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Technical, allocative and economic efficiencies in sugarcane production in Pakistan: A non-parametric approach

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ARTICLE

Technical, Allocative and Economic Efficiencies in Sugarcane Production in Pakistan: A Non-parametric Approach

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ABSTRACT

The objective of this paper is to measure the technical, allocative and economic efficiencies of sugarcane farms in Pakistan. These efficiencies are measured by data envelopment analysis method using the farm level data collected from 333 sugarcane growers of Pakistan in 2008. The results show that the average technical efficiency of the sugarcane farms is 75 percent, the average allocative efficiency is 83 percent, and the average cost efficiency is 62 percent. The results indicate that the sugarcane farms of Pakistan can reduce the costs of production by 38 percent to produce the same level of output by using the inputs in optimal proportion and by improving the technical efficiency. The results also show that the existing level of sugarcane production can potentially be increased by 33.33 percent with the same level of inputs by improving the technical efficiency of the sugarcane farms.

Key words: Data envelopment analysis, efficiency, sugarcane

JEL classification: D24, Q12

INTRODUCTION

Sugarcane is one of the major crops of Pakistan. In the year 2009-10, sugarcane was sown in the area of 0.943 million hectares with estimated sugarcane production of 49.373 million tonnes and yield of 52.357 tonnes per hectare (Government of Pakistan, 2010). According to FAOSTAT (2010), Pakistan has become the fourth largest sugarcane producer in the world in terms of area harvested and the fifth largest in terms of production. However, it stands at 63rd place in the world in terms of yield. Despite among the top growers in the world, Pakistan has been net importer of sugar almost each year due to lower sugarcane yield and the rising demand for sugar. Thus, there is need to investigate the productivity and

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efficiency across sugarcane farms, and to evaluate the gap between the actual and potential production of sugarcane in Pakistan.

Sugarcane is an important cash crop of Pakistan, especially for small farmers, as about 68.5 percent of the total area under sugarcane is cultivated on farms with farm size under 10 hectares (Government of Pakistan, 2003). To achieve its target production, the government announces the procurement price for sugarcane each year. However, the government is also facing increased pressure to reduce the price of sugar to protect the low-income consumers. Furthermore, with open world market competition and increasing costs of production, the sugarcane growers who are cost-inefficient will face challenges to continue producing sugarcane. Thus, to investigate the implications for sugarcane growers, there is a need to measure the cost efficiency of sugarcane producers as well as its distribution across farms. In the regime of the WTO, farmers face much variation in input prices, especially the price of fertilizer and diesel. Thus, there is a need to investigate the ability of farmers to respond optimally in using various inputs due to changes in the input prices.

The above issues are investigated by various measures of efficiency. Input-oriented technical efficiency measures the ability of a firm to reduce all inputs to produce the given level of output. Input-oriented allocative efficiency measures the ability of a firm to reduce the cost of production by using the inputs in optimal proportion given their respective prices and the production technology. Input-oriented economic efficiency (cost efficiency) measures the ability of firm to minimize the costs of production to produce the given level of output through the input-oriented technical and allocative efficiencies. Output-oriented technical efficiency[5] measures the ability of a firm to produce maximum output by using the given level of inputs (Coelli et al., 2005).

The efficiency of firms can be measured by two broad approaches: parametric and non-parametric. The parametric approach is based on the specification of a functional form for a production function (or cost function, profit function), estimated by econometric techniques. The parametric approach is stochastic, and includes the random error term. However, it imposes parametric restrictions. For example, Cobb-Douglas production function assumes unitary elasticity of substitution (Chavas and Aliber, 1993). Furthermore, estimating econometric model poses challenges of including the all relevant inputs in the production function due to multicollinearity problem. The nonparametric approach for measuring efficiency is data envelopment analysis (DEA), which is based on

[5] Output-oriented allocative and economic efficiencies are measured when there are multiple products. We do not investigate these efficiency measures, as there is a single product, namely sugarcane crop, in the present study.

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mathematical programming technique. This approach is nonstochastic, but it does not impose the parametric restrictions and does not have the multicollinearity problem. Distinctions and advancement of these two approaches are discussed in Fried et al. (2008, pp.31-33).

The objective this paper is to measure the technical, allocative and economic efficiencies of sugarcane farms in Pakistan using the nonparametric DEA method. In this study we measure the input-oriented technical, allocative and economic efficiencies and output-oriented technical efficiency. We investigate the average as well as the distribution of these efficiency measures. The rest of the paper is organized as follows. The next section describes the model followed by a section on data and definition of variables. The fourth section presents the empirical results. The last section draws conclusions.

MODEL

Technical, allocative and economic efficiencies are measured for the sampled sugarcane farms of Pakistan using data envelopment analysis (DEA), which is a nonparametric approach based on mathematical programming technique. DEA method was first introduced in the study by Charnes et al. (1978), which was based upon the work of Farrell (1957), Boles (1966), Shephard (1970), and Afriat (1972). Charnes et al. (1978) introduced input-oriented measure of efficiency with the assumption of constant returns to scale (CRS) technology. The CRS assumption was relaxed by Banker et al. (1984), who proposed a variable returns to scale model of DEA. A comprehensive overview of DEA methods is presented in Fare et al. (1994), Coelli et al. (2005), and Fried et al. (2008), which were reviewed in developing the DEA model of the present study.

The DEA model is presented for single output and multiple inputs, as in the case for this study. We use DEA method with the variable returns to scale technology. Suppose there are n firms producing the single product by using K inputs.

To measure the input-oriented technical efficiency of a firm j, the following linear programming problem is solved:

$$\min_{\theta, \{\lambda_i\}_{i=1}^{n}} \theta \tag{1}$$

subject to:

$$\sum_{i=1}^{n} y_i \lambda_i \geq y_j \tag{2}$$

$$\sum_{i=1}^{n} x_{ki} \lambda_i \leq \theta x_{kj} \text{, for } k = 1, 2, \ldots, K \tag{3}$$

$$\sum_{i=1}^{n} \lambda_i = 1 \tag{4}$$

$$\lambda_i \geq 0 \tag{5}$$

where θ is the input-oriented measure of technical efficiency of firm j, y_i is the quantity of output produced by firm i, where i = 1, 2,…, j,…, n, and n is the number of firms, x_{ki} is the quantity of input k applied by firm i (for i =1, 2,…, j, …, n) for k = 1,2,…, K, where K is the number of inputs used by the firms, and $\{\lambda_i\}_{i=1}^{n}$ are the weights to be determined. Note that there are K equations in Equation (3). The above model, given in Equations (1)–(4), is solved for firm j to obtain the optimal value of the objective function, θ^*, which is a measure of the input-oriented technical efficiency of the firm j (TEj):

$$TE_j = \theta^* \tag{6}$$

This technical efficiency measure satisfies these bounds: $0 < \theta^* \leq 1$, where the value of 1 indicates fully efficient firm. Thus, the above problem is solved to obtain θ^* for each firm (for j = 1, 2, …, n).

To measure the input-oriented economic efficiency (or cost efficiency) of firm j, the following linear programming problem is solved:

$$\min_{\{x_{kj}\}_{k=1}^{K}, \{\lambda_i\}_{i=1}^{n}} \sum_{k=1}^{K} w_{kj} x_{kj} \tag{7}$$

subject to:

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$$\sum_{i=1}^{n} y_i \lambda_i \geq y_j \quad (8)$$

$$\sum_{i=1}^{n} x_{ki} \lambda_i \leq x_{kj} \text{ , for } k = 1, 2, \ldots, K \quad (9)$$

$$\sum_{i=1}^{n} \lambda_i = 1 \quad (10)$$

$$\lambda_i \geq 0 \quad (11)$$

where w_{kj} is the price of input k applied by firm j. The above model, given in Equations (7)–(11), is solved for firm j to obtain the optimal solution: $\{x^*_{kj}\}_{k=1}^{K}$ and $\{\lambda^*_i\}_{i=1}^{n}$. The economic efficiency of firm j (EEj) is calculated as follows:

$$EE_j = \frac{\sum_{k=1}^{K} w_{kj} x^*_{kj}}{\sum_{k=1}^{K} w_{kj} x_{kj}} \quad (12)$$

Equation (12) indicates that EE_j is the ratio of minimum cost of production to the actual observed cost of production.

The allocative efficiency of firm *j* (AE_j) is then computed using Equations (6) and (12) as follows:

$$AE_j = \frac{EE_j}{TE_j} \quad (13)$$

To measure the output-oriented technical efficiency of a firm *j*, the following linear programming problem is solved:

$$\max_{\phi, \{\lambda_i\}_{i=1}^{n}} \phi \quad (14)$$

subject to:

$$\sum_{i=1}^{n} y_i \lambda_i \geq \phi y_j \quad (15)$$

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$$\sum_{i=1}^{n} x_{ki}\lambda_i \le x_{kj} \text{ , for } k = 1,2,\ldots, K \tag{16}$$

$$\sum_{i=1}^{n} \lambda_i = 1 \tag{17}$$

$$\lambda_i \ge 0 \tag{18}$$

where $\phi \ge 1$, and $(\phi - 1)$ is proportional increase in the output that could be achieved by firm *j* given the input levels. The above model, given in Equations (14)–(18), is solved for firm *j* to obtain the optimal value of the objective function, ϕ^*. To express it in relative measure, the output-oriented technical efficiency of firm *j* (TEO_j) is defined as:

$$TEO_j = \frac{1}{\phi^*} \tag{19}$$

This technical efficiency measure satisfies these bounds: $0 < TEO_j \le 1$, where the value of 1 indicates fully efficient firm.

The above optimization problems are solved *n* times to compute the measures of efficiency for each firm *j*, for *j* = 1, 2,…, *n*. We solve these models using software DEAP 2.1 developed by Coelli (1996).

DATA AND VARIABLES

Farm level data are collected from sugarcane farms where sugarcane is grown as a fresh crop[6]. Primary data are collected from 333 sugarcane growers by conducting survey during January–May 2008 in five major sugarcane-producing districts of Pakistan, namely Mirpurkhas and Badin from Sindh province, Faisalabad and Jhung from Punjab province, and Mardan from NWFP. Data were collected on a pretested questionnaire by taking face-to-face interviews on the farms.

The output and inputs are measured per farm of sugarcane crop. The output is measured as kilograms of sugarcane harvested per farm. There are seven inputs including farmland acres under sugarcane crop, labor in man-days per farm, quantity of fertilizer in kilograms per farm, acre-irrigations per farm, tractor hours per farm, bullock hours per farm, and quantity of seed in kilograms per farm. The price of each of these inputs is computed as the market price or the opportunity cost per unit.

[6] Sugarcane fresh crop refers to the recently grown crop with the first harvest.

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EMPIRICAL RESULTS

Technical, allocative and economic efficiencies are measured by DEA method for each of the 333 sampled sugarcane farms in Pakistan. Table 1 presents the descriptive statistics of the efficiency measures, including the average, standard deviation, minimum and maximum values. The results show that the average input-oriented technical efficiency score is 0.75, which indicates that on average 25 percent of the input use can be reduced to produce the observed level of sugarcane production by improving the technical efficiency of farms. The average input-oriented allocative efficiency score is 0.83, which indicates that on average sugarcane farms can reduce the costs of production by 17 percent by using the inputs in optimal proportion given their respective prices even without improving their technical efficiency. The results show that on average the farms have higher allocative efficiency (0.83) than the technical efficiency (0.75).

The average input-oriented economic efficiency is 0.62, which indicates that the sugarcane farms can reduce the costs of production by 38 percent to produce the same level of output by using the inputs in optimal proportion given their respective prices and by improving their technical efficiency. The results in Table 1 show that the average output-oriented technical efficiency is 0.75, which indicates that on average the observed level of sugarcane production is 75 percent of the potential production which can be produced by using the given level of inputs. This implies that the existing level of sugarcane production can potentially be increased by 33.33 percent with the same level of inputs by improving the technical efficiency of the sugarcane farms.

Table 1 also presents the standard deviation of various efficiency measures. The standard deviation was 0.16 in both the input-oriented and output-oriented technical efficiency measures, 0.08 in input-oriented allocative efficiency, and 0.15 in input-oriented economic efficiency. These results indicate that the variation in allocative efficiency across farms is less than that in the other efficiency measures.

Table 2 presents the relative frequency distribution (in percent) of the various efficiency measures of sugarcane farms in Pakistan. Histograms of these distributions are presented in Figure 1. The results show that about 13.2 percent of the farms are fully efficient in terms of input-oriented as well as output-oriented technical efficiency measures. However, there is a lot of variation across the farms in these efficiency measures. The variation in allocative efficiency across farms is less than that in the other efficiency measures, as about 63 percent of the sugarcane farms have the allocative efficiency in the range of 0.75–0.89. The results show that the input-oriented economic efficiency varies across farms, where the majority of farms (57 percent) have the economic efficiency in the range of 0.50–0.69.

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Table 1. Descriptive Statistics of Efficiency Measures of Sugarcane Farms in Pakistan

	Input-oriented Technical Efficiency	Input-oriented Allocative Efficiency	Input-oriented Economic Efficiency	Output-oriented Technical Efficiency
Mean	0.75	0.83	0.62	0.75
Std. dev.	0.16	0.08	0.15	0.16
Minimum	0.32	0.62	0.26	0.34
Maximum	1.00	1.00	1.00	1.00

Table 2. Relative Frequency Distribution (in percent) of Efficiency Measures of Sugarcane Farms in Pakistan

	Input-oriented Technical Efficiency (% Farms)	Input-oriented Allocative Efficiency (% Farms)	Input-oriented Economic Efficiency (% Farms)	Output-oriented Technical Efficiency (% Farms)
<0.29	0	0	0.6	0
0.30 – 0.34	0.3	0	2.4	0.3
0.35 – 0.39	1.2	0	2.7	1.5
0.40 – 0.44	0.9	0	6.3	1.5
0.45 – 0.49	3.9	0	5.7	3.0
0.50 – 0.54	3.9	0	12.9	3.9
0.55 – 0.59	6.3	0	15.6	8.1
0.60 – 0.64	12.6	2.4	18.0	11.4
0.65 – 0.69	10.2	5.4	10.5	11.4
0.70 – 0.74	10.5	12.0	8.7	9.9
0.75 – 0.79	12.6	14.4	3.0	11.4
0.80 – 0.84	8.4	22.2	3.6	7.8
0.85 – 0.89	6.3	26.4	5.1	7.2
0.90 – 0.94	5.4	12.6	0.9	5.1
0.95 – 0.99	4.2	3.3	2.7	4.2
1.00	13.2	1.2	1.2	13.2
Total	100	100	100	100

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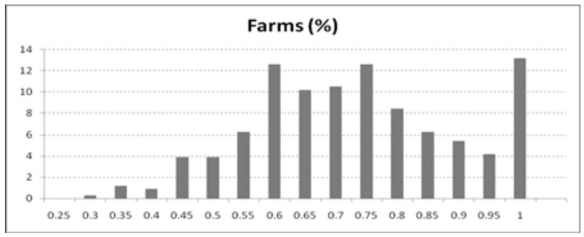
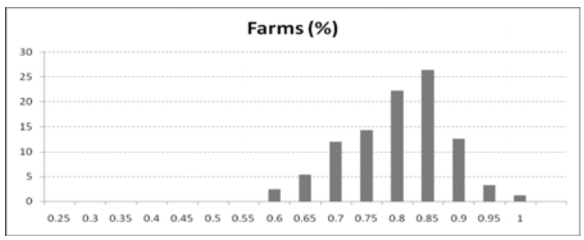
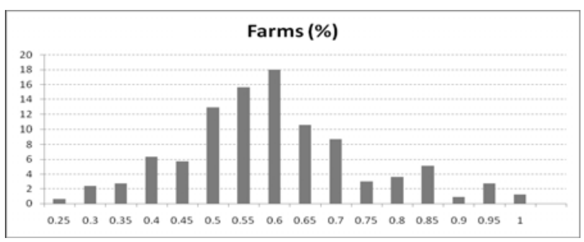


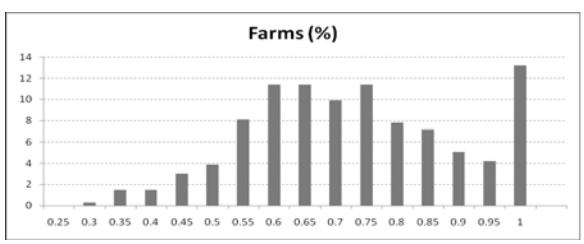
(a) Input-oriented Technical Efficiency



(b) Input-oriented Allocative Efficiency



(c) Input-oriented Economic Efficiency



(d) Output-oriented Technical Efficiency

Figure 1. Histogram of Efficiency Measures of Sugarcane Farms in Pakistan

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CONCLUSIONS

This paper measures the technical, allocative and economic efficiencies of sugarcane farms in Pakistan by DEA method using data collected from 333 sugarcane growers of Pakistan in 2008. The results of this study indicate that sugarcane farms of Pakistan can reduce the costs of production by 38 percent to produce the same level of output by using the inputs in optimal proportion and by improving the technical efficiency. The results also show that the existing level of sugarcane production can potentially be increased by 33.33 percent with the same level of inputs by improving the technical efficiency of the sugarcane farms. It is concluded that the priority should be given to improve the efficiency of the sugarcane farms by introducing technical training programs for farmers and by promoting agricultural extension services.

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It is little short of a miracle that modern methods of instruction have not already completely strangled the holy curiosity of inquiry…. I believe that one could even deprive a healthy beast of prey of its voraciousness if one could force it with a whip to eat continuously whether it were hungry or not…

Albert Einstein

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There is only one Education, and it has only one goal: the freedom of the mind. Anything that needs an adjective, be it civics education, or socialist education, or Christian education, or whatever-you-like education, is not education, and it has some different goal. The very existence of modified "educations" is testimony to the fact that their proponents cannot bring about what they want in a mind that is free. An "education" that cannot do its work in a free mind, and so must "teach" by homily and precept in the service of these feelings and attitudes and beliefs rather than those, is pure and unmistakable tyranny.

~Richard Mitchell, *The Underground Grammarian*, September 1982

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