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DETERMINANTS OF TECHNICAL EFFICIENCY OF WHEAT FARMS IN PAKISTAN

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Food security and economic growth are interrelated and supportive to each other during development process but cereal yield per hectare for Pakistan compared to the developing counties is among the lowest. Especially in wheat production, the level of technical efficiency of agricultural farms in Pakistan is relatively low mainly because of comparatively old methods of production and inefficient use of farm inputs. This paper assesses and estimates the impact of different farm specific variables on efficiency of wheat producers in Pakistan. The data on 120 wheat farms from Sargodha region was collected in May, 2014. Data envelopment analysis (DEA) has been employed for measuring technical efficiency whereas; Tobit regression has been used to identify the factors associated with the technical efficiency. The mean level of overall technical inefficiency has been estimated to be 12 percent. This indicates that technical efficiency of the farmers can be increased by 12 per cent through adoption of best farm practices of the efficient farms in the sample. Medium farmers appear as relatively more inefficient compared to small and large farms mainly because of their relatively less expenditure on fertilizers. The appropriate policy response would be to provide trainings to farmers and encourage the use of fertilizers and pesticides in optimal proportions. Agricultural extension policy can also be reformed to reorganize the duties of extension officials so as they spend more time on field visits, thereby improving farmers' cultivation practices.
Keywords: Technical efficiency, wheat production, data envelopment analysis, Tobit regression, policy

INTRODUCTION

Despite structural shift towards industrialization, agriculture is still the most important sector of Pakistan's economy. It contributes about one-fifth to GDP of the economy and provides employment opportunities for about 45 percent of the labor force. About 60 percent of rural population directly or indirectly depends upon this sector for its livelihood. Wheat production contributes 10.3 percent to the total value added in the agricultural sector and 2.2 percent to GDP. Wheat production in 2013-14 stood at 25.3 million tons compared to 23.3 million tons in 2009-10 thereby registering 4.4 percent growth compare to previous financial year (Ministry of Finance, 2014). Agriculture sector thus plays a key role in reducing poverty and provides raw material to industry thus contributing significantly to country's exports. Agriculture sector also plays a vital role in promoting the overall GDP. Estimates suggest that one percentage increase in agricultural per capita income growth results in an increase of 1.5 percent non-agricultural per capita growth in the Asian countries. This high elasticity of non-agricultural per capita income to the agricultural per capita income is attributed to the heavy backward and forward linkages of agricultural sector with the rest of the sectors in the economy. Although Pakistan's economy has been dominated by the agriculture sector historically, its growth rate has been volatile with the coefficient of variation approaching unity. This high volatility in the agricultural growth not only presents the existing grim situation of the sector but also reflects the uncertainty and future risks about its performance. This relatively low and volatile growth in Pakistan's agriculture sector could be due to the lack of efficiency in wheat production, which is an issue of great concern.

Given the volatile trends in agriculture sector growth in Pakistan, this paper investigates the issue from efficiency and productivity perspective using wheat farms as the case study mainly due to the following reasons. First, food security and economic growth interrelate and support each other during development process. The recent food shortages in Pakistan and increase in agricultural prices reinforce the probing of this issue from supply perspective. Estimates suggest that other than landless rural residents (45 percent), more than 30 percent of the cultivators remain the net buyers of staple food; accounting for about 62 percent of the overall rural population being to some extent or completely reliant on market for food needs (Sher and Ahmad, 2008). Moreover, since 2000, Pakistan's population has been growing at 1.8 percent per year, which is higher than the increase in domestic food grain production (percentage of 1.5 per year) (Nazli *et al*., 2012). Current rate of growth of food grain production may not be sufficient to provide food to Pakistan's increasing population. Second, cereal yield in Pakistan is among the lowest in the developing countries and could be the result of traditional modes of cultivation/lack of technological innovations in the sector, low R&D expenditures, less use of high yield verities, the terms of trade against the agriculture sector compared to the industry etc. or the suboptimal use of the resources available to the farmers in Pakistan. Ali *et al*. (2012) and Ahmad *et al*. (2008) point out that the level of technical efficiency of agricultural sector in Pakistan is generally low mainly due to comparatively old methods of production and ineffective use of inputs.

Therefore, this paper examines the level of technical efficiency of wheat growers at the farm level in Pakistan. Especially, it is important to assess the factors that affect efficiency of the farmers to quantify the micro determinants of different variants of farm efficiency in Pakistan.

MATERIALS AND METHODS

We have adopted two steps DEA methodology to first estimate the efficiency of wheat farms and then employ a Tobit regression to measure the effect of different determinants on farm level technical efficiency.

***DEA representation- stage 1*:** We employ the following DEA representation to estimate the level of technical efficiency of wheat farms in Pakistan;

$$\min_{\theta,\lambda}\theta$$
$$\text{st} \quad -q_i + Q\lambda \geq 0$$
$$\theta x_i - X\lambda \geq 0$$
$$\lambda \geq 0$$

where θ is a scalar and while λ is l x 1 vector of constants. This envelopment form requires less constraints than multiplier form therefore it is in generally preferred to find the solution of the value of θ as we get the efficiency score for each of the farmer. If the value of $\theta = 1$, then it shows that i^{th} farmer is on the frontier and hence a technically efficient farm (Farrell, 1957). DEA has multiple advantages compared to other techniques for estimating the level of technical efficiency of DMUs. First, it avoids the complexity of using a discretionary decision. DEA uses the weight for each input and output that permit each DMU to reach its maximum possible efficiency value (Charnes *et al*., 1994). Second, it does not require any assumptions about the functional forms to identify the relationship between inputs and outputs (Krasachat, 2004). Third, it does not involve any assumption about the distribution of the fundamental data and finally, it provides an intuitive way of decomposing economic efficiency into technical and allocative efficiency and technical efficiency into pure technical and scale efficiency.

***Tobit regression-stage 2*:** In the second stage, the study investigates the impact of different determinants of efficiency on technical efficiency of farms. The efficiency estimates provided by DEA are regressed on some farm and household specific attributes using Tobit model. This approach has been used widely in efficiency literature (Nyagaka *et al*., 2010). Tobit model was presented by James Tobin (1958) to describe the relationship between a non-negative dependent variable y_i and the independent variables. Tobit model is also known as censored regression model and is mostly applied in the situations when the dependent variable is censored either from below or above (Verbeek, 2008). Since, efficiency scores (dependent variable) range between 0 and 1, standard Tobit regression was used to estimate the impact of farm specific variables on technical efficiency scores obtained from Stage-1. Application of standard OLS regression in such instances yields biased estimates (Verbeek, 2008). The tobit model can be represented as;

$$Y_i = X_i\beta + \varepsilon i$$

$$Y_i = \begin{cases} y_i^* & \text{if } y_i^* < 1 \\ 1 & otherwise \end{cases}$$

***Survey and variable description*:** To assess the level of technical efficiency of wheat farms in Pakistan, we conducted a survey of wheat producers during 2013 in District Sargodha for data collection from 120 farmers using stratified random sampling technique. We have selected Sargodha as a case study because it is typically known for the wheat cultivation and produces one of the best quality seed for wheat in Pakistan (Safdar *et al*., 2009). Sargodha uses canal water for irrigation purposes and is one of biggest wheat producing cities in Pakistan where wheat production stood at 469 million tons in 2007-08 (GOP, 2009). Area under wheat cultivation in Sargodha is about 35 percent of the total are under crop cultivation (PBS, 2010). There are seven tehsils in Sargodha city; namely Bhera, Bhalwal, Kot Momin, Sahiwal, Sargodha and Shahpur. Sargodha Tehsil was chosen for data collection. Sargodha Tehsil is also divided into sixty two unions councils from which twenty two are urban and forty are rural. We randomly selected twenty UCs from forty rural UCs and then 6 farmers from each rural UCs randomly to collect data on a structured questionnaire. Description of variables used in DEA analysis is presented in Table 1.

RESULTS AND DISCUSSION

The primary objective of this study is to determine the farm level technical efficiency on a sample of wheat farms using DEA technique. A summary of the results on the constant returns to scale (CRS) technical efficiency, variable returns to scale (VRS) technical efficiency and scale efficiency (SE) are presented in Table 2.

Table 1. Description of variables.

Outputs		Inputs	
Variables	**Unit of measure**	**Variables**	**Unit of measure**
Wheat production	KG per hector	Total bund cost	Rupees
		Total drill cost	Rupees
		Total seed cost	Rupees
Wheat Straw	KG per hector	Total fertilizer cost	Rupees
		Total pesticides cost	Rupees
		Total numbers of workers	Number of workers employed on
		Wheat cultivation area	Acres

Table 2. Number of farms under different variants of efficiency.

Efficiency Level	Number of farms under CRS TE	%	Number of farms under VRS TE	%	Number of farms under SE	%
Below 0.50	6	5.00	4	3.33	1	0.83
0.50–0.60	3	2.50	2	1.67	2	1.67
0.60–0.70	5	4.17	0	0.00	1	0.83
0.70–0.80	10	8.33	5	4.17	2	1.67
0.80–0.90	37	30.83	25	20.83	10	8.33
Above 0.90	59	49.17	84	70.00	104	86.67
Total No. of farmers	120	100.00	120	100.00	120	100.00
Mean	0.878		0.932		0.968	
Minimum	0.323		0.363		0.332	
Maximum	1		1		1	

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Under the constant returns to scale, technical efficiency of farms ranges between 0.323 to 1.00 with mean efficiency score of 0.878 and standard deviation of 0.158. Variable returns to scale technical efficiency score ranges from 0.363 to 1.00 with mean efficiency score of 0.932 and standard deviation of 0.131. Similarly the scale efficiency score ranges from 0.332 to 1.00 with mean efficiency score of

0.968 and standard deviation of 0.096. About 59 farms under constant returns to scale and 84 farms under variable returns to scale have efficiency score greater than 0.90. This suggest that about 49 per cent of the farms fall under the category of relatively efficient farmers (technical efficiency above 90 per cent) with the assumption of constant return to scale, whereas sample farms falling under least efficient category (below 50 per cent) constitutes only 5 per cent of sample farms.

Thus, the mean level of overall technical inefficiency is estimated as 12 per cent. This result indicates that the farmers are not making use of their production resources efficiently and technical efficiency among the sample farms can be increased by 12 per cent through adoption of best farm practices of efficient farms. It follows that a large proportion of farms operates far from the efficient frontier, implying a substantial scope for improving productivity by efficient use of the existing level of inputs and resources.

With the assumption of variable return to scale (VRS) the estimated mean efficiency score of 0.93 indicates that there exists a potential for efficiency enhancement in wheat farms and agricultural production can be increased up to 7 percent by adopting the technology and the techniques used by the "best practice" farms.

In scale efficiency, the estimated mean efficiency score 0.97 indicates that that there is a small potential to enhance productivity of wheat farms. Wheat farms can increase agricultural production up to 3 percent by adopting the technology and the techniques used by the "best practice" farms and moving to the optimal scale of production. Technical efficiency in our sample could vary with respect to the farm size. Therefore, the relationship between differences can be due to the technologies being applied at different sizes and to the economies of scale related to the degree of on-farm diversification. This result is consistent with the findings of Kiani (2008).

The results in Table 4 confirm that one reason for inefficiency of medium sized farmers is their relatively low spending on fertilizers and pesticides per acre. Medium farms might be using some sorts of traditional agriculture means of production in which the inputs use per acre is lower. There are relatively low annual rainfalls in Sargodha, so there is shortage of nutrients and organic material in soil. There is big need of nitrogen for the sake of higher productivity. Therefore, the use of quality agricultural inputs such as seeds, fertilizers, pesticides is critical to promote diversification, and increase productivity.

The results presented in Table 5 reflect the farm expenditures on seeds, fertilizers and a pesticide with respect to their relative returns to scale. Farms on DRS spend less on seed but more on fertilizers and pesticides because most of the small farms operate under DRS. This means that input congestion is found in DRS farms. Congestion refers to the phenomenon when increase in input quantities even reduces the output when the use of factor inputs goes beyond certain physical limits.

Table 6 presents results on the relationship between efficiency and input cost. Results suggest that efficient farmers spend more on all inputs like seeds, fertilizer and pesticides. Reasons for least efficient farms to be least efficient as that these farmers are spending less on pesticides and seed but spending much on fertilizer as they want to get more output with more fertilizers. This means that input congestion is found in the least efficient farms.

Table 4. Farm size and input use.

Farms Size	Average seed cost per acre (Rs.)	Average Fertilizer cost per acre (Rs.)	Average Pesticides cost per acre (Rs.)
Less than 12.5 acres (Small)	2389.48	6373.45	1401.31
12.5-25 acres (Medium)	2035.78	5994.76	717.64
25 and more acres (Large)	2006.31	6458.81	890.91

Table 5. Farms level of scale efficiency and input cost.

Farms Size	Average seed cost per acre (Rs.)	Average Fertilizer cost per acre (Rs.)	Average Pesticides cost per acre (Rs.)
IRS	2316.909	7649.855	2321.364
DRS	2174.045	6316.596	1057.689
CRS	2170.835	5761.692	720.1335

Table 6. Efficiency distribution and input costs.

Comparison items	Average of Fully efficient farms (Rs.)	Average of 10 Least efficient farms (Rs.)	Average of Remaining farms (Rs.)
Seed cost per acre	2486.500	2307.21	1941.034
Fertilizer cost per acre	6793.632	10702.02	5677.245
Pesticides cost per acre	924.270	787.50	947.489

Discussion of these results implies that considerable room exists for increasing output levels through efficiency improvement. Medium farmers in sample are not using adequate amount of fertilizer and pesticides. The appropriate policy response would be to implement policies or programs that encourage the use of fertilizers and pesticides. Potential barriers to increase may be the cost of these inputs, lack of access to credit to purchase inputs, lack of access to these inputs in market, and lack of knowledge regarding which products to use and how to use them most effectively.

Most of the small farms were under DRS. These farmers were using more quantity of inputs than required. So there is potential to achieve output gains given current input levels and existing technologies. In order to make more effective use of current inputs, policy makers should focus on improving production management and increase in technical efficiency of the farms.

***Determinants of technical efficiency*:** Variable returns to scale (VRS) technical efficiency scores were regressed on farm and household specific variables to identify the sources of inefficiencies. Since efficiency scores range between 0 and 1, Tobit model was employed in place of OLS regression. Results of the Tobit regression analysis are presented in Table 7. All the variables of interest except education and tractor ownership dummy appear to be statistically significant at least at 10 percent level of significance.

Table 7. Determinants of technical efficiency.

	Coefficient	Std. Err.	T	p>[t]
Age	-0.030	0.013	2.22	0.028
Age and education	0.002	0.001	1.71	0.090
Experience and education	-0.002	0.001	-1.89	0.062
Experience	0.026	0.014	1.86	0.066
Family size	0.011	0.005	2.21	0.029
Education	-0.022	0.019	-1.15	0.253
Age2	0.0001	0.00006	2.12	0.036
Traction power	0.0112	0.019	0.61	0.540
Area under wheat Cultivation	0.094	0.054	1.73	0.086
Constant	1.231	0.275	4.48	0.000
Sigma	0.129	0.013		

Age enters the model with a negative sign. This could be because most of the elder farmers are likely to be less adaptive to new technology and better cultivation practices. This observation finds support from other studies that found negative relationship between age and technical efficiency (Admassie and Matambalya, 2002; Alam *et al*., 2012). Similarly, Interaction terms between Age and education show positive and insignificant relationship with efficiency. We also find a positive relationship between experience of the farmer and technical efficiency. This may be due to lessons that farmers have learnt over the years. These findings are consistent with the findings of Idiong (2007).

Family size has a statistically significant and positive relationship with technical efficiency because a large household size is a source of farm and off-farm income generating activities in the traditional agriculture. Similarly, age-squared also has a statistically significant positive relationship with technical efficiency. However, tractor ownership dummy appears statistically insignificant in the model. This implies that although some farmers do not own a tractor, they can rent it to perform their sowing activities without delays.

This implies that extension programs can be used to re-orientate the application of methods and timing of application of inputs and production methods. Agricultural extension policy can also be reformed to reorganize the duties of extension officials so as they spend more time on field visits, thereby improving farmers' understanding. This would reduce the extent of variation in output from the maximum output.

***Conclusion*:** This study uses data envelopment analysis (DEA) to analyze the efficiency of wheat farmers. The study also estimates the effects of farm and household specific variables on technical efficiency of wheat farms using primary data collected from district Sargodha, Pakistan. The mean level of overall technical inefficiency is estimated to be 12 per cent. This indicates that the farmers are not making use of their production resources efficiently and technical efficiency among the sample farms can be increased by 12 per cent through adoption of best farm practices of efficient farms.

We found that improved technology significantly increases the technical efficiency of wheat farms. Furthermore, there is a positive relationship between experience of the farmer and efficiency. This may be due to lessons farmers learnt over the years. Ability to handle difficult situation develops in farmers with the help of experience. These results have far reaching policy implications as far as the agricultural extension policy is concerned. The older farmers who have limited educational opportunities can be assisted with adequately trained extension advisers who can advise farmers on new production technologies and implement programs that encourage the use of fertilizers and pesticides. Extension programs can be used to update application methods and timing of application of inputs and harnessing of outputs. Agricultural extension policy can also be reformed to reorganize the duties of extension officials so as they spend more time on field visits, thereby improving farmers' understanding.

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