

EFFICIENCY ANALYSIS OF RICE-WHEAT SYSTEM IN PUNJAB, PAKISTAN

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The main objectives of this study were to estimate technical, allocative and economic efficiency and subsequently to investigate the determinants of technical, allocative and economic inefficiency of rice-wheat cropping system in Punjab, Pakistan. Technical, allocative and economic efficiencies were estimated by using data envelopment analysis (DEA) technique. The mean technical, allocative and economic efficiency scores of the sample farms were of the order 0.83, 0.477 and 0.402 respectively. An econometric analysis based on Tobit Regression models indicated that farm size, age of farm operator, years of schooling, number of contacts with extension agents, access to credit and farm to market distance were significant determinants of technical efficiency whereas years of schooling, number of contacts with extension agents and access to credit had significant impact on allocative and economic inefficiencies of sample farms in the rice-wheat system in Punjab.

Keywords: Technical efficiency, allocative efficiency, economic efficiency, DEA, Tobit

INTRODUCTION

Rice-wheat cropping system has a long history in Asia. This system has been practiced in China since 700 AD and in Pakistani Punjab since 1920 (Gupta *et al.* 2004). It is one of the widely practiced cropping systems in Pakistan and is practiced on 4.25 million hectares; about 66 percent of this area is concentrated in Punjab. Total agricultural area under rice-wheat system in Punjab is 2.8 million hectares (FAO, 2004). Total area under rice in Punjab is 1.76 million hectares which is 68 percent of total rice area in Pakistan. Out of 2.6 million hectares rice area in Pakistan, 64 percent is under fine varieties. Punjab occupies 94 percent of area under fine rice varieties (Government of Pakistan, 2006).

The agricultural productivity in Pakistan can be increased either by improved agricultural technology or improvement in efficiency or both. The pace of development and adoption of improved agricultural technology is slow in Pakistan. Therefore, improvement in efficiency is the most suitable option to enhance agricultural productivity in Pakistan in the short term. Farrell (1957) proposed that efficiency of a firm has two components: technical efficiency and allocative efficiency. Technical efficiency is the ability of a firm to produce a maximal output from a given set of inputs or it is the ability of a firm to produce a given level of output with the minimum quantity of inputs and with the available technology (Bukhsh, 2006). Allocative efficiency is the ability of a firm to use the inputs in optimal proportions, given the market prices of inputs and outputs. Economic efficiency is the multiplicative product of technical and allocative efficiency (Coelli, *et al.* 1998).

The main objectives of this study were to estimate the technical, allocative and economic efficiency and subsequently to investigate the determinants of technical, allocative and economic inefficiency of farms in rice-wheat system in Punjab, Pakistan.

Analytical Framework

In this study data envelopment analysis (DEA) technique was used to estimate the technical and economic efficiency of farms in rice-wheat system in Punjab. Data envelopment analysis (DEA) was first developed by Charnes, *et al.* (1978) to measure efficiency of a firm under the assumption of constant return to scale. It is a linear programming technique which uses data regarding inputs and outputs to construct a best practice production frontier over the data points. The frontier surface is constructed by the solution of a sequence of linear programming problems-one for each firm in the sample. The efficiency of a firm is measured relative to that frontier (Mbaga, *et al.* 2000).

According to Coelli (1995) and Krasachat (2003) Data envelopment analysis (DEA) technique has the following main advantages:

- 1) It does not require the assumption of a functional form to specify the relationship between inputs and outputs.
- 2) It does not require the assumption about the distribution of the underlying data.

In this study data envelopment analysis (DEA) technique was used to estimate the technical and economic efficiencies. Allocative efficiency is the ratio of economic efficiency to the technical efficiency.

Estimation of Technical Efficiency

Input oriented DEA model under the assumption of variable return to scale was used to estimate the technical efficiency in this study. Coelli, *et al.* (1998) argued that one should select orientation from input oriented DEA model or output oriented DEA model according to which quantities the operator has more control over. As, farmers in Punjab have more control over inputs than outputs, therefore, input oriented DEA model was used in the study. Constant return to scale DEA model is only appropriated when all firms are operating at optimal scale (Coelli, *et al.* 1998) but it is not possible in agriculture in Pakistan due to many constraints such as financial constraints, imperfect competition etc. In order to accommodate this possibility,

Output variable used for estimating technical efficiency was total farm income (Y). Total farm income included income from crops and income from livestock. Total income of crops was estimated by multiplying the output of each crop with price received by the farmers while total income of livestock was obtained by aggregating the value of milk and sale proceeds of live animals. The inputs used in this study included land (X_1), tractor (X_2), seed (X_3), NPK (X_4), pesticide (X_5), labour (X_6), irrigation (X_7), fodder (X_8) and concentrates (X_9).

Following Coelli, *et al.* (1998), an input oriented variable return to scale DEA model for estimation of technical efficiency was specified as:

$$\begin{aligned} \text{Min } \theta, \lambda \quad & \theta \\ \text{Subject to} \quad & -y_i + Y\lambda \geq 0 \\ & \theta x_i - X\lambda \geq 0 \\ & N1'\lambda = 1 \\ & \lambda \geq 0 \end{aligned}$$

where

Y represents an output matrix for N farms.

θ represents the input technical efficiency score having a value $0 \leq \theta \leq 1$.

X represents an input matrix for N farms.

λ is an $N \times 1$ vector of weights which defines the linear combination of the peers of i-th farm

y_i represents the total farm income of the ith farm in Rs.

x_i represents the input vector of $x_{1i}, x_{2i}, \dots, x_{9i}$ inputs of the ith farm.

x_{1i} represents the total cropped area in acres on the ith farm.

x_{2i} represents the total quantity of seed in kg used on the ith farm.

x_{3i} shows the total number of tractor hours used for all farm operations on the ith farm.

x_{4i} represents NPK nutrients (kg) used on the ith farm.

x_{5i} represents the total quantity of pesticides/insecticides/weedicides (active ingredient) in grams used on the ith farm.

x_{6i} indicates the labour input consisting of family and hired labour and was calculated as the total number of man-days required to perform various farms operations on the i-th farm.

x_{7i} represents the total irrigation hours used on the ith farm.

x_{8i} represents the total quantity of fodder in kg used to feed the animals on the ith farm.

x_{9i} represents the total quantity of concentrates in kg used to feed the animals on the ith farm.

Estimation of Economic Efficiency

Economic efficiency is the ratio of the minimum cost to the observed cost. Following Coelli, *et al.* (1998), a cost minimization DEA model used to estimate minimum cost was specified as:

$$\begin{aligned} \text{Min } \lambda, x_i^E \quad & X_i^E w_i \\ \text{Subject to} \quad & -y_i + Y\lambda \geq 0 \\ & X_i^E - X\lambda \geq 0 \\ & N1'\lambda = 1 \\ & \lambda \geq 0 \end{aligned}$$

where

w_i is a vector of input prices w_1, w_2, \dots, w_9 of inputs used on the ith farm.

N refers to total number of farms in the sample.

w_{1i} represents land rent of the ith farm in Rs.

w_{2i} represent total cost of seed used on the ith farm in Rs.

w_{3i} represents total amount paid for the use of tractor on the ith farm in Rs.

w_{4i} represents total cost of NPK used on the ith farm in Rs.

w_{5i} represents total cost of pesticides/insecticides/weedicides used on the ith farm in Rs.

w_{6i} represents total cost of labour used on the ith farm in Rs.

w_{7i} represents total cost of irrigation water used on the ith farm in Rs.

w_{8i} represents total cost of fodder used on the ith farm in Rs.

w_{9i} represents total cost of concentrates used on the ith farm in Rs.

Economic efficiency was calculated by the ratio:

$$\text{Economic Efficiency} = \text{minimum cost/observed cost}$$

$$EE = \frac{X_i^E w_i}{X_i w_i}$$

Technical and economic efficiency scores in this study were estimated by using the computer software **DEAP 2.1** developed by Coelli (1996).

Estimation of Allocative Efficiency

Allocative efficiency is the ratio between economic efficiency and technical efficiency and was estimated by dividing economic efficiency with technical efficiency.

Sources of technical, allocative and economic inefficiency

Technical, allocative and economic inefficiencies from DEA were separately regressed on socio-economic and farm specific variables to identify sources of technical, allocative and economic inefficiencies respectively. However, as indicated by Dhangana, *et al.* (2000) that the inefficiency scores are limited between 0 and 1, therefore, the dependent variable in regression model does not have normal distribution. This suggests that ordinary least square (OLS) regression is not appropriate and estimation with an OLS regression would lead to a biased parameters estimate (Krasachat, 2003). Green (1993) argues that it is more convenient to have data censored at zero than at 1. As the distribution of estimated inefficiency scores are censored at zero, Tobit regression model of the following form was specified:

$$E_i = E_i^* = \beta_0 + \beta_1 Z_{1i} + \beta_2 Z_{2i} + \beta_3 Z_{3i} + \beta_4 Z_{4i} + \beta_5 Z_{5i} + \beta_6 Z_{6i} + \mu_i \quad \text{if } E_i^* > 0$$

$$E_i = 0 \quad \text{if } E_i \leq 0$$

where

i refers to the i th farm in the sample.

E_i is an inefficiency measures representing technical, allocative and economic inefficiency of the i th farm.

E_i^* is the latent variable.

Z_{1i} represents the total farm area in acres operated by the i th farmer.

Z_{2i} represents the age of the i th farm's operator in years

Z_{3i} represents the education of the i th farmer in years of schooling

Z_{4i} represents the number of contacts of the i th farmer with extension agents

Z_{5i} represents the distance of the i th farm from main market in kilometers.

Z_{6i} is a dummy variable having value equal to one if farmer has access to credit otherwise zero

β 's are unknown parameters to be estimated

μ_i is the error term

EViews 5.0 computer software was used to estimate Tobit regression model.

Sampling Procedure and the Data

The data used in this study were generated by a cross sectional survey using a multistage random sampling technique. A four-stage sampling design was used for collection of data from the field. First stage units were districts, second stage units were tehsils, third stage units were villages and fourth stage units were farmers. During the first stage, Gujranwala and Hafizabad Districts were selected randomly from the rice-wheat system in Punjab. Noshara Virkan and Kamonki Tehsils from Gujranwala District and Hafizabad and Pindi Bhattian Tehsils from Hafizabad District were taken. Two villages from each tehsil were chosen. Twenty-five farmers were selected from each village. In all two hundred farmers were selected as respondents from the rice-wheat system in Punjab.

The data were collected for the crop year 2005-06 (*Kharif* 2006 and *Rabi* 2005-06 and). A comprehensively designed and pre-tested questionnaire was used to collect information from the farm respondents.

RESULTS AND DISCUSSIONS

Technical, allocative and economic efficiencies of sample farms in rice-wheat system

Technical, allocative and economic efficiency of sample farms in rice-wheat system is presented in Table 1. It is evident from the results that the mean technical efficiency of the sample farms is 0.83, with minimum level of 0.317 and maximum level of 1. The mean allocative efficiency of the sample farms is estimated at 0.477, with a low of 0.047 and a high of 1. The mean economic efficiency of the sample farms is 0.402, ranging between 0.04 and 1.0. These results indicate that if sample farmers in rice-wheat system operated at full efficiency levels they could reduce, on an average, input use by 17 percent and cost of inputs by about 52 percent without reducing the level of output, with existing technology.

Frequency distribution of technical, allocative and economic efficiency of farms in rice-wheat system is given in Table 1. It is evident from the results that the majority of the sample farms in rice-wheat system fall within the range of 0.60 and 1.0. Out of 200 sample

Table 1. Deciles Range of Frequency Distribution of Technical, Allocative and Economic Efficiencies of Rice-Wheat System

Efficiency Level	Technical Efficiency		Allocative Efficiency		Economic Efficiency	
	Frequency	Percent	Frequency	Percent	Frequency	Percent
0.01 – 0.10	-	-	10	5	14	7
0.11 – 0.20	-	-	16	8	33	16.5
0.21 – 0.30	-	-	29	14.5	40	20
0.31 – 0.40	2	1	25	12.5	31	15.5
0.41 – 0.50	5	2.5	27	13.5	13	6.5
0.51 – 0.60	23	11.5	27	13.5	23	11.5
0.61 – 0.70	24	12	31	15.5	25	12.5
0.71 – 0.80	34	17	17	8.5	12	6
0.81 – 0.90	12	6	8	4	2	1
0.91 – 1.0	100	50	10	5	7	3.5
Total	200	100	200	100	200	100
Mean	0.83		0.477		0.402	
Minimum	0.317		0.047		0.40	
Maximum	1.0		1.0		1.0	

farms, 50 percent farms have technical efficiency greater than 0.90, 6 percent farms have technical efficiency between 0.81-0.90, 17 percent farms have technical efficiency between 0.71-0.80, 12 percent farms have technical efficiency between 0.61-0.70, 11.5 percent farms have technical efficiency between 0.51-0.60 and only 3.5 percent farms have technical efficiency less than 0.50. Allocative efficiency of majority of the sample farms fall within the range of 0.21 and 0.7. Out of 200 sample farms, only 5 percent farms have allocative efficiency greater than 0.90, 4 percent farms have allocative efficiency between 0.81-0.90, 8.5 percent farms have allocative efficiency between 0.71-0.80, 15.5 percent farms have allocative efficiency between 0.61-0.70, 13.5 percent farms have allocative efficiency between 0.51-0.60, 13.5 percent farms have allocative efficiency between 0.41-0.50, 12.5 percent farms have allocative efficiency between 0.31-0.40, 14.5 percent farms have allocative efficiency between 0.21-0.30 while 13 percent farms have allocative efficiency less than 0.21. Economic efficiency of majority of the sample farms fall within the range of 0.11 and 0.7. Out of 200 sample farms, 4.5 percent farms have economic efficiency greater than 0.80, 6 percent farms have economic efficiency between 0.71-0.80, 11.5 percent farms have economic efficiency between 0.6-0.70, 11.5 percent farms have economic efficiency between 0.51-0.60, 6.5 percent farms have economic efficiency between 0.40-0.51, 15.5 percent farms have economic efficiency between 0.30-0.40, 20 percent farms have economic efficiency between 0.21-0.30, 16.5 percent farms have economic efficiency between 0.11-0.20 and 7 percent farms have economic efficiency less than 0.11.

Determinants of Technical, allocative and economic Inefficiencies of the sample farms

Tobit results are presented in Table 2. it is indicated from the that the farm size and farm to market distance variables are positively and significantly associated while years of schooling, age of farm operator, number of contacts with extension agent and access to credit variables are negatively and significantly related with the technical inefficiency of farms in rice- wheat system in Punjab.

Years of schooling, number of contacts with extension agents and access to credit variables are negatively and significantly associated with the allocative and economic inefficiencies of farms. Farm size, age of farm operator, farm to market distance variables have non-significant impact on technical and economic inefficiencies of rice-wheat system in Punjab.

CONCLUSIONS AND SUGGESTIONS

Results of the study indicated that the average technical, allocative and economic efficiencies of rice wheat system were 0.83, 0.447 and 0.402 respectively. An analysis of the determinants of technical, allocative and economic inefficiencies was carried out which showed that the years of schooling, number of contacts with extension agents and access to credit had negative impact on technical, allocative and economic inefficiencies of rice-wheat system in Punjab. Small farms were technically less inefficient. There was no significant difference between the allocative and economic inefficiency of small and large farms in the system. Younger farmers were found to be technically

Table 2. Sources of Technical, Allocative and Economic Inefficiencies of Rice-Wheat System in Punjab

Variable	Technical Efficiency		Allocative Efficiency		Economic Efficiency	
	Coefficient	Prob.	Coefficient	Prob.	Coefficient	Prob.
Constant	0.019 (0.064)	0.77	0.817 (0.067)	0.000	0.785 (0.069)	0.00
Farm Size (acre)	0.003 (0.001)	0.01	0.001 (0.001)	0.193	0.002 (0.001)	0.11
Years of Schooling	-0.007 (0.004)	0.08	-0.008 (0.004)	0.080	-0.011 (0.004)	0.01
Age of Farm's Operator (years)	0.003 (0.001)	0.02	-0.002 (0.001)	0.214	-0.000 (0.001)	0.90
Contact with Extension Agents (No.)	-0.006 (0.002)	0.01	-0.013 (0.002)	0.000	-0.012 (0.002)	0.00
Farm to Market Distance (km)	0.007 (0.004)	0.09	-0.002 (0.004)	0.583	0.002 (0.004)	0.60
Access to Credit Dummy	-0.054 (0.030)	0.07	-0.061 (0.034)	0.078	-0.055 (0.033)	0.10

Figures in parentheses are standard error

less inefficient than the older ones. There was no significant difference between the allocative and economic inefficiency of younger and older farmers. Results of the study also showed that those farms which were located closer to the market were technically less inefficient than the farms located away from the markets. It was also found that farm to market distance variable had insignificant impact on the allocative and economic inefficiencies of sample farms in rice-wheat system.

In view of the findings of this study, following suggestions are put forth to reduce technical, allocative and economic inefficiency of rice-wheat system in Punjab, Pakistan.

- 1- It is evident from the results of the study that education was negatively related to the technical, allocative and economic inefficiencies of rice-wheat system in Punjab. It is recommended that government should focus on increasing the education level of farming communities by opening more schools in the rural areas. Government should design policies to attract more educated people into farming by providing incentives to the educated people.
- 2- Results of the study indicated that the farmers having more contacts with extension agents were technically, allocatively and economically less inefficient than the farmers having less contacts with extension agents. Therefore, it is suggested that Government should allocate more funds in strengthening the extension department and expanding net of extension services in the rural areas.
- 3- According to Fraser and Cordina (1999), *"It is all very well having best practice described by an extension officer on a farm visit, but being able to observe directly best-practice farming techniques will enhance the learning experience."* It is therefore suggested that Adaptive Research Wing of Agriculture Department should be activated to play its due role in developing and disseminating

latest agricultural production technology to the farmers.

- 4- Results of the study revealed that access to credit had negative impact on the technical, allocative and economic inefficiencies of rice-wheat system. It is therefore, recommended that farmers should be provided assistance in the form of soft loans to enable them to cope with the ever increasing prices of inputs like seeds, fertilizer, fuels, pesticides, labour etc.
- 5- It is evident from results that the farms having better access to market and road infrastructure are technically less inefficient than the farms having poor access to market and road infrastructure. It is, therefore, suggested that government should focus on development of market and road infrastructure in the rural areas.
- 6- The results of the study indicated that younger farmers were technically less inefficient than the older farmers in the study area. It is therefore recommended that government should focus on ways to attract and encourage younger farmers in farming. This would lead to enhance productive efficiency by the injection of new blood in agriculture.
- 7- The results of the study showed that the small farms in rice-wheat system in Punjab are technically less inefficient than the large farms. It is, therefore, recommended that government should devise programs aimed at supporting the small farms. However, these programs should not hinder the growth of the large farms.

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