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Research Note

Technical Efficiency of Rice Farms under Irrigated Conditions in Central Gujarat[§]

Anuradha Narala and Y.C. Zala*
Department of Agricultural Economics, B.A. College of Agriculture,
Anand Agricultural University, Anand - 388 110, Gujarat

Abstract

The present investigation undertaken in the central Gujarat, has estimated the technical efficiency in rice production and has assessed the effect of farm-specific socio-economic factors on this technical efficiency. A stochastic frontier production function has been estimated to determine technical efficiency of individual farms and variance as well as regression analyses have been carried out to find the influence of socio-economic factors. The study has revealed that the farm-specific technical efficiencies range from 71.39 per cent to 99.82 per cent, with the mean of 72.78 per cent, which indicates that on average, the realized output can be raised by 27 per cent in the region with the available technology and resources, without any additional resources. It has been found that factors like operational area, experience, education and distance of field from canal structure are the most influential determinants of technical efficiency, while the variable, number of working family members, has shown significant but negative relationship with technical efficiency. By adopting good management practices and proper allocation of the existing resources and technology, along with sound extension programmes, the potential that exists for improving the productivity of rice in the state, could be exploited.

Introduction

Rice is the most important cereal food crop of India, and is cultivated in 43.81 million hectares. It plays a vital role in the national food grain supply and is the main driver of India's food security. Rice occupies about 23 per cent of the grossed cropped area in the country. It occupies 35 per cent of the total area under food grains and contributes around 43 per cent to the total food grain production in the country.

Despite having a firm footage on rice cultivation, India is facing a formidable challenge to feed its growing population. It is estimated that about 260 Mt of food grains are to be produced annually by the year 2030 to meet its rising food requirement (Reddy and Sen, 2004). With limited scope for area expansion, coupled with diversion of cultivable land to non-agricultural uses (Deshpande and Bhende, 2003), the growing demand for food grains resulting from swelling population and rising per capita income can only be met by increasing the food grain production through productivity enhancement. Despite having largest area under rice in the world, the country has achieved only 41 per cent productivity of the USA and 48 per cent of China. Available literature suggests that farmers in the developing countries fail to exploit the full potential of a technology and make allocative errors (Taylor and Shonkwiler, 1986; Ali and Flinn, 1989; Kalirajan and Shand, 1989; Bravo-Ureta and Evenson, 1994; Banik, 1994; Shanmugan and Palanisami, 1994; Sharma and Datta, 1997; and Thomas and Sundaresan, 2000). Thus, increasing the efficiency in production assumes greater significance in attaining potential output at the farm level. Improvement in technical efficiency is a potential source of further productivity growth. But, embarking

* Author for correspondence, Email: yczala@yahoo.co.in
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on new technologies is meaningless unless the existing technology is used to its full potential, (Kalirajan *et al*., 1996). Further, the analysis of variations between the potential and actual yields on the farm, given the technology and resource endowment of farmers, provide better understanding of the yield gap. Thus, technical efficiency is an indicator of the productivity of the firm and the variation in technical efficiency can reflect the productivity difference across firms. It helps for hunting the potentiality of the existing technology. Therefore, improvement in technical efficiency is the key for meeting the growing food grain demand in the years to come. The present study has assessed the technical efficiency in rice production along with the influence of various socio-economic factors on this efficiency of the rice farms in the central Gujarat.

Methodology

Data Collection and Sampling

Rice is grown intensively in the central Gujarat region which accounts for 64 per cent of the total area under rice and contributes 61 per cent to the total rice production in the state. Moreover, rice ranks first among food grain crops in the central Gujarat. As such, the central Gujarat region was selected purposively for the present study. For sample selection, multistage stratified random sampling method was adopted. At the first stage, two districts were selected randomly from the six districts of central Gujarat region. Talukas formed the second stage of sampling units, where two talukas from each district were selected on the basis of concentration of area under rice cultivation. Then, a total of twelve villages were chosen from the four selected talukas. From each selected village, a list of rice growers was prepared and they were stratified into four size groups, viz. marginal (up to 1 ha), small (1.01-2 ha), medium (2.01-4 ha) and large (above 4 ha). Further, from each village list of rice growers, 20 farmers were randomly selected ensuring proportionate representation of the four strata. Thus, in all 240 cultivators (109 from marginal, 76 from small, 38 from medium and 17 from large) were selected from the twelve villages. The primary data for the study were collected through personal interview method with help of pre-tested comprehensive interview schedule for the year 2007-08.

Method of Analysis

In the present study, the stochastic frontier production function approach was used to measure technical efficiency of rice cultivating farms (Aigner *et al*., 1977; Kalirajan and Shand, 1989; Sharma and Dutta, 1997). In analyzing technical efficiency, it is not the average output, but the maximum possible output obtainable from a given bundle of inputs, is of importance. The frontier production function is defined as the maximum possible output that a farm can produce from a given level of inputs and technology. In stochastic frontier, the disturbance term is decomposed into two components: asymmetric component which captures randomness outside the control of the farmer, such as droughts, floods, etc. and the statistical noise contained in every empirical relationship and the other one-sided component capturing randomness under the control of the farmer (i.e., inefficiency).

Specification of the Model

The stochastic frontier production function of the Cobb-Douglas type was specified for this study (Kalirajan and Flinn, 1983; Dawson and Lingard, 1989; Bravo-Ureta and Evenson, 1994).The model used is depicted in Equation (1):

$$\ln Y_i = \beta_0 + \beta_1 \ln X_1 + \beta_2 \ln X_2 + \beta_3 \ln X_3 + \beta_4 \ln X_4 + \beta_5 \ln X_5 + \beta_6 \ln X_6 + \beta_7 \ln X_7 + (v_i - u_i) \quad \ldots(1)$$

where, the subscript 'i', denotes the ith farmer in the sample, and

Y_i = Output of rice (q/ha),
$\beta_0, \ldots, \beta_7$ = Parameters to be estimated,
X_1 = Quantity of seed (kg/ha),
X_2 = Human labour (human days/ha),
X_3 = Machine labour (hours/ha),
X_4 = Irrigation (numbers per hectare),
X_5 = Quantity of fertilizers (NPK) (kg/ha),
X_6 = Quantity of manure (kg/ha),
X_7 = Plant protection chemicals (litres/ha),
$v_i - u_i$ = Random error-term, and
n = Number of farms growing rice.

The computer programme FRONTIER 4.1 (Coelli, 1996) was used to estimate simultaneously the parameters of the stochastic production frontier and the technical inefficiency effects.

Determinants of Technical Efficiency

Several studies have shown a positive relationship between technical efficiency and the socio-economic variables (Kalirajan, 1990; Bravo-Ureta and Evenson, 1994; Parikh and Shah, 1994; Shanmugham, 2003; Bhende and Kalirajan, 2007). In the present study, the farm-specific factors such area under rice crop, experience, education level of farmer, number of working members in the family, land fragmentation index, contact with extension agency and distance of field from canal irrigation structure have been considered which affect the level of technical efficiency of crop production. In this study a simple linear multiple regression equation of the form of Equation (2) was estimated using ordinary least square (OLS) technique.

$$TE_i = b_0 + b_1 X_1 + b_2 X_2 + b_3 X_3 + b_4 X_4 + b_5 X_5 + b_6 X_6 + b_7 X_7 + b_8 X_8 + e_i \quad \ldots(2)$$

where,

TE_i = Technical efficiency of the i^{th} farm,

X_1 = Area under rice crop (in ha),

X_2 = Experience in rice cultivation (in years),

X_3 = Education level of the farmer (school years),

X_4 = Number of working members in the family,

X_5 = Land Fragmentation Index

[Land Fragmentation Index (LFI) = (No. of fragments / Total area under rice)],

X_6 = Contact with extension agency (ies),

X_7 = Distance of field from canal irrigation structure (km),

X_8 = Proximity to the market yard (km),

b_0 = Intercept term,

$b_1, \ldots, b_8$ = Coefficients of respective factors influencing the technical efficiency, and

e_i = Random error-term.

Results and Discussion

Estimation of Frontier Production Function

For estimating technical efficiency, stochastic production function approach was used. The parameters of frontier production function were estimated using the maximum likelihood estimation (MLE) and the results are presented in the Table 1. A high value of γ (0.864) in all the farms indicates the presence of significant inefficiencies in the production of rice crop. It shows about 86 per cent of differences between the observed and maximum production frontier outputs were due to the factors which were under farmer's control. The stochastic frontier analysis has further shown that 86 per cent of observed inefficiency was due to farmer's inefficiency in decision-making and only 14 per cent of it was due to random factors outside their control in the case of all farms. The values of γ were 94 per cent, 66 per cent, 100 per cent and 97 per cent in marginal, small, medium and large size farms, respectively. Thus, the one sided-error u_i dominated

Table 1. Maximum likelihood estimates of stochastic frontier production function for sample rice farms in central Gujarat

Variables	Marginal farm		Small farm		Medium farm		Large farm		All farms	
	Coefficient	SE	Coefficient	SE	Coefficient	SE	Coefficient	SE	Coefficient	SE
Constant	2.426***	0.796	3.344***	0.895	0.669	0.733	1.267	0.986	2.423***	0.357
Seed	0.081	0.082	0.265**	0.110	0.099	0.081	-0.224	0.366	0.040	0.046
No. of irrigations	0.181	0.103	0.197**	0.096	-0.126	0.175	-0.047	0.902	0.092	0.065
Fertilizers	0.342***	0.080	0.083	0.072	0.424***	0.111	0.738	0.624	0.262***	0.048
Pesticides	0.000	0.031	-0.036	0.024	0.035	0.040	-0.159	0.137	-0.042***	0.015
Human labour	-0.216	0.130	-0.208	0.171	0.167	0.092	-0.067	0.303	-0.035	0.050
Manures	0.003	0.011	0.018	0.012	0.022	0.028	0.000	0.043	0.013	0.008
Machine labour	0.053	0.075	-0.037	0.098	-0.189	0.138	-0.031	0.396	-0.010	0.049
Sigma square (σ^2)	0.339***	0.054	0.113***	0.041	0.104***	0.024	0.037	0.025	0.261***	0.031
Gamma (γ)	0.941***	0.026	0.665***	0.262	1.000	0.022	0.976	0.659	0.864***	0.036
log likelihood	36.766		-3.597		10.841		12.213		73.463	

Note: SE =Standard error

*** and ** denote significance at 1 per cent and 5 per cent levels, respectively.

the symmetric error v_i and the short fall of realized productivity from the frontier was largely due to technical inefficiency and was mainly within the control of individual farmers.

Further, the estimates of stochastic frontier have shown that in the case of all farms, the estimated value of the coefficient of fertilizers was positive and highly significant, indicating fertilizers to be productive input for successive production of rice crop. The estimated value of pesticides was negative and significant, indicating overuse of the factor in producing the crop. Seeds, number of irrigations and manures have shown positive impact on output; however, the estimated coefficients were not statistically significant. The coefficients of human labour and machine hours were negative, but were found to be non-significant. Statistically significant and positive values of the estimated coefficients indicated that farmers could increase per hectare yield by applying more units of these inputs.

In the case of marginal farms, all the independent variables considered had positive coefficient, except human labour. But, all were statistically insignificant, except fertilizer, which was positive and significant, indicating the scope for increasing the productivity by increasing the application of fertilizers.

The estimated values of the coefficients of seed and number of irrigations were positive and significant on small farms. Thus, the small farmers can increase per hectare yield by applying more units of these inputs. Other variables, except pesticides, human labour and machine labour, were positive, but all were statistically insignificant.

Across the medium farms, the estimated value of the coefficient of fertilizers was positive and significant at 1 per cent level. All other variables, except the number of irrigations and machine labour were positive, but all were statistically insignificant.

In the case of large farms, the estimated elasticity coefficients for all variables, except fertilizers and manures, were negative, indicating overuse of these factors in producing rice crops. However, all were statistically insignificant.

Technical Efficiency of Sample Farms

Details regarding farm-specific technical efficiencies are important as they provide detailed information to policymakers on the nature of production technology used in farms. Table 2 shows the frequency distribution of sample farms by the level of technical efficiency in raising the rice crop. It was observed that there were wide variations in the level of technical efficiency across the sample farms in raising the rice crop. The average level of technical efficiency has been estimated as 72.78 per cent for farms as a whole, implying that on an average the sample farmers tend to realise around 73 per cent of their technical abilities. Hence, on an average, approximately 27 per cent of the technical potentials are not realised. Therefore, it is possible to improve the yield by 27 per cent by following efficient crop management practices without increasing the level of inputs application.

Table 2. Distribution of sample rice farmers of central Gujarat under different levels of technical efficiency

Efficiency (%)	Number of farms	% to total
Less than 50	8	3.33
50-60	12	5.00
60-70	34	14.17
70-80	52	21.67
80-90	71	29.58
More than 90	63	26.25
Total farms	240	100.00
Mean efficiency (%)	72.78	

It was also observed that a majority of the farmers (51.25%) operated at technical efficiency levels between 70 per cent and 90 per cent. About 22.50 per cent of the rice farms lied below 70 per cent of the technical efficiency level. Further, the analysis revealed that about 26.25 per cent of sample farmers were operating close to the frontier with the technical efficiency of more than 90 per cent.

Technical Efficiency by Farm-size Groups

The frequency distribution of estimated technical efficiency for the sample households by farm-size groups, given in Table 3, reveals that the mean technical efficiency ranged from 71.39 per cent on marginal farms to 99.82 per cent on medium farms. On the other hand, around 15 per cent, 4 per cent and 6 per cent of marginal, small and large farms were found to be at efficiency level of less than 60 per cent. Around 57 per cent of marginal farmers operated at the efficiency

Table 3. Frequency distribution of farm-specific technical efficiency in central Gujarat

Efficiency (%)	Frequency of sample rice farms							
	Marginal	% to total	Small	% to total	Medium	% to total	Large	% to total
Less than 50	8	7.34	0	0.00	0	0.00	0	0.00
50-60	8	7.34	3	3.95	0	0.00	1	5.88
60-70	27	24.77	5	6.58	0	0.00	2	11.76
70-80	35	32.11	16	21.05	0	0.00	1	5.88
80-90	23	21.10	45	59.21	0	0.00	3	17.65
More than 90	8	7.34	7	9.21	38	100.00	10	58.82
Total farms	109	100.00	76	100.00	38	100.00	17	100.00
Mean efficiency (%)	71.39		81.48		99.82		86.74	

levels between 60 and 80 per cent, while 80 per cent of small farmers operated at the efficiency levels between 70 and 90 per cent. The results also revealed that around 59 per cent of large farmers operated closer to the frontier level with technical efficiency of more than 90 per cent. Medium farm-size groups were found to be most efficient in rice farming as they were operating closer to the frontier with the mean technical efficiency of 99.82 per cent. This implies that on an average, medium-size farms are more efficient than large, small and marginal ones. Presumably, the observed high efficiency of medium farms was due to farmers having agriculture as their main occupation and allocating their resources more effectively, leading to higher farming efficiency. The findings of Tadesse and Krishnamoorthy (1997), Bhende and Kalirajan (2007 and Adhikari and Bjorandal (2009) reinforce this result.

Determinants of Technical Efficiency

Given a particular technology to transform physical inputs into outputs, some farmers were able to achieve maximum technical efficiency, while others were found relatively inefficient. This divergence could be due to many factors. Therefore, it is important to identify the factors which cause the difference in farm-specific technical efficiency. A number of studies (Kalirajan, 1991; Kalirajan and Shand, 1989; Shanmugam and Venkataramani, 2006) have suggested that efficiency of farmers is determined by various socio-economic and demographic factors. The results of regression analysis carried out in this regard are presented in Table 4.

The results have shown that the operational area, experience in rice cultivation, education level of a farmer and distance of field from canal irrigation structure were the positive and significant factors, their coefficients being 0.0100, 0.0026, 0.0457 and 0.0305, respectively. This implies that farmers with large operational area, higher educational level and more experience were more efficient in producing rice. The variable, number of working family members, has shown a significant but negative relationship with the technical efficiency. It indicates that as the number of workers in a family

Table 4. Factors affecting technical efficiency in rice production in central Gujarat

Variables	Coefficients	Standard error
Constant term	0.5446***	0.0387
Operational area (in ha)	0.0100*	0.0052
Experience in rice cultivation (in years)	0.0026***	0.0008
Education level of the farmer (school years)	0.0457***	0.0076
Number of working family members (No.)	-0.0127**	0.0064
Land Fragmentation Index	0.0074	0.0048
Contact with extension agency(ies) (No.)	0.0200	0.0182
Distance of field from canal irrigation structure (km)	0.0305*	0.0165
Proximity to the market yard (km)	0.0009	0.0014
R^2	0.3174	

Note: *, ** and *** indicate statistical significance at 10 per cent, 5 per cent and 1 per cent levels, respectively.

increases, the technical efficiency decreases. This may be due to the fact that farmers are already using excess human labour in rice production. Hence, human labour utilization increases with increase in the number of farm workers in the family.

The coefficients of land fragmentation index, contact with extension agencies and proximity to the market yard have shown a positive relationship with technical efficiency. However, the variables were found statistically non-significant.

Conclusions and Policy Implications

The study has revealed that variation in the output across agricultural farms in the region is due to difference in their technical efficiency levels. The level of technical efficiency among agricultural households differs significantly across farm-size groups. Medium-size farms could achieve the highest technical efficiency. Fertilizers and irrigation have been found to be the major determinants of rice productivity in the region. The shortfall in realized rice productivity from the frontier has largely been due technical inefficiency and is largely within the control of individual farmers. The mean technical efficiency has been found 73 per cent among the sample farms, which indicates that on an average, the realized output can be raised by 27 per cent without any additional resources in the region. By proper management and proper allocation of the existing resources and technology, sufficient potential exists for improving the productivity of rice.

Further, operational area, experience, education and distance of field from canal structure have been identified as the most influential determinants of technical efficiency. These are also the shifting factors of the production frontier. The government policies should target to increase operational farm-size by changing the land tenancy laws, which would help in creating liberalized land lease market in the state. As the education level has been found to influence technical efficiency significantly, efforts should be strengthened to promote both formal and informal education in the farming community. Also, the government may adjust the timings of the release of water in the irrigation projects, keeping in mind the optimum time of sowing for different crops in different regions, so that farmers can plan their operations better and thus help in judicious use of irrigation water. The study has revealed that the number of working family members has a negative impact on technical efficiency, hence government should take up some policies or design some programmes to provide alternative employment opportunities in the region, maybe in non-farm sector.

The study has observed that government efforts through agriculture extension programmes have not been able to have a significant effect on technical efficiency. The government policies should strengthen the extension machinery to improve farmers' practices through extension service and training programmes, so that farmers can apply available agricultural technology more efficiently. It will help increase the national pool of rice and its productivity as well as farm income of the rice growers in the central Gujarat region.

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