MEASUREMENT OF TECHNICAL EFFICIENCY OF RICE-WHEAT SYSTEM IN PUNJAB, PAKISTAN USING DEA TECHNIQUE*

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ABSTRACT

This study was conducted in the Department of Agricultural Economics, University of Agriculture, Faisalabad, Pakistan during the year 2007 to estimate technical efficiency and identify the determinants of technical inefficiency of rice-wheat farming system in Punjab. For this purpose a non-parametric data envelopment analysis (DEA) technique was applied. Tobit regression model was estimated to investigate determinants of technical inefficiency of the system. The results revealed that mean technical efficiency of the system was 0.83, with minimum level of 0.317 and maximum of 1. This indicated the existence of substantial technical inefficiency in rice-wheat system in Punjab. The study further revealed that if sample farms in rice-wheat system operated at full efficiency level these could reduce their input use by 17 percent without any reduction in level of output and with existing technology. Results of the Tobit regression model showed that years of schooling, number of contacts with extension agents and access to credit variables had negative impact while farm size, age of farm's operator and farm to market distance had positive impact on technical inefficiencies of rice-wheat system in Punjab. It is suggested that government should focus on attracting young and educated people in farming by providing incentives in the form of soft loans.

KEYWORDS: ***Oryza sativa; Triticum aestivum;*** **farmers; appropriate technology; efficiency; Punjab; Pakistan.**

INTRODUCTION

The recent food scarcity and rising prices have affected majority of people in every country of the world including Pakistan. The present food crisis is an eye opener for the policy makers and agricultural scientists in Pakistan. Food riots erupted in several parts of the country due to scarcity of food and price

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hike. The present government has decided to import 2.5 million tons of wheat to cope with problem of food shortage in the country in short run. In order to get self sufficiency in food production and also to earn agro-dollars, government has to make both short term and long term policies.

Possible ways to enhance agricultural production are: expansion in cultivated area, technological change and improvement in technical efficiency. Last option is the most suitable in short period of time because it does not require more area, higher cropping intensity and development of new technology. Technical efficiency is the ability of a firm to obtain maximum output from a given set of resources and available technology or it is the ability of a firm to produce given level of output with minimum quantity of inputs and available technology. The former is called input oriented measures of technical efficiency and the latter is known as output-oriented measures of technical efficiency (10).

The estimation of technical efficiency in agriculture has remained an area of research in both developing and developed countries. This is more important for developing countries like Pakistan where potential to increase the production through expansion in cultivated area and development/adoption of new technology is limited. The previous studies on technical efficiency in agriculture in Pakistan fail to give a clear picture of farmer’s efficiency and to use of farm level data on a single crop (1, 6, 7, 8, 18, 19). Moreover, these studies do not seem to have estimated technical efficiency of a farming system in Pakistan.

Rice-wheat system has a long history in Asia. It has been practiced in China since 700 AD and Punjab, Pakistani since 1920 (17). It is one of the widely practiced cropping systems in Pakistan and is existed on 4.25 million hectares, about 66 percent of this area lies in Punjab. Total agricultural area under rice-wheat system in Punjab is 2.8 million hectares (2). 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 (3).

METHODOLOGY

This study was conducted in the Department of Agricultural Economics, University of Agriculture, Faisalabad, Pakistan during the year 2007.

Analytical framework

According to Farrell (13) efficiency is defined as the actual productivity of a firm relative to its maximal productivity. Maximal productivity (also called best practice) is defined by the production frontier (24).

Principal approaches to estimate production frontier are: (1) parametric approach through Stochastic Frontier Analysis (SFA) and (2) non-parametric approach through data envelopment analysis (DEA). Both approaches estimate the best practice frontier and calculate the efficiency relative to that frontier (23).

In this study DEA technique was used to estimate technical-efficiency due to following main advantages:

- It does not require the assumption of a functional form to specify the relationship between inputs and outputs. This implies that one can avoid unnecessary restrictions about functional form that can affect the analysis and distort the results (14).
- It does not require the assumption about the distribution of the underlying data (22).

Data envelopment analysis (DEA)

DEA was first developed by Charnes *et al*. (9) to measure efficiency of a firm under the assumption of constant return to scale. It is a linear programming technique which uses data on inputs and outputs to construct the best practice production frontier over the data points. The frontier surface is constructed by the solution of a sequence of linear programming problems-one problem for each firm in the sample. The efficiency of a firm is measured relative to that frontier (25).

Coelli *et al*. (11) argue 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 have more control over inputs than outputs, therefore, input oriented DEA model was selected. According to Coelli *et al.* (11) constant return to scale DEA model is only appropriated when all firms are operating at optimal scale but it is not possible in agriculture in Punjab due to many reasons like financial constraints, imperfect competition, etc. In order to accommodate this problem, Banker *et al*. (5) suggested variable return to scale DEA model. Therefore, input oriented variable return to scale DEA model was used in this study to estimate the technical efficiency.

Following Coelli *et al*. (11), an input oriented variable return to scale DEA model for estimation of technical efficiency was specified as:

$$\min_{\theta,\lambda} \theta,$$

$$\text{Subject to} \quad -y_i + Y\lambda \geq 0$$

$$\theta x_i - X\lambda \geq 0$$

$$N1'\lambda = 1$$

$$\lambda \geq 0$$

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 NX1 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 $x_{1i}, x_{2i}, \ldots\ldots x_{9i}$ 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 *ith* 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.

Technical efficiency scores in this study were estimated by using the computer software ***DEAP 2.1*** as described by Coelli (10).

Tobit regression model

There are two alternate approaches to investigate the relationship between farm inefficiency and various socio-economic and farm specific factors. The first method is to compute correlation coefficient or to conduct other simple non-parametric analysis. The second method is first to measure inefficiency and then to use regression model in which inefficiency is expressed as a function of socio-economic and farm specific factors. The latter approach is also known as 'two step procedure' and is the most commonly used procedure (20). The same approach is adopted in this study.

Technical Inefficiency scores were obtained by subtracting efficiency scores from 1. Technical inefficiency scores were regressed on socio-economic and farm specific variables to identify sources of technical inefficiency. However, as indicated by Dhangana *et al*. (12) that technical inefficiency scores are limited between 0 and 1, therefore, the dependent variable in regression model doesn't 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 (22). Greene (15) argues that it is more convenient to have data censored at zero than at 1. As the distribution of estimated inefficiency scores is censored at zero, Tobit regression model of following form was specified:

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

$$E = 0 \qquad if \quad E \le 0$$

where

i refers to the *ith* farm in the sample.
E_i represents technical inefficiency of the *ith* farm.
E_i^* is the latent variable.
Z_{1i} represents the total farm area in acres operated by the *ith* farm.
Z_{2i} represents the age of the *ith* farm's operator in years.
Z_{3i} represents the education of the *ith* farmer in years of schooling.
Z_{4i} represents the number of contacts of the ith farmer with extension agents.
Z_{5i} represents the distance of the ith 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.
ß'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 data collection

The data used in this study were generated by a cross sectional survey using a four-stage random sampling technique. First stage units were districts, second stage units were tehsils, third stage units were villages and fourth stage units were farmers. During first stage, Gujranwala and Hafizabad districts were selected randomly from the rice-wheat system in Punjab. Noshera Virkan and Kamonki tehsils from Gujranwala district and Hahizabad 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, 200 farmers were selected as respondents from rice-wheat system in Punjab. Interview schedule was adopted to collect detailed information from the farm respondents. The data were collected for the crop year 2005-06 (rabi 2005-06 and kharif 2006). A comprehensively designed and pre-tested questionnaire was used to collect information from the farm respondents.

RESULTS AND DISCUSSION

Technical efficiency of rice-wheat system in Punjab

The data (Table 1) derived from Annexure indicated that mean technical efficiency of the sample farms is 0.83 with minimum level of 0.317 and maximum level of 1. These results indicate that if sample farms in rice-wheat system operated at full technical efficiency levels they could reduce, on an average, input use by 17 percent with the application of same technology and without reducing the level of output.

It also revealed that technical efficiency level of majority of sample farms in rice-wheat system ranged from 0.60 to 1.0. Of 200 sample farms, 50 percent farms had technical efficiency greater than 0.90, 6 percent farms from 0.81 to 0.90, 17 percent farms from 0.71 to 0.80, 12 percent from 0.61 to 0.70, 11.5 percent from 0.51 to 0.60 and only 3.5 percent farms had technical efficiency less than 0.50 (Table1).

Determinants of technical inefficiency of rice-wheat system in Punjab

Tobit results (Table 2) showed that farm size variable had significant positive impact on technical inefficiency of farms which implies that small farms were technically less inefficient than large farms.

Table 1. Frequency distribution of technical efficiency of rice-wheat system.

Efficiency level	Farmers frequency	Percent
0.01 – 0.10	-	-
0.11 – 0.20	-	-
0.21 – 0.30	-	-
0.31 – 0.40	2	1
0.41 – 0.50	5	2.5
0.51 – 0.60	23	11.5
0.61 – 0.70	24	12
0.71 – 0.80	34	17
0.81 – 0.90	12	6
0.91 – 1.0	100	50
Total	200	100
Minimum	0.317	
Maximum	1.00	
Mean	0.83	

Table 2. Sources of technical, allocative and economic inefficiency of rice-wheat system in Punjab.

Variable	Technical inefficiency	
	Coefficient	Prob.
Constant	0.019 (0.064)*	0.77
Farm size (acre)	0.003 (0.001)	0.01
Years of schooling (No.)	-0.007 (0.004)	0.08
Age of farm's operator (years)	0.003 (0.001)	0.02
Contact with extension agents (No.)	-0.006 (0.002)	0.01
Farm to market distance (km)	0.007 (0.004)	0.09
Access to credit dummy	-0.054 (0.030)	0.07

*Figures in parentheses are standard error.

The years of schooling variable is negatively and significantly associated with technical inefficiency of farms implying that farmers having more years of schooling are technically less inefficient than farmers with less/no years of schooling. The parameter estimate of age variable had a positive sign and was significant. The results indicate that younger farmers are technically less inefficient than their older counterparts. The obvious reason for this relationship may be that younger farmers are likely to have some education and have more access to information and extension services. The coefficient of contact with extension agents variable was negative and significant revealing that farmers having more contacts with extension agents are technically less inefficient than their counterparts who have less/no contacts with extension agents. Similar results have been reported earlier (1, 19, 26). The possible reason for this relationship may be that farmers having more contacts with extension agents are able to get information about agricultural technology, pest management and proper/timely use of inputs.

The farm to market distance variable is positively and significantly correlated with the technical inefficiency of farms. It indicates that the farms located closer to the market are technically less inefficient than the farms located away from the market. The access to credit dummy variable had a significant negative impact on technical inefficiency of sample farms. This implies that farmers with better access to credit are technically less inefficient than those having poor/no access to credit in sample area.

CONCLUSION AND SUGGESTIONS

The study concludes that average technical efficiency of rice wheat system was 0.83 ranging between 0.317 and 1.0. It was deserved that there is a considerable room to increase agricultural production in rice-wheat system in Punjab without additional inputs and with existing technology. The result suggests that if sample farms in rice-wheat system operated at full efficiency levels these could reduce their input use by 17 percent without any reduction in output level. Analysis of determinants of technical inefficiency showed that years of schooling, number of contacts with extension agents and access to credit variables had negative impact while farm size, age of farm's operator and farm to market distance had positive impact on technical inefficiencies of rice-wheat system in Punjab.

Following suggestions are made to reduce technical inefficiency of rice-wheat system in Punjab, Pakistan.

- Government should focus on increasing the education level of farming communities by opening more schools in the study areas. Government should design policies to attract more educated people in farming by providing incentives to the educated people.
- Government should allocate more funds in strengthening the Extension Department and expanding net of extension services in the study area for maintaining more contacts with the farmers.
- Farmers should be provided soft loans to enable them to cope with ever increasing prices of inputs like seeds, fertilizer, fuels, pesticides, labour, etc.
- Better access to market and road infrastructure positively affected technical efficiency. Ghura and Just (16) argued that better access to roads expands output markets at one hand and increase demand for modern inputs on the other. It is, therefore, suggested that government should focus on development of market and road infrastructure in study area.

- Government should focus on ways to attract and encourage younger farmers in farming. This would lead to reduce technical inefficiency of rice-wheat system by injecting new blood.
- Government should also devise programmes aimed at supporting the small farms. However, these programmes should not hinder the growth of large farms.

The present study has estimated technical efficiency of rice-wheat system in Punjab. Future research should consider allocative and economic efficiency not only of the rice-wheat system of study area but also all farming systems of Pakistan. In this study DEA technique was applied. Further studies may use Stochastic Frontier approach alongwith DEA approach for comparison of results.

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Annexure

Technical efficiency of rice-wheat system.

Farmer's number	Technical efficiency	Farmer's number	Technical efficiency	Farmer's number	Technical efficiency	Farmer's number	Technical efficiency
1	0.724	51	1.0	101	1.0	151	1.0
2	11.0	52	1.0	102	0.982	152	0.903
3	0.585	53	0.866	103	0.907	153	0.52
4	1.0	54	0.748	104	0.948	154	0.532
5	1.0	55	0.751	105	0.814	155	0.637
6	0.771	56	0.793	106	0.996	156	0.919
7	1.0	57	0.752	107	0.465	157	0.563
8	1.0	58	0.708	108	0.784	158	0.968
9	0.809	59	1.0	109	0.91	159	0.934
10	1.0	60	0.957	110	0.5	160	0.975
11	0.637	61	1.0	111	1.0	161	0.732
12	0.735	62	0.994	112	1.0	162	0.631
13	0.793	63	0.735	113	0.603	163	0.933
14	1.0	64	1.0	114	1.0	164	0.698
15	0.713	65	1.0	115	0.981	165	1.0
16	0.531	66	0.933	116	1.0	166	1.0
17	1.0	67	1.0	117	1.0	167	0.735
18	0.64	68	0.707	118	0.971	168	0.868
19	1.0	69	0.591	119	1.0	169	0.982
20	0.74	70	1.0	120	0.799	170	0.653
21	0.813	71	1.0	121	0.608	171	0.473
22	0.988	72	0.911	122	0.577	172	0.537
23	1.0	73	1.0	123	0.895	173	0.635
24	0.767	74	1.0	124	0.514	174	0.735
25	0.58	75	1.0	125	0.679	175	0.503
26	0.638	76	1.0	126	1.0	176	1.0
27	0.864	77	1.0	127	0.467	177	0.773
28	1.0	78	0.97	128	0.77	178	0.548
29	1.0	79	0.945	129	1.0	179	0.874
30	0.753	80	1.0	130	0.643	180	0.999
31	1.0	81	0.961	131	0.555	181	1.0
32	0.657	82	1.0	132	0.51	182	0.56
33	1.0	83	0.825	133	0.686	183	0.646
34	0.317	84	0.648	134	0.563	184	0.656
35	1.0	85	0.842	135	0.971	185	0.65
36	0.838	86	1.0	136	0.538	186	1.0
37	1.0	87	0.796	137	0.685	187	0.771
38	1.0	88	1.0	138	1.0	188	0.607
39	1.0	89	1.0	139	0.87	189	1.0
40	0.793	90	1.0	140	0.928	190	1.0
41	0.724	91	1.0	141	0.692	191	0.75
42	1.0	92	0.772	142	0.69	192	1.0
43	0.533	93	0.544	143	1.0	193	0.57
44	0.984	94	0.998	144	0.776	194	0.616
45	0.642	95	1.0	145	1.0	195	1.0
46	0.803	96	0.681	146	0.708	196	0.589
47	0.763	97	0.537	147	1.0	197	0.927
48	0.962	98	1.0	148	0.991	198	1.0
49	1.0	99	0.966	149	0.333	199	0.972
50	1.0	100	0.778	150	0.559	200	0.709