ANALYSIS OF FRONTIER TRANSLOG PRODUCTION FUNCTION FOR ESTMATING TECHNICAL EFFICIENCY IN RICE FARMERS OF CANAL IRRIGATED SYSTEMS IN TAMIL NADU

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Abstract

The present study undertaken in Cauvery delta zone has estimated the resource use efficiency in rice production and has assessed the effect of farm specific socio economic factors affecting the technical efficiency. A stochastic frontier production function was estimated to determine technical efficiency of individual farms. The data were collected for two years from the Cost of Cultivation scheme of Tamil Nadu centre. The statistical Model specification test performed to revealed the superiority of the Translog production frontier functional form over Cobb-Douglas model. The results of Translog stochastic production function indicated that fertilizer, seed and labour hours significantly influenced yield of paddy. Moreover the marginal value product to input price ratios for seed at 2.369 indicated that it will be highly profitable to increase the use of seed. The study has revealed that the farm-specific technical efficiencies, most farms were in the efficiency range of 80-90 per cent followed by 90-100 per cent. The production elasticities indicate seed is the foremost important input followed by fertilizer. The returns to scale at 0.5144 would indicate the operation of decreasing returns to scale at the present level of technology and the need for breakthrough in technology by way of new varieties or management methods and research extension farmer linkage.

Key words: RICE, CANAL IRRIGATION, TECHNICAL EFFICIENCY, TRANSLOG PRODUCTION FUNCTION, STOCHASTIC FRONTIER.

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I. INTRODUCTION

Rice is the stable food of over half the world's population. Rice is one of the most important food crops of India contributing to 43 per cent of total food grains production in the country. The rice harvesting area in India is the world's largest. The major rice growing states are West Bengal, Uttar Pradesh, Andhra Pradesh, Punjab, Tamil Nadu, Orissa, Bihar & Chhattisgarh, which together contribute about 72 per cent of the total area and 76 per cent of the total production in the country. In Tamil Nadu, rice is grown over an area of 18 lakh to 20 lakh hectares annually primarily in canal and tank irrigated conditions.

The Economic efficiency can be classified in to technical_efficiency and allocative efficiency (Farrell, 1957). Technical efficiency can be used to increase the productivity, provided the new technologies are used in the field. (Kalirajan *et al*.,1996). The analysis of variations between the potential and actual yields on the farm, provide better understanding of the yield gap. Thus technical efficiency can be used as an indicator of the productivity and the variation in technical efficiency can reflect the productivity difference across firms. Thus the growing demand can be met by increasing the technical efficiency.

The present study undertaken in Cauvery delta zone in the state of Tamil Nadu has estimated the resource use efficiency in rice production under canal irrigated farms and has assessed the effect of farm specific socio economic factors affecting the technical efficiency. Usually the Stochastic frontier production functions are estimated by using maximum likelihood estimation by considering Cobb – Douglas production function. But translog production function produce stronger results since it have interaction terms effect. The main objective of the paper is to apply Stochastic Frontier Translog production technique and to estimate the technical efficiencies of the farms over time.

The following hypotheses were tested:

1. H0: That there is no significant difference in the level of input use between years of farmers under canal irrigation.
2. H0:That there is no absolute differential in technical efficiency between years of farmers in canal irrigation.

2. Methodology:

2.a 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

Stochastic frontier production function was first formulated by Aigner *et al. (*1977) and Meeusen and van den Broek (1977). Assuming that each farm uses *m* inputs (vector *x*) and produces a single output *y*, the production technology of the i[th] farm is specified by the stochastic frontier production function

$$y_i = f(x_i;\beta)\exp(\varepsilon_i) \qquad (1)$$

where $i=1,2,\ldots n$ refers to farms, β is a vector of parameters and ε_i is an error term and the function $f(x;\beta)$ is called the 'deterministic kernel'. The frontier is also called as 'composed error' model because the error term ε_i is assumed to be the difference of two independent elements,

$$\varepsilon_i = v_i - u_i \qquad (2)$$

where v_i is a two sided error term representing statistical noise such as weather, strikes, luck etc which are beyond the control of the farm and $u_i \geq 0$ is the difference between maximum possible stochastic output (frontier) $f(x_i;\beta)\exp(v_i)$ and actual output y_i. Thus u_i represents output oriented technical inefficiency. Thus, the error term ε_i has an asymmetric distribution. From (1) and (2), the farm-specific output-oriented technical efficiency can be shown as

$$TE_i^o = \exp(-u_i) = y_i \big/ f(x_i;\beta)\exp(v_i) \qquad (3)$$

Since $u_i \geq 0$, $0 \leq \exp(-u_i) \leq 1$ and hence $0 \leq TE_i^o \leq 1$. When $u_i = 0$ the farm's output lies on the frontier and it is 100% efficient. Thus, the output oriented technical efficiency tells how much maximum output is possible with the existing usage levels of inputs. The 'Cobb-Douglas' function in log form is given by

$$\ln(y_i) = X_i\beta + v_i - u_i, i = 1, 2, \ldots n \quad (4)$$

where X_i is a vector consisting of the logarithms of m inputs. Similarly the translog form which is more flexible is given by

$$lny_i = \beta_o + \sum_i \beta_j \, lnx_{ij} + \frac{1}{2}\sum_i \sum_k \beta_{jk} \, ln\,x_{ij} \, lnx_{ik} + v_i - u_i. \quad (5)$$

For panel data, Battesse and Coelli (1995), have modified the model which allows for firm-specific patterns of efficiency change over time. In this case, the Cobb-Douglas production frontier becomes

$$\ln(y_{it}) = X_{it}\beta + v_{it} - u_{it}, i = 1, 2, \ldots n \text{ and } t = 1, 2, \ldots T \quad (6)$$

A similar model can be written for translog production frontier. Where y_{it} denotes the production of the i^{th} firm during the t^{th} period and T is the total number of periods. The firm-specific inefficiencies, u_{it} are specified by

$$u_{it} = z_{it}\delta + w_{it} \quad (7)$$

and are assumed to be non-negative and independently distributed random variables such that u_{it} is obtained by truncation at zero of the normal distribution with mean $z_{it}\delta$ and variance σ^2, where z_{it} is a vector of explanatory variables associated with technical inefficiency of production of firms over time and δ is a vector of unknown coefficients. In other words, w_{it} are defined by truncation of the normal distribution with zero mean and variance σ^2. The technical efficiency of production for the i^{th} firm at the t^{th} time period is given by

$$TE_{it} = \exp(-z_{it}\delta - w_{it}) \quad (8)$$

The generalized likelihood test was applied to test a number of hypotheses. The relevant test statistic was calculated using the formula

$$LR = -2\ \left[ln\left[L\ H_0\ \right] - ln\left[L\ H_1\ \right]\right] \quad (9)$$

Where; LR- Log likelihood ratio $L(H_0)$ and $L(H_1)$: the values of the likelihood function under the null and alternative hypotheses respectively. 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.

2.b Data Collection and Sampling:

Tamil Nadu ranks the fifth position in rice production in India. The Cauvery delta produces plenty of rice. Tamil Nadu has historically been an agricultural state and is a leading producer of agricultural products in India. In 2008, Tamil Nadu was India's fifth biggest producer of Rice. The total cultivated area in the State was 5.60 million hectares in 2009–10. The Cauvery delta region is known as the *Rice Bowl of Tamil Nadu*. As such, the Cauvery delta region was selected for canal irrigation, purposively for the present study. The data collected under the cost of cultivation scheme were used. Under the scheme Stratified random sampling method was adopted. Thanjavur and Thiruvarur districts were selected for canal irrigation under Cauvery delta zone. These districts were selected on the basis of concentration of area under rice cultivation. Data were collected for two consecutive years from 2009-2011.

In Cauvery delta zone totally seven taluks were selected for the present study about canal irrigation. The number of farmers in canal irrigated region is 109 for each year as the sample farmers raising paddy for two years were considered. Therefore total number of farmers is kept at 109 for each year. Thus, in all 218 farmers were selected from seven taluks.

3. Results & Discussion:

3.a Empirical model:

In the data set, the dependent variable is the yield of rice production measured in quintal per hectare. The inputs considered in the analysis are; (1) Seeds measured in kilograms per hectare, (2) N,P,K fertilizer nutrients drawn from DAP, Urea, Muriate of Potash,17:17:17 Complex, Ammonium sulphate and Super phosphate measured in kilograms per hectare, (3) Total labour hours comprising of hired (permanent and casual), family and contract labour, measured in working hours, (4) Machine hours (Tractor and power sprayer) measured in hours per hectare, (5) Pesticide expenses measured in rupees per hectare and (6) Trend variable indicating year-1 and year-2.

The explanatory variables also includes the following: (1) Age of the in farmer in years, (2) Area in hectares, (3) a dummy variable for marital status of the farmer, (married=1, unmarried=0)

(4) Education of the farmer (illiterate(1), upto primary(2), upto secondary(3), upto collegiate(4) and post graduate(5)), (5) Size of the farmer's household(number of family members), (6) dummy variables for seasons 1,2 and 3.

The descriptive statistics are presented in Table 1.

Table1. Descriptive statistics for different variables.

Year	2009-10				2010-2011				2009-10 & 2010-11			
Measures	Mean	SD	Min	Max	Mean	SD	Min	Max	Mean	SD	Min	Max
Yield	**47.4**	**9.0**	**17.3**	**69.4**	**48.6**	**9.8**	**32.1**	**77.3**	**47.99**	**9.4**	**17.2**	**77.3**
Inputs used in rice cultivation in Cauvery delta zone												
Seed(kg)	92.1	18.7	45.5	127.4	91.4	16.6	38.5	142.9	91.75	17.6	38.4	142.8
Fertilizer	200.3	41	109.2	333.5	210.1	36.1	119.4	354.5	205.2	38.8	109.2	354.5
Pesticide (Rs)	847.2	597.2	20.8	2776.6	972.5	603.2	7.6	2625.5	909.8	602.1	7.5	2776
Labour (Hrs)	500.4	195.7	271.4	1512	573.6	431.4	255.9	4686.9	536.9	336.2	255.9	4686.9
Machine (Hrs)	6.4	3.6	3.2	37.9	6	2.3	2.7	15	6.21	3.1	2.65	37.8
Socio Economic variables												
Age	58.9	11.7	20	84	58.7	12.1	21	82	58	11.8	20	84
Household.size	5.6	2.9	2	13	5.6	2.9	2	13	5.5	2.9	2	13
Area of the farm	1.5	1.4	0.2	7.14	1.48	1.47	0.1	7.14	1.5	1.45	0.1	7.14

The average age of the is found to be 58 years indicating that the majority of the people involved in farming activities are old. The Mean farm size is 1.5 hectares. The average fertilizer rate is 205.2 kgs. The average rice yield was 47.4 quintal per hectare in 2009-10 and it was 48.6 quintal per hectare in 2010-11

3.b Model results:

The estimated parameters of the Translog and Cobb Douglas stochastic production frontier are presented in Table 2.

Table 2. Maximum Likelihood estimates of Translog and Cobb Douglas Stochastic frontier function

Variables	Translog			Cobb-Douglas		
	Coefficient	SE	t-ratio	Coefficient	SE	t-ratio
const	8.291	7.456	1.112	4.029	0.515	7.826
ln seed(X1)	-5.010**	2.474	-2.025	0.242	0.062	3.884
ln fer(X2)	6.774***	1.966	3.445	-0.019	0.077	-0.243
ln Labr hrs(X3)	-3.249**	1.422	-2.286	-0.119	0.038	-3.130
ln machine hrs(X4)	-1.451	1.348	-1.076	-0.044	0.051	-0.877
ln pest(X5)	0.110	0.836	0.132	-0.041	0.020	-2.073
x1^2	0.312	0.181	1.721	-	-	-
x2^2	-0.857***	0.264	-3.249	-	-	-
x3^2	0.045	0.040	1.126	-	-	-
x4^2	-0.060	0.067	-0.891	-	-	-
x5^2	-0.027***	0.008	-3.205	-	-	-
x1x2	0.221	0.330	0.671	-	-	-
x1x3	0.176	0.196	0.900	-	-	-
x1x4	-0.118	0.230	-0.513	-	-	-
x1x5	0.062	0.091	0.682	-	-	-
x2x3	0.259	0.225	1.152	-	-	-
x2x4	-0.108	0.182	-0.593	-	-	-
x2x5	-0.008	0.104	-0.075	-	-	-
x3x4	0.348***	0.121	2.865	-	-	-
x3x5	-0.039	0.063	-0.617	-	-	-
x4x5	0.098	0.058	1.678	-	-	-
trend	0.035	0.024	1.425	0.050	0.027	1.812
const	0.402	0.227	1.776	2.090	1.093	1.912
Age	-0.003	0.003	-0.831	-0.001	0.004	-0.405
Area	0.008	0.023	0.337	-0.017	0.026	-0.637
Edn	0.179**	0.082	-2.177	0.080	0.045	-1.780

Household Size	-0.001	0.012	-0.091	0.007	0.013	0.493
S1	-2.176	1.190	-1.828	1.701	1.111	-1.532
S2	-0.575**	0.229	-2.517	0.303	0.119	-2.545
sigma-squared	0.115	0.043	2.657	0.071	0.023	3.154
Gamma	0.885***	0.047	18.735	0.779	0.086	9.052
log likelihood function	94.035			71.111		

*=significant at 10% level,**=significant at 5% level, ***= significant at 1% level

The MLE estimates of Cobb Douglas and Translog production function are reported in Table 2. The coefficients of different input variables and the interaction terms in Translog production function given in table 2. revealed that the parameters of seed, fertilizer and human labour are significant and hence, playing a major role in influencing rice production. The coefficient for seed and labour hours happened to be negative and significant at 5 per cent probability level. The coefficient of fertilizer was positive and highly significant at one per cent level. The coefficient of machine hours and pesticide cost was not significant

It could be observed that MLE for γ happened to be 0.885 and highly significant, consistent with the theory that true γ-value should be greater than zero. The value of γ-estimate is significantly different from one, indicating that random error is playing significant role to explain the variation in rice production and this is normal especially in case of agriculture where uncertainty is assumed to be a main source of variation. This implies that stochastic frontier model is significantly different from deterministic frontier, which does not include random error. However, it should be noted that 89 per cent variation in output is due to technical inefficiency and 11 per cent is due to stochastic random error.

In order to investigate the determinants of inefficiency we estimated the technical inefficiency model using Frontier 4.1. The coefficient of education is positive happened to be highly significant, implying that the potential of education in appreciating the note and utilization of information on improved technology by the farmers as well as introducing new ideas in agriculture. The coefficient of education is positive and highly significant, implying that farmers that are experienced, with high level of education and have more extension contact tend to be more efficient in farming and hence increase in the output level.

The coefficients of the seasonal dummies indicating that the second season happens to be significant. The variable, trend is not significant. In order to select the production function that fits best to our data set, The statistical test were performed and the results given in Table 3. According to the results the model becomes stochastic and also that the model has to be estimated by Translog stochastic frontier production function.

Table 3. Model specification tests

Hypothesis	$\lambda - Statistic$	Critical value ($\alpha = 0.01$)	Conclusion
H_0: Cobb Douglas H_1: Translog	111.14	χ_{15}^{2} = 30.57***	H_0 *is rejected*
$H_0 : \gamma = 0$	47.22	χ_1^{2} = 5.412***	H_0 *is rejected*

***= significant at 1% level

Hypotheses testing regarding model specification are reported on Table3. The null hypotheses that $H_0 : \gamma_i = 0 = \delta_0 = \delta_m = 0$, and γ=0 for all i are both rejected at 1% level of significance indicating respectively that the technical inefficiency effects are in fact present and stochastic in nature. After testing the hypothesis whether Cobb Douglas production function is an adequate representation of the data, given the specification of the translog model we can finally choose the best production function that fits best to our data set. According to the results presented in table 3. , we reject the null hypothesis that the production function is Cobb- Douglas and the Translog frontier production function adequately represents the data is accepted.

3.c Technical efficiency:

Average estimates of Technical efficiency are presented in Table.4 in the form of frequency distribution with in a decile range. The estimated mean output oriented technical efficiency is found to be 83% for 2009-10 and 79% for 2010-11. Most farms were in the efficiency range of 80-90 per cent followed by 70-80 per cent. The study by Ayinde*et.al.*, (2009) revealed that the mean technical efficiency at 55%, 58% and 57% for Ofada, Mai-Nasara and NERICA varieties, respectively, implying that the better performance of rice farms in Tamil Nadu.

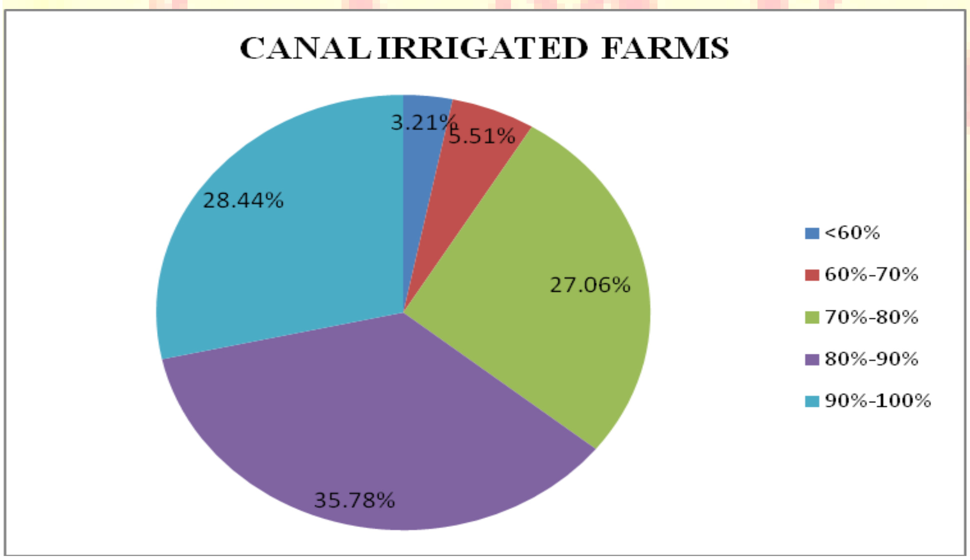
Table 4. Frequency distribution of Technical efficiency

Range	**Canal irrigated farms**		
	2009-10	2010-11	Total
<60	6	1	7

	(5.50)	(0.91)	(3.21)
60-70	3 (2.75)	9 (8.26)	12 (5.51)
70-80	19 (17.43)	40 (36.70)	59 (27.06)
80-90	43 (39.45)	35 (32.11)	78 (35.78)
90-100	38 (34.86)	24 (22.02)	62 (28.44)
Number of farmers	109 (100.00)		218 (100.00)
Mean Technical Efficiency (per cent)	83.89	82.09	82.97

(Numbers in parentheses indicate percentage to total)

Average estimates of Technical efficiency are presented in Table.4. in the form of frequency distribution within a deciles range. In canal irrigated farms, the estimated mean output oriented technical efficiency was found to be 82.97 per cent. Most farms (35.78 per cent) were in the efficiency range of 80-90 per cent followed by 28.44 per cent of farms in the range of 90-100 per cent. Farms in efficiency range of 70-80 per cent accounted for 27.06 per cent and the est of farms have in the range below 70 per cent efficiency. The results would show that in canal irrigated farms 64.22 per cent of the sample farms were in the range of technical efficiency 80-100 per cent. The Distribution of Sample farms based on Technical Efficiency in Canal irrigation is shown in fig.1



Estimates of production elasticities, marginal value product to input price ratio and returns to scale are presented in Table.5

Table. 5 Estimated elasticities

S.No.	Variable	Elasticity	MVP_y/P_x
1.	Seed(kg)	0.3997	2.369
2.	Fertilizer(kg)	0.224	0.849
3.	Labour(hrs)	-0.1093	-3.96
Returns to scale		0.5144	

The estimated production elasticities reported in table.5 indicate that the production elasticities of seed and fertilizer are positive but labour hours happens to be negative. The results indicate that seed are the foremost important input reveal the potential to invest more only in seed in respect of canal irrigated sample paddy farms.

The difference in average technical efficiencies of rice farmers in canal, tank irrigated farms during the two time periods 2009-10 and 2010-11 were tested using Z-test. The results indicate that the Z-statistic value 1.36 and remained lower than the table value 2.57 (10 per cent probability level). This shows that there is no significant difference between the mean technical efficiency between two time periods. The inputs usage were also tested using Z-test and the results are presented in Table.6

Table. 6 Z-test values of inputs

S.no.	Variables	Z-Statistic value	Conclusion
1.	Seed(kg)	0.33	Not Significant
2.	Fertilizer(kg)	1.87*	Significant
3.	Human lab(hrs)	1.54	Not Significant
4.	Machine hrs	1.81*	Significant
5.	Pesticide cost(Rs)	0.95	Not Significant

*- significant at 10% probability level

According to the results the inputs Fertilizer and Machine hours are significant and Seed, Human labours and Pesticide cost were remain not significant. This shows that among all the inputs there is a significant difference between the usage of fertilizer and machine hours between years.

The MVP_y/P_x ratios for those input variables that turned out to be significant, reveal the potential to invest more only in seed in respect of canal irrigated sample paddy farms. This ratio for labour happened to be negative and greater than one indicating the need for firm steps to reduce use of labour. The returns to scale at 0.5144 would indicate the operation of decreasing returns to scale at the present level of technology and the need for breakthrough in technology by way of new varieties or management methods and research extension farmer linkage.

4. Conclusion & Policy implications:

From the results of the study it is concluded that seed and fertilizer are the inputs that significantly influence the yield, besides the qualitative variable namely education. However, further evaluation of the production elasticities in terms of the ratio of the marginal value product to the input prices revealed that it will be profitable to increase the use of seed alone. But the usage of labour should be reduced, since the ratio is negative and more than one. The analysis also indicated the need to rationalize the use of fertilizer where the ratio remains at less than one.

The coefficient of education level was positive and significant, implying that higher education leads to improvements in technical efficiency of rice farmers. As regards the functional forms the Translog frontier production function was found to be the best fit for the data set as revealed by the Model specification test. The test also revealed that the production function is stochastic in nature.

The results of Z-test indicates that there is no significant difference between the mean technical efficiency between two time periods. Also it indicates that among all the inputs there is a significant difference between the usage of fertilizer and machine hours between years.

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