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A comparative study of technical efficiency between canal and tank irrigated paddy farms using corrected OLS models in Tamil Nadu

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Abstract

Background/Objectives: To make a comparative study between canal and tank irrigation environments of paddy farms.
Methods: Corrected ordinary least square method was used to determine technical efficiency in paddy production in their respective irrigation pattern. Further the study has assessed the effect of farm specific socio economic factors affecting the technical efficiency. This study was conducted in Cauvery delta zone of seven TALUKS about canal irrigation and Southern zone of four TALUKS about tank irrigation. Ultimately, there were 218 sample points under canal irrigation and 106 sample points under tank irrigation for two years (2009-10 and 2010-11). The data were obtained from the cost of cultivation scheme of Tamil Nadu centre.
Findings: The results of Cobb Douglas production function indicated that seed, labour hours and pesticide cost are the inputs that significantly influence the yield of paddy in canal irrigated paddy farms; while, seed, fertilizer, labour hours are the are the inputs that significantly influence the yield of paddy in tank irrigated paddy farms. Besides, the qualitative variable namely education and seasons are significant in canal irrigated paddy farms while age and area were significant in tank irrigated paddy farms. The output oriented mean technical efficiency was found to be 86% in canal irrigated farms whereas 91% in tank irrigated farms. The study results also implied that in controlled irrigation condition namely tank irrigation, particularly in canal fed tanks when water availability becomes relatively more consistent, the yield levels were higher, and the mean technical efficiency was also relatively higher.
Keywords: Canal Irrigation, Tank irrigation, Paddy farm, Technical Efficiency, Corrected OLS models.

1. Introduction

Rice plays a vital role in the national food grain supply and is the main driver of India's food security. It occupies 23 per cent of the grossed cropped area in the country and 35 per cent of the total area under food grains. Rice contributes around 43 per cent to the total food grain production in the country. In spite of all these, Indian faces a huge challenge to feed the people. By the year 2030, India needs to grow 260 million tons of food grains to feed its growing population [1]. With limited scope for area and cultivable lands being converted to non cultivable lands [2], the rising population can be fed only by increasing the productivity. In spite of having largest area under rice in the world, the country has productivity less compared to other growing countries. Thus, increasing the efficiency in production plays a major role. The Economic efficiency can be classified in to technical efficiency and allocative efficiency [3]. Technical efficiency can be used to increase the productivity, provided the new technologies are used in the field [4]. 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. Thus the growing demand can be met by increasing the technical efficiency.

The economic efficiency can be classified in to technical efficiency and allocative efficiency [5]. Technical efficiency is an indicator of the productivity of the farm and the variation in technical efficiency can reflect the productivity difference across farms. It can be used to increase the productivity, provided the new technologies

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are used in the field [6]. The ability of a firm to maximize output given a set resource input is known as Technical efficiency while allocative efficiency is the ability of a firm to use inputs optically given their prices and production technology [7]. On the other hand, economic efficiency can be described as capacity of the firm to produce a predetermined quantity of output with minimum cost at a given level of technology. Thus the growing demand can be met by increasing the technical efficiency. The present study has assessed the technical efficiency in rice production among two different environments as canal and tank irrigated farms along with the influence of various socio-economic factors affecting it on the rice farms in Cauvery delta zone and Southern zone of Tamil Nadu state. The main objective of the paper is to compare the resources used for paddy production in canal and tank irrigated farms and also estimating technical efficiency between two different environments using corrected OLS technique and identify some socio-economic factors which influence its production efficiency.

2. Materials and methods

2.1. Method of analysis

In the present study, the corrected OLS technique were used to measure Technical efficiency of rice cultivating farms [8,9 and 10]. 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 this case, the Cobb-Douglas production frontier becomes

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

Which is used for the present study?

Where *yit* 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

$$u_{it} = z_{it}\delta + w_{it}$$

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} is 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

$$TE_{it} = \exp\left(-z_{it}\delta - w_{it}\right)$$

2.2. Corrected OLS technique

The two OLS (Ordinary Least Square) approaches are Corrected OLS (COLS), developed by Winsten (1957) and Greene (1980) and Modified OLS (MOLS) by Richmond (1974). Both of these methods rely on OLS to estimate the production function parameters, but differ in their treatment of the OLS residuals ε_i .

A slightly different approach than OLS involves shifting the line towards the best performing company, which is called Corrected Least Squares methodology (COLS). In a general sense, COLS is merely a shifted average function. Two steps are needed, one to get the expected value of the error term and another to shift or to "center" the equation. The COLS estimator is obtained by turning the least squares estimator into a deterministic frontier model. This is done by shifting the intercept in the OLS estimator upward (for a production frontier) or downward (for a cost frontier) so that all points lie either below or above the estimated function [11].

The COLS procedure shifts the frontier up by the amount of the largest residual, thus generating a frontier that truly envelops the data. As an example, using our notation, at the first stage a (log-linear) production model such as the following would be estimated by OLS.

$$\ln yi = \beta_0 + \Sigma\beta_i \ln x_i + \varepsilon_i$$

In the second stage the residuals would be utilized to shift the frontier to envelop the data. The maximum residual is denoted as $\varepsilon_{max} = \max(\varepsilon_i)$

The COLS intercept would be estimated as,

$$\beta_{COLS} = \beta_0 + \varepsilon_{max}$$

This shifts the frontier up so that the observation coinciding with the largest positive residual will be on the frontier, with other observations under the frontier. Efficiency analysis in this approach can be viewed as a

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relative comparison with the frontier observation being defined as being fully efficient and other observations receiving efficiency scores relative to the fully efficient observation. Also notable is the fact that the COLS frontier does not necessarily bound the data from above as closely as possible [12] as the corrected frontier is parallel to the OLS frontier by definition.

2.3. Data collection and sampling

Paddy is raised in three season's viz., Kar, Samba and NAVARAI. During the year 2011-12, paddy covered an area of 1.9 mh of which, 1.78 mh (93.75 per cent) was irrigated and 0.11mh (6.25 per cent) was not irrigated. Paddy is grown predominantly in two irrigation regimes namely; canal and tank in Tamil Nadu. As far as paddy is concerned, paddy is hydrophilic crop or water guzzler, i.e., it requires lot of irrigation water. If the water is scarce, it impinges upon the area, production and productivity of rice crop to a great extent. Samba crop accounted for 75.86 per cent of area of 1.9 mh under paddy and 74.95 per cent of total rice production of 7.459 mt. Next to Samba, Kar season formed 17.6 per cent of area and 18.56 per cent of total production. Contribution of NAVARAI crop stood at 6.5 per cent in area coverage and 6.47 per cent in total production of rice. (Season and crop report, 2011-12)

Among the districts in Tamil Nadu, paddy is extensively grown in TIRUVARUAR (9.8 per cent), THANJAVUR (9.5 per cent), NAGAPATTINAM (8.9 per cent), VILLUPURAM and RAMANATHAPURAM (6.8 per cent each) districts. The production was found to be higher in TIRUVARUR (9.8 per cent) followed by THANJAVUR (9.5 percent) and NAGAPATTINAM (8.9 per cent) districts. (Season Crop Report of Tamil Nadu, 2011-12).The Cauvery delta zone is known as the *Rice Bowl of Tamil Nadu*. As such, the Cauvery delta zone was selected for canal irrigation, and Southern zone was selected for tank irrigation purposively, for the present study. The data collected under the cost of cultivation scheme were used. Under the scheme a stratified random sampling method was adopted. THANJAVUR and THIRUVARUR districts in the Cauvery delta Zone were covered for canal irrigation and TIRUNELVELI, VIRUTHUNAGAR and SIVAGANGAI districts in the southern zone were covered for tank irrigation under the above scheme during the two consecutive years from 2009-10 and 2010-11(these were normal years).In Cauvery delta zone 109 farmers from seven taluks and in southern zone 53 farmers from four taluks were selected for the present study. Ultimately, there were 218 sample points under canal irrigation and 106 sample points under tank irrigation for two years (2009-10 and 2010-11).

3. Results and discussion

3.1. Empirical model

In the present study, both Cobb-Douglas production functions was initially considered to study the technical efficiency among rice farms.

$$\ln y_i = \beta_0 + \sum_j \beta_j \ln x_j \quad ,j = 1,2,3,...5 \text{ (Cobb- Douglas type)}$$

$$\mu = \delta_0 + \sum_{i=1}^{5} \delta_i z_i \quad \text{(Linear type)}$$

Where

y	=	Yield of paddy (quintal /ha)
Seed (x_1)	=	Quantity of seeds (kg. /ha.)
Fer (x_2)	=	Quantity of NPK nutrients (kg. /ha.)
Lab (x_3)	=	Human labour (hrs. /ha.)
Mach (x_4)	=	Machine hours (hrs. /ha.)
Pes (x_5)	=	Cost of plant protection (Rs. /ha.)
Age (z_1)	=	Age of the farmer in years
Farm Size (z_2)	=	Area in hectares
Edn (z_3)	=	Education of the farmer (illiterate(1), up to primary(2), upto secondary(3), up to collegiate(4) and post graduate(5)),
Household size (z_4)	=	Size of the farmer's household (number of family members)
Sea 1 (z_5)	=	Season dummy variable indicating season 1 (June-Sept.); 0 otherwise.
Sea 2 (z_6)	=	Season dummy variable indicating season 2 (Oct.-Jan.); 0 otherwise.

Season 3 is taken as base.

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3.2. Mean yield and Input use levels in Sample farms

The descriptive statistics are presented in Table 1 and Table 2

Table 1. Mean yield and input use levels in the canal irrigated paddy farms

Year	2009-10		2010-2011		2009-10 & 2010-11	
Measures	Mean	SD	Mean	SD	Mean	SD
Yield (quintal/ha)	47.4	9.0	48.6	9.8	47.99	9.4
Inputs used in paddy cultivation in Cauvery delta zone						
Seed (kg)	92.1	18.7	91.4	16.6	91.75	17.6
N,P,K nutrients (kg)	200.3	41	210.1	36.1	205.2	38.8
Labour (Hrs)	500.4	195.7	573.6	431.4	536.9	336.2
Machine (Hrs)	6.4	3.6	6	2.3	6.21	3.1
Pesticide (Rs)	847.2	597.2	972.5	603.2	909.8	602.1
Socio Economic variables of Sample Farms						
Age	58.9	11.7	58.7	12.1	58	11.8
House hold Size	5.6	2.9	5.6	2.9	5.5	2.9
Area of the farm (ha)	1.5	1.4	1.48	1.47	1.5	1.45

The mean yield of paddy was relatively higher in tank irrigated farms. While the use of seeds was higher in canal irrigated farms, use of fertilizer, labour, machine power and pesticide value were higher in tank irrigated farms.

Table 2. Mean yield and input use levels in the tank irrigated paddy farms

Year	2009-10		2010-2011		2009-10 & 2010-11	
Measures	Mean	SD	Mean	SD	Mean	SD
Yield (quintal/ha)	54.3	9.8	52.4	9.3	53.4	9.6
Inputs used in paddy cultivation in Southern zone						
Seed (kg/ha)	78.6	13.6	74.8	13.7	76.7	13.7
N,P,K nutrients (kg/ha)	214.6	45.9	192.2	48.7	203.4	48.4
Labour (Hrs/ha)	620	172.5	640.9	236.6	630.5	206.3
Machine (Hrs/ha)	12.1	6.2	13.5	10.5	12.8	8.6
Pesticide (Rs/ha)	1016.9	402.2	1808.8	2450	1412.8	1792
Socio Economic variables						
Age	50.3	12.2	51.3	12.2	50.8	12.1
Household size	5.1	2.0	5.2	2.0	5.1	2
Area of the farm(ha)	0.6	0.4	0.5	0.4	0.6	0.4

3.3. Model results

The estimated parameters of Corrected OLS of Cobb Douglas production function are presented in Table 3. The Corrected OLS estimates of Cobb Douglas production function of canal irrigated paddy farms shows that the parameters of seed, Labour hours and Pesticide cost are significant and hence, playing a major role in influencing rice production. The coefficient for seed happened to be positive and highly significant at one per cent probability level. It indicates that 1% increase in the usage of seed will increase the output by 0.18%. The coefficient of labour hours and pesticide cost were found to be negative and significant at five per cent level. This indicated that 1% increase in the labour hours will decrease the output by 0.07% and 1% increase in the pesticide usage would also decrease the yield by 0.03%. The coefficient of fertilizer and machine hours were not significant.

The COLS estimates of Cobb Douglas production function in tank irrigated paddy farms revealed that the response variables Seed, Fertilizer, Labour hours were highly significant at one per cent probability level. But machine hours and pesticide cost were significant at ten per cent probability level. Since the coefficient of seed and pesticide cost were found to be negative indicated that to increase the yield the usage of seed and pesticide could be decreased. But the coefficient of fertilizer, labour hours and machine hours were found to be positive and shows that the paddy production in tank irrigated farms may be increased by increasing the usage of these variables. These variables indicates that 1% increase in the usage of fertilizer, labour hours and machine hours, will increase the yield by 0.16%, 0.23% and 0.06% respectively. The Socio Economic variables indicated that, the variables education and both the seasons were significant in canal irrigated Paddy farms, while the variables Age and Area were significant in tank irrigated paddy farms.

Table 3. Corrected OLS estimates of Cobb Douglas production function

Variables	Canal			Tank		
	Coefficient	Standard Error	t-ratio	Coefficient	Standard Error	t-ratio
constant	3.9166	0.5607	6.0735	3.5919	0.5031	6.5482
ln seed(X1)	0.1749***	0.0704	2.7100	-0.3416***	0.0779	-4.3841
ln fer(X2)	0.0592	0.0741	0.8011	0.1633***	0.0549	2.9764
ln Labr hrs(X3)	-0.0703**	0.0392	-1.9917	0.2311***	0.0523	4.4231
ln machine hrs(X4)	-0.0326	0.0437	-0.7444	0.0511*	0.0295	1.7366
ln pest(X5)	-0.0323**	0.0180	-1.9933	-0.0401*	0.0243	-1.6502
const	0.5496	0.0522	10.5320	0.5390	0.0793	6.8016
Age	-0.0006	0.0007	-0.8839	0.0032***	0.0010	3.1128
Area	0.0030	0.0052	0.5722	0.2561***	0.0226	2.5755
Edn	0.2113***	0.0062	2.8147	-0.0033	0.0109	-0.3028
Household Size	0.0004	0.0026	0.1453	0.0048	0.0054	0.8799
S1	0.1463***	0.0321	4.5610	0.0400	0.0271	1.4772
S2	0.0714***	0.0205	3.4838	-0.0254	0.0218	-1.1673

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

3.4. Technical efficiency

The Technical efficiency estimates of canal and tank irrigated paddy farms are presented in Table 4 in the form of frequency distribution within a decile range. The estimated mean output oriented technical efficiency is found to be 86% for canal irrigated paddy farms and 91% in tank irrigated paddy farms. Most farms were in the efficiency range of 50-60 per cent followed by 60-70 per cent in canal irrigated paddy farms whereas in the case of tank irrigated farms 70-80 percent followed by 60-70 per cent. It is also found that only 2.83 per cent of farmers were lies in the efficiency range less than 50 per cent in tank irrigated paddy farms, but in canal irrigated farms 11.93 per cent farmers fall in that efficiency range.

Table 4. Frequency distribution of Technical efficiency

	Canal irrigation		Tank irrigation	
TE	No. of farms	Percentage	No. of farms	Percentage
20-30	1	0.46	0	0.00
30-40	7	3.21	1	0.94
40-50	18	8.26	2	1.89
50-60	81	37.16	3	2.83
60-70	72	33.03	30	28.30
70-80	28	12.84	41	38.68
80-90	9	4.13	18	16.98
90-100	2	0.92	11	10.38
Total	218	100	106	100
Mean TE	0.86		0.91	

4. Conclusion

From the results of the study it is concluded that of seed, Labour hours and pesticide cost are the inputs that significantly influence the yield of paddy in canal irrigated paddy farms, while, Seed, Fertilizer, Labour hours are the are the inputs that significantly influence the yield of paddy in tank irrigated paddy farms. Moreover in canal irrigated paddy farms the usage of pesticide and labour hours may be reduced to get more yield, since the coefficient of these variables are negative. In tank irrigated paddy farms, to increase the paddy yield the farmers should decrease the seed and pesticide usage, but increase the usage of fertilizer, labour hours and machine hours. Besides the qualitative variable namely education and seasons are significant in canal irrigated paddy farms while age and area were significant in tank irrigated paddy farms.

This 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 in canal irrigated paddy farms. Also the co-efficients of the seasonal dummies happen to be significant in canal irrigated farms, perhaps an indication of relatively greater consistency in the production situation including water availability, etc. In the case of tank irrigated systems the older farmers are performing better than the younger one since they were all well experienced. Also it is highly profitable to increase the area of paddy farms in tank irrigation systems.

In terms of distribution of technical efficiency among the farmers, the result showed that 97% of farmers having their technical efficiency above 0.5 in tank irrigated systems but 88% of farmers were falls in this range in canal irrigated farms. The output oriented mean technical efficiency was found to be 86% in canal irrigated farms whereas 91% in tank irrigated farms. The study results also implied that in controlled irrigation condition namely tank irrigation, particularly in canal fed tanks when water availability becomes relatively more consistent, the yield levels were higher, and the mean technical efficiency was also relatively higher.

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