during crop season, otherwise zero)

D_2 = Dummy for contact with extension agent (Value is one if farmer contacted extension agents for wheat crop, otherwise zero)

Table 1: Distribution of farmers by farm size categories across cropping zones

Categories	Mixed	Cotton-wheat	Rice-wheat	Rain-fed	Total
Small (<12.5 acres)	41 (58.6)	35 (50.0)	26 (37.1)	56 (80.0)	158 (56.4)
Medium (12.51-25.0 acres)	18 (25.7)	23 (32.9)	24 (34.3)	10 (14.3)	75 (26.8)
Large (>25.0 acres)	11 (15.7)	12 (17.1)	20 (28.6)	04 (5.7)	47 (16.8)
Total	70 (100)	70 (100)	70 (100)	70 (100)	280 (100)

Note: Figures in parenthesis are percentages

RESULTS AND DISCUSSION

The mean and standard deviations of the variables used in the estimation of technical efficiency and its determinants are presented in Table 2. The wheat yield was highest in mixed cropping zone (1608 kgs or 40.2 mounds/acre) followed by in cotton-wheat (1368 kgs or 34.2 mounds/acre) and rice-wheat zone (1182 kgs or 29.6 mounds/acre), with a lowest in the rain-fed zone (277.3 kgs or 6.9 mounds/acre). In irrigated zones, average area under wheat crop per farm was highest in the rice-wheat zone (17.3 acres) and lowest in the mixed cropping zone (9.2 acres). In the rain-fed zone, area allocation to wheat crop was 4.4 acres per farm. Mean number of ploughings for seed bed preparation was around seven in both irrigated and rainfed zones, with a minimum of four to five ploughings in cotton-wheat zone and a maximum of eight in the mixed zone. Average seed usages in the irrigated and rain-fed zones were 49.3 and 45.12 kgs per acre respectively. Mean expenditures on weeds control in irrigated and rain-fed areas were Rs.491 and Rs.377 per acre respectively, with a highest in cotton-wheat zone and a lowest in rice-wheat zone. Average numbers of irrigation applications per acre were around four in irrigated zones. One-fifth (19.4 percent) of the farmers in the rain-fed zone reported to have dugwells at their farms. These farmers reported to irrigated limited area of the crop (14.5% of total wheat area at farm) two to three times during whole crop season. The use of NPK fertilizer nutrients was highest in the cotton-wheat zone (79.4 kgs/acre), followed by in mixed (75.2 kgs/acre), rice-wheat (68.8 kgs/acre) and rain-fed zone (45.5 kg/acre). Use of farm yard manure for the crop was highest in the rice-wheat zone (1.1 tons/acre) followed by in cotton wheat zone and rain-fed zone (0.8 tons/acre each), with a minimum use in the mixed cropping zone (0.6 tons/acre).

Mean age of the wheat farmers in irrigated and rain-fed zones were 43.8 and 49.9 years with average education of 7.2 and 8.6 years of formal schooling and mean crop farming experience of 25.1 and 31.0 years respectively. Average *Rabi* season operational size of the farmers in the irrigated zones was 22.0 acres with a highest of 24.2 acres in the rice-wheat zone. In the rain-fed zone average operational size of the farmers was 9.7 acres. Average age or sowing period of the main wheat variety at the farm in the irrigated zones and rain-fed zones were 4.5 and 4.1 years, respectively with a highest of 7.1 years in the rice-wheat zone. About two-third of the farmers in the irrigated zones (62.9%) and one-fifth in the rain-fed zone (19.6%) reported to face technical or financial problems in wheat cultivation during crop season 2009-10. Agricultural extension system was very weak in the study area, as only about one-fifth (22.4%) and less than one-tenth (8.6%) of the wheat farmers reported contact with the extension agents during last one year in the irrigated and rain-fed zones respectively. The technical efficiency and the 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 3.

Weed control cost, fertilizer use and have contributed positively and significantly, while seed rate contributed negatively and significantly towards wheat production in the mixed cropping zone. Findings about weed control cost are almost identical to Kaur et al. (2010) and Ghaderzadeh and Rahimi (2008), who examined the technical efficiency of wheat farmers in Punjab state of India and Kurdistan province of Iran respectively. They reported that spending on chemical inputs was positively and significantly associated with wheat production. Similarly findings about fertilizer use are in line with findings of Kaur et al. (2010) and, Ghaderzadeh and Rahimi (2008). Battese and Broca (1997) determined the technical efficiency for wheat farmers in Faisalabad district of Punjab and also reported a positive and significant contribution of fertilizer use to wheat production. As far as findings about negative and significant contribution of seed rate to wheat production are concerned. These were similar to Kamruzzaman and Islam (2008), who examined technical efficiency of wheat farmers in Bangladesh and Hassan and Ahmad (2005), who analyzed technical efficiency of wheat farmers in the mixed cropping zone of Punjab province of Pakistan. Hassan and Ahmad reported that average seed rate used by the farmers was 52.4 kg per acre, higher than recommended seed rate of 45 kg per acre. The positive and significant values of fertilizer use and weed control cost indicate that there is a scope for increasing production of wheat by enhancing the use of these inputs. The elasticities of fertilizer nutrients and weed control cost indicate that increase in fertilizer use and weed control cost by one percent would add 0.0537 and 0.0151 percent to wheat production, respectively. The elasticity of seed rate

Table 2: Mean and standard deviations of key variables

Variables	Irrigated Zones				Rainfed
	Mixed	Cotton-wheat	Rice-wheat	All	Zone
Yield (kg per acre)	1607.7(303.2)	1368.0 (268.1)	1181.7 (326.8)	1385.8 (346.2)	277.3(217.1)
Wheat area (acres)	9.2(19.3)	13.5(15.4)	17.3(20.3)	13.3(18.7)	4.4(3.5)
Ploughings for seed bed preparation (No.)	8.0(1.7)	4.6(0.9)	7.2(2.0)	6.6(2.7)	6.7(1.8)
Seed use (kg/acre)	47.6(5.3)	52.7(4.8)	47.7(3.5)	49.3(5.1)	45.1(4.2)
Expenditures on weeds control (Rs./acre)	537.7(329.9)	591.3(267.0)	344.4(305.6)	491.1(318.8)	377.2(318.7)
Irrigation applications (No.)	3.9(0.8)	3.8(0.9)	2.7(0.6)	3.5(1.0)	0.5(1.1)
NPK fertilizer nutrients (kg/acre)	75.2(34.5)	79.4(16.9)	68.8(18.8)	74.5(25.0)	45.5(14.5)
Farm yard manure use (tons/acre)	0.6 (1.4)	0.8 (2.1)	1.1 (1.4)	0.8 (1.6)	0.8 (1.6)
Farm-specific variables					
Age (years)	44.3(14.6)	43.6(13.7)	43.6(13.7)	43.8(14.3)	49.9(15.0)
Education (years)	7.4 (4.3)	7.9(4.5)	6.3 (5.1)	7.2(4.7)	8.6 (2.7)
Crop farming experience (years)	25.9(16.3)	26.2(15.4)	23.1(14.9)	25.1(15.5)	31.0(16.6)
Operational farm size in *Rabi* season (acres)	21.7(48.2)	20.3(22.9)	24.2(24.3)	22.0(33.7)	9.7 (8.8)
Age of the main variety at the farm (years)	3.2(2.7)	3.3(2.9)	7.1(5.1)	4.5(4.1)	4.1(3.1)
Technical/financial problem (% Farmers)	69.0	70.0	50.0	62.9	19.6
Contact with extension agents (% Farmers)	19.0	38.6	10.0	22.4	8.6

Note: The values within parenthesis denote standard deviations.

Table 3: Maximum likelihood estimates of stochastic frontier production model among different cropping zones of Punjab: 2009-10

	Irrigated Zones				Rain-fed
Variables	Mixed	Cotton-wheat	Rice-wheat	All	Zone
Constant	8.5478	7.3823	5.2478	7.8560	-3.2626
	(10.7845)****	(7.3251) ****	(4.5246)****	(14.1087) ****	(-0.6931)
Wheat area (acre)	-0.0407	0.0381	-0.0608	-0.0227	0.0296
	(-0.9437)	(1.6821)**	(-1.1999)	(-1.2528)	(0.1414)
Cultivations (number)	0.0011	0.2880	0.1110	0.0422	0.3649
	(0.0191)	(2.5497)****	(0.9640)	(0.9580)	(0.8090)
Seed (kg)	-0.3080	-0.0173	0.4961	-0.2050	-2.5725
	(-1.4579)*	(-0.0825)	(1.5687)*	(-1.4995)*	(-3.0535)****
Weed control cost (Rupees)	0.0151	0.0045	0.0031	0.0036	0.0064
	(1.6388)*	(0.0986)	(0.2487)	(0.4973)	(0.1881)
Irrigations (number) /moisture availability	0.0227	0.1625	-0.1697	0.1408	3.5691
	(0.3880)	(2.0464)***	(-0.9911)	(2.4672)****	(2.6517)****
NPK nutrients (kg)	0.0537	-0.1731	0.0357	0.0177	-0.0178
	(3.4121)****	(-0.9890)	(0.2988)	(0.8837)	(-0.1401)
NP Ratio	0.0033	0.1251	0.0928	0.0142	0.2655
	(0.0687)	(1.0839)	(0.8800)	(0.3328)	(1.6839)**
FYM (tons)	0.0154	0.0373	0.1897	0.0625	0.2540
	(0.4500)	(1.5540)*	(3.4835)****	(4.4596)****	(1.6186)*
Sigma square	0.054	0.0866	0.0781	0.1991	0.7552
	(3.341)****	(1.5543)*	(2.7895)****	(2.7485)****	(3.0174)****
Gamma	0.997	0.9283	0.7688	0.9210	0.8132
	(146.113)****	(17.0778)****	(6.9774)****	(26.8409)****	(5.8009)****
Log likelihood function	27.408	29.8383	40.3253	28.5698	-54.2596

Figures in parenthesis are t-ratios and ****, ***, **, * indicate significance at 1, 5, 10 and 15 per cent levels, respectively

indicates that one unit decrease in seed use would add 0.3080 to wheat production in the mixed cropping zone. In the cotton-wheat zone, wheat area at the farm, and number of irrigations applied to the crop contribute positively and significantly towards wheat production. These results are in line with Kaur et al. (2010) and Fatima (2010), who analyzed technical efficiency of cotton-wheat production system in Punjab. Similarly, number of cultivations for seed bed preparation contributes positively and significantly towards its production. This finding is in accordance with Ahmad and Qureshi (1999), who studied the relationship between farm size and land productivity in Pakistan. Quantity of farm yard manure (FYM) applied to the crop also contributes positively and significantly towards its production. Azhar (1991) studied the efficiency of irrigated wheat and crop farms in Pakistan and reported that farm yard manure application had positive and significant contributions to wheat production. The number of cultivations for seed bed preparation had highest elasticity (0.2880) followed by number of irrigations (0.1625), area under wheat cultivation (0.0381) and FYM use (0.0373).

In the rice-wheat zone of the province, FYM use and seed rate have contributed in positive and significant ways towards wheat production. Elasticities of seed rate and FYM were 0.4961 and 0.1897 respectively. Average seed rate of wheat crop in the rice-wheat zone was almost equal to that in mixed crop zone (47.7 kg per acre) and less than that in cotton-wheat zone. However, its positive contribution to wheat production indicates towards low germination rate, as the soils in this zone have become compact due to sowing of rice crop, which demands intensive irrigations. Results of the overall model about irrigated zones revealed that number of irrigations and FYM use contributed positively and significantly, while seed rate contributed negatively and significantly towards wheat production.

In the rain-fed zone, seed rate has contributed negatively and significantly to wheat production, while moisture availability, FYM use and Nitrogen-Phosphorus (NP) ratio have contributed positively and significantly to wheat production. Negative coefficient of seed rate imply that farmers use more than recommended level of 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 that ultimately results into low crop production. Results about FYM use were similar to Azhar (1991). Findings about NP ratio were similar to Fatima (2010) who reported that appropriate use of NP fertilizer nutrients results into better crop production in cotton-wheat zone of Punjab. The elasticity of moisture availability was highest followed by NP ratio and FYM use. The elasticity of moisture availability indicates that one percent improvement in moisture availability would add 3.5691 percent towards wheat production in the rain-fed zone of the province. The elasticity of NP ratio indicates that one percent improvement in NP ratio would add 0.2655 percent towards wheat production in the zone. The elasticity of FYM use shows that one percent improvement in FYM use would add 0.2540 percent towards wheat production in the rain-fed zone. Significant values of gamma being 0.9970, 0.9283, 0.7688, 0.9210 and 0.8132 for mixed, cotton-wheat, rice-wheat, all irrigated zones and rain-fed zone respectively indicates the presence as well as dominance of inefficiency effect over the random error in all the regions and for the irrigated zones as a whole, i.e. more than 92 percent of the difference between the observed and frontier outputs was mainly due to inefficient use of resources by the farmers in irrigated areas of the province.

Table 4 shows the frequency distribution of estimated technical efficiency for the sample households. The estimated mean technical efficiency for the irrigated areas as a whole was 81.8 per cent, implying that about 18 per cent of their technical potentials were not being realized in wheat production. Mean technical efficiencies of the farmers in mixed, cotton-wheat, and rice-wheat zones were 76.2, 83.5 and 76.9 per cent, respectively. Distribution of the sample households across different technical efficiency categories in the mixed and rice-wheat zones were quite similar, about two-third of the farmers in these zones had technical efficiency scores equal to or less than eighty percent. However, in the cotton-wheat zone, technical efficiency levels of most of the farmers (70%) were >80 per cent. Mean technical efficiency of the farmers in the rain-fed zone was 56.8 per cent i.e. wheat yield was less than potential yield by 43 per cent. Technical efficiency scores of most of the farmers (62%) were less than or equal to seventy percent.

The inefficiency could be due to personal, household and farm specific factors (Table 5). On overall basis in the irrigated areas of the province, coefficients of age of main variety at farm, percent *Rabi* season area under wheat and dummy variable of technical/financial problem have positive sings and were statistically significant. It means that these farm specific factors are causing inefficiency in wheat production. Hussain (1990) and Bashir et al. (1995) analyzed the technical efficiency of wheat farmers in Mardan and Dera Ismail Khan districts of Khyber Paktunkhwa respectively and reported that one of the main factors of technical inefficiency was sowing of very old varieties. On the contrary, coefficients of farmer age, operational farm size and dummy variable of farmer's contact with extension agents have negative signs and were statistically significant. It means that increase in farmers' age results into a decrease in technical inefficiency as farmers learn more with experience. Increase in operational farm size has a negative relationship with technical inefficiency as large operational size is an indicative of financial strength of the farmers and their ability to mange the crop in better way. This result is in accordance with Ahmad et al. (2002) analyzed the technical efficiency of wheat farmers in rice-wheat and cotton-wheat cropping zones

Table 4: Distribution of the sample farms by level of technical efficiency among different cropping zones of Punjab: 2009-10 (Percent Farmers)

Technical Efficiency (%)	Irrigated Zones				Rain-fed Zone
	Mixed	Cotton-wheat	Rice-wheat	All	
≤50	1.0	1.0	1.0	3.0	40.0
51-60	12.0	6.0	12.0	4.0	12.0
61-70	23.0	11.0	21.0	11.0	10.0
71-80	31.0	12.0	30.0	19.0	13.0
81-90	17.0	27.0	19.0	36.0	20.0
≥91	16.0	43.0	17.0	28.0	5.0
Mean efficiency levels	76.2	83.5	76.9	81.8	56.8
	(13.4)	(12.3)	(16.6)	(12.3)	(25.6)

Table 5: Estimates of the Influence of Farm-Specific Factors on Technical Efficiency among Different Cropping Zones of Punjab: 2009-10

Variables	Irrigated Zones				Rain-fed
	Mixed	Cotton-wheat	Rice-wheat	All	
Constant	0.5533	0.0506	-0.3512	-1.3094	1.2862
	(3.2695)**	(0.0783)	(-0.5697)	(-1.7027)**	(0.7511)
Farmer age (year)	-0.0025	-0.0087	0.0023	-0.0061	-0.0038
	-0.9391)	(-1.0754)	(0.4092)	(-1.6025)*	(-0.2584)
Education (year)	-0.0086	-0.0093	0.0259	0.0092	0.0093
	(-0.0086)	(-0.4714)	(1.8135)**	(0.7817)	(0.1085)
Dummy technical/ financial problem	0.1148	0.3276	0.4821	0.5008	-4.3328
	(1.4247)	(1.3094)	(3.2266)****	(2.3814)***	(-1.2627)
Dummy extension	-0.1232	0.2612	-0.5066	-0.2619	-2.9986
	(-1.0586)	(1.2084)	(-1.5364)*	(-1.5850)*	(-0.9037)
Age of main variety at farm (years)	-0.0201	0.0155	0.0103	0.0499	-0.0248
	(-1.0442)	(0.7690)	(0.6665)	(2.2425)***	(-1.1634)
Percent *Rabi* season area under wheat	-0.0012	-0.0024	0.0048	0.0089	0.2586
	(-0.7135)	(-0.3545)	(0.9884)	(2.2521)***	(4.1688)****
Operational farm size (acre)	-0.0049	0.0026	-0.0231	-0.0076	0.0207
	(-1.8901)**	(0.9874)	(-3.2488)****	(-1.6509)**	(0.6094)

Note: Figures in parenthesis are t-ratios and ****, ***, **, * indicate significance at 1, 5, 10 and 15 per cent levels, respectively

of the country and reported that that farm size had a positive association with technical efficiency. Positive sign of dummy variable of farmer's contact with extension agents implies that farmers who had contact with extension agents were technically less inefficient in wheat production. Croppenstedt (2005) measured technical efficiency of wheat farmers in Egypt and also reported a positive impact of farmers contact with extension agents on farmers' technical efficiency. In the rain-fed cropping zone, coefficient of percent winter (*Rabi*) season area under wheat crop has a positive sign and was significant, which means that an increase in wheat area as a percent of operational farm size results into increase in inefficiency of the wheat farmers. The findings are in line with Alemdar and Oren (2006) and Kaur et al. (2010), who analyzed the technical efficiency of wheat farmers in Turkey and India respectively. This positive relationship between percent winter (*Rabi*) season area under wheat crop and inefficiency is indicative of farmers' inability to manage crop in better way. Rain-fed crop farming is very risky in nature and poor farmer in rain-fed zone are diverted to different farm and non-farm activities hence efficiency for the crops is reduced. Most of the other variables had appropriate signs but all were insignificant.

Conclusions

A decrease in technical efficiency level of wheat farmers has occurred over time in the country due to indirect influence of high input prices on farmers' managerial ability. Though support prices have been raised by the government in year 2008-09 from Rs.625 to Rs.950 per mound and further in year 2011-12 to Rs.1050 per mound. However, increases in prices of crop inputs have gravely affected the technical efficiency of the farmers mainly through their delayed, low, and imbalanced usage. Mean technical efficiency levels of the wheat farmers in irrigated and rain-fed zones of Punjab were 81.8 and 56.8 percent. This clearly demonstrates that under existing conditions of input use and technology farmers can improve wheat yield by about 18.0 percent (by 250 kg per acre) in irrigated areas and by about 43.0 percent (by 108 kg per acre) in rain-fed zone by adopting better crop management practices. If we take an increase of just 18.0 percent in wheat production in Punjab, this would raise national production of wheat from current level of 24.0 million ton to about 28.5 million ton. Rise in wheat production will not only help in stabilizing wheat prices in the country but also raise export earning of the state. To achieve this goal, it is need to devise region specific interventions keeping in view crop zone wise use of wheat production technology and factors of technical inefficiency. This finding of the study provided an insight into technical efficiency of wheat farmers across main cropping zones in the Punjab province. Last but not least, findings of this study along with that of similar studies for wheat and other crops in the developing countries can be helpful regarding policy formulations in the country.

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