JACOBS PUBLISHERS

OPEN ACCESS

Jacobs Journal of Biostatistics

Review article

A Parametric Approach for Estimation of Technical efficiency of Carp Culture Farms of Kolleru Lake, Andhra Pradesh, India

Ajit Kumar Roy[1,2,3*]

[1]Ex. National Consultant (IA) for East and North East Region, NAIP (World Bank funded project); ICAR, India

[2]Ex.Pr. Scientist and Head, Social Science Section, Central Institute of Freshwater Aquaculture, Kausalyaganga, Bhubaneswar-751002, India.

[3]Ex. Consultant (Statistics), Dept. of fisheries Economics and Statistics, College of Fisheries, Central Agricultural University, P.O.Lembucherra, Agartala-799210, India.

*Corresponding author: Dr. Ajit Kumar Roy, 4th Floor, 1/2D/4 Ram Krishna Naskar Lane, Kolkata-700010, India,

Email: akroy1946@yahoo.co.in

Received: 07-12-2016

Accepted: 08-08-2016

Published: 08-12-2016

Abstract

A stochastic frontier production function model was utilized to estimate the technical efficiency of carp farms operating in Kolleru Lake area that is the largest freshwater wetland ecosystem with shallow water area covering 955 sq. km upto 10.7' contour located in between Krishna and Godavari delta of southern India. Analysis was based on sample of 221 carp farms. The estimated mean technical efficiency (TE) was found to be 0.7260. The highest significant elasticity of coefficient was observed for feed (0.2001) followed by organic manure (0.1411) justifying the importance of these two inputs in yield of carps. The empirical results suggest that there are significant possibilities to increase efficiency levels by increasing pond size, provision for regular supply of fresh water, right method of application of drugs, employing labour on regular basis and leasing out the water bodies to farmers whose primary occupation is fish farming and educating the farmers to procure seed from reliable sources, to follow proper harvesting technique and avoiding periodical netting. Analysis of potential TE improvement of aquaculture farms reveals that if the average farmer in the sample was to achieve the TE level of its most efficient counterpart then the average farmer would realize an 26.7 percent cost saving. A similar calculation for the most technically inefficient farmer revealed a cost saving of 48.9 percent. Differences in efficiency levels are identified and explained with respect to various farm specific variables having impact on TE through estimating a model for technical inefficiency effects. The study suggests that with the same level of input, there is potential to enhance the yield to the extent of 27.40% through efficient use of resources and improvement of technical efficiency at farm level from Kolleru Lake area which is known as Carp Pocket of India producing and supplying quality fish protein to almost all the eastern states of India.

Keywords: Non Parametric; Carp Culture; Technical Efficiency; Determinant; Stochastic; Frontier; Elasticity

Introduction

India is rich in freshwater aquaculture resources that includes 2.35 million hectare of ponds and tanks, 1.3 million hectare of oxbow lakes and derelict waters, 0.19 million km of rivers and canals, 3.15 million hectare of reservoirs that could be utilized for aquaculture. Ponds and tanks are the prime resources for aquaculture, however only about 0.8 – 0.9 million ha is used for aquaculture currently. The total aquaculture production of 2.47 million tones that constitutes 4.2% of global production was valued at US$ 2.9 billion [1]. If aquaculture is to play a vital role in ensuring future fish availability for food security and nutrition in India, this sector has to develop and grow in an economically viable and environmentally sustainable fashion.

That is possible through improved farm water management, better feeding strategies, genetic improvement of cultivable species and better health management leading to enhanced production efficiency of aquaculture at farm level. Therefore, measuring Technical Efficiency (TE) at farm level, identifying factors associated with efficient production, assessing potential for and sources of future improvements are need of the hour for establishing sustainable aquaculture. Instead of increasing the use of inputs to increase production, efforts should be made towards output growth through improved TE that means to produce more by utilizing inputs at hand more efficiently.

Keeping these points in view an attempt was made to estimate the technical efficiency of aquaculture farms of Kolleru Lake area, which is known as Carp Pocket of India producing about an estimated production of 70,000 tones per year. Kolleru Lake (16° 32'and 16° 47'N latitude and 81° 5' and 81° 21'E longitude) is the largest freshwater wetland ecosystem located between the major perennial rivers Godavari and Krishna in South India. It has an area of 955 sq. km at 10.7 feet msl contour level. Water depth in the lake varies between 1 and 2.5 metre for most of the year and reaches a maximum depth of 3 to 4 meters during high floods and is reported to very productive for aquaculture with favourable temperature ranging between 18-49°C. A report highlighting the technological changes of Kolleru Lake area covering pond construction and renovation, weed control, application of fertilizers, species combination, stocking density, use of supplementary feed, biomass & disease checking and control, harvesting, live fish transport, marketing and market spread, impact of technological changes on employment generation, growth of ancillary industries, environmental impacts, education, operational economics is available [2]. Scientific studies on statistical and econometric aspects have also appeared in the literature [3-10].

In recent years, Farmers of Kolleru Lake area have intensified their effort towards aquaculture, as a result, demand for natural resources like water, land and seed have increased. Under the situation, enhanced production through improvement of technical efficiency may lead to right direction for sustainable production and consistent supply, i.e. through efficient use of resources and productivity at farm level. Technical Efficiency (TE) may be estimated either through parametric (frontier analysis) or through nonparametric methods (DEA). A review of literature reveals that compared with agriculture, estimation of technical efficiency applying frontier analysis is very limited in aquaculture sector in India and abroad [11-15]. The present study is aimed at measuring the technical efficiency of carp farms of Kolleru Lake area and also to identify the determinants, which in turn may help in drawing policy implications.

Data and variables

Data sources

The present analysis was carried out on a data set of 221 aquaculture farms that was collected using multistage stratified random sampling covering 73 revenue villages spread over 9 Mandals of West Godavari and Krishna districts of Andhra Pradesh under the AP-Cess fund project entitled "Technological innovations in aquaculture and its effects on sustainability of farming systems in Andhra Pradesh" funded by Indian Council of Agricultural Research (ICAR), Government of India during 1998-2002.

Input and output variables

All input and output variables used in the stochastic frontier production function model in this study are clearly defined along with measurement units (Table 1). Summary statistics of organic manure, inorganic fertilizer, lime, chemicals, drugs, and feed and socio-economic profiles like religion, caste, age, no. of children, education, experience, asset, etc. of the farm operators and farm specific variables like size and depth of pond, ownership type, water source, harvesting techniques, types of labour engaged, method of application of drug, feed etc. are furnished in table-2.

Sample Characteristics

A close look at the sample characteristics of the carp farms indicates that average pond size of the sample farmers of Kolleru Lake is 8.7 ha, which ranges from 0.8 – 61 ha. On average primary occupation of the 79% of the farmers is aquaculture. On average 96% of the farmers is receiving water from the adjoining irrigation canal and the rest are taking from natural water resources. It is observed that 92% of the farmers are owner operators and the rest are practicing aquaculture possessing land on lease basis. The survey revealed that 83% farmers reported renovating their ponds as part of pond management practices. It was noticed that all the sample farmers used to practice two species culture (catla and rohu) at a species ratio of 1:4 and at an average stocking biomass of 1939 kg/ha. Single stocking and single harvesting practices was resorted to by 95% of the farmers. Feed is generally applied in perforated bags those are hanged in poles and submerged inside pond water by 97% of the farmers. Average yield of fish was observed to be 10.63 t/ha/year.

Empirical Model for Estimation of Technical Efficiency

It is mentioned that the level of technical efficiency of a particular firm is characterized by the relationship between observed production and some ideal production [16]. The frontier production function defines potential output that can be produced by a farm with a given level of inputs and technology. Farrell, [17] first developed frontier production model

Variables	Description
Output (Y) = Yield	Aggregated quantity of fish yield (in ton/ha/year)
Input	
Organic Manure	Amount of organic manure (cowdung, poultry dropping) used in carp production (in ton/ha)
Inorganic fertilizer	Amount of inorganic fertilizers used in carp production (in kg/ha)
Lime	Quantity of Lime used during culture duration (kg/ha)
Stocking weight	Number of fishes stocked multiplied by average weight (kg/ha)
Chemicals and Drugs	Amount spent during culture operation (Rs./ha)
Feed	Total dry weight of feed ingredients consisting of deoiled rice bran and mustard oil cake/groundnut oil cake/cotton seed cake and soyabean applied in carp ponds (in ton/ha)
Labour	Hired labour engaged in carp culture for stocking, harvesting, feeding, watch and word, etc. (mandays/ha)
Water management	Water management cost included expenditure incurred during initial intake of water and periodical replenishment for loss due to seepage and evaporation (Rs./ha) to maintain level of water suitable for aquaculture.
Technical efficiency (TE)	
Religion	Value 1 if Hindu, 0 if otherwise
Caste	Value 1 if SC, 2 if OBC and 3 if general caste
Age	Age of the farmers (in years)
No. of children in family	Children of the farmer in number
Education	Number of years in school
Experience in carp culture	Number of years the farmer is engaged in fish farming
Primary occupation	Value 1 if primary occupation in fish farming, 0 otherwise
Pond size	Area of pond in hectares
Pond renovation	Value 1 if renovation done or 0 if otherwise
Asset cost	Value (Rs./ha) of various types of assets like water pump, boat, net, godown, etc.
Ownership type	Value 1 if owner operated, 0 if otherwise
Source of water	Value 1 if taken from adjoining irrigation canal, 0 if otherwise
Depth of water	Average depth (m) of water of the culture pond
Source of seed	Value 1 if reared in own farm, 0 if otherwise
Sources of advice taken	Value 1 if govt. sector, 2 if fish doctor, 3 if self and 4 if fellow farmer
Loan	Value 1 if taken from bank, 0 if otherwise
Harvesting technique	Value 1 if adopted single stocking and single harvesting practice, 0 if otherwise
Method of application of drug	Value 1 if mixed with feed and applied, 2 if sprayed on water, 3 if diluted in water.
Method of application of feed	Value 1 if given in perforated bags hanged in poles and submerged inside pond, 0 if otherwise.
Calamities faced	Value 1 if calamities faced during last five years, 0 if not faced
Periodical netting for biomass checking	Value 1 if netting done for biomass checking, 0 if otherwise
Types of labour	Value 1 if permanent labor engaged, 0 if otherwise.
Types of organic manure	Value 1 if poultry droppings only, 2 if cowdung and poultry dropping
Types of feed	Value 1 if applied cereal grain byproduct (DORB); 2 if applied [DORB and oil seed cake (GNOC, MOC, Sun flower seed cake)]; 3 if applied [DORB, oil seed cake and Protein (Soyabean and Nutra)]; 4 if applied DORB and Soyabean
Disease encountered	Value 1 if fungal only, 2 if bacterial only, 3 if viral only, 4 if parasite only, 5 if fungal and bacterial, 6 if fungal and viral, 7 if viral and bacterial, 8 if fungal, bacterial and viral, 9 if parasite and bacterial, 10 if parasite and viral and 11 if parasite, fungal and bacterial

DORB: De oiled Rice Bran; CSC: Cotton Seed Cake; GNOC: Ground Nut Oil Cake; MOC: Mustard Oil Cake

Table 1. Definitions and measurement units of input and output variables for empirical model.

Variable	Mean	SD	Minimum	Maximum
Output (ton/ha)	10.630	1.470	7.400	14.800
Organic manure (ton/ha.)	22.790	5.100	3.700	37.100
Inorganic fertilizer (kg/ha.)	1507.250	501.640	617.750	3953.600
Lime (kg/ ha.)	1075.130	379.700	494.200	2471.000
Stocking weight (kg/ ha.)	1939.000	512.450	474.430	3059.100
Chemicals and Drugs (Rs./ ha.)	3161.61	1409.95	432.00	8159.00
Feed (ton/ha.)	27.650	5.760	13.700	44.500
Labour (mandays/ha.)	88.400	53.300	5.0	242.0
Water management cost (Rs./ ha.)	9360.00	6127.00	634.00	21004.00
Farm-specific				
Religion (0 or 1)	0.99	0.116	0	1
Caste (1 or 2 or 3)	2.50	0.698	1	3
Age (year)	42.07	5.703	30	80
No of children (no.)	2.36	1.016	0	5
Education (no. of years in school)	10.18	1.952	9	17
Experience (years)	10.42	5.141	1	20
Primary occupation (0 or 1)	0.79	0.41	0	1
Pond size (ha.)	8.7	8.6	0.8	61.0
Renovation (0 or 1)	.83	.37	0	1
Asset cost (Rs./ha.)	12873.12	9374.50	1060.00	67950.00
Ownership type (0 or 1)	0.92	0.27	0	1
Source of water (0 or 1)	0.96	0.19	0	1
Depth of water (meter)	2.44	0.35	1.68	3.35
Source of seed (0 or 1)	0.66	0.475	0	1
Advice taken from (1 or 2 or 3 or 4)	3.38	0.85	1	4
Loan (0 or 1)	0.30	0.46	0	1
Harvesting technique (0 or 1)	0.95	0.22	0	1
Method of application of drug (1 or 2 or 3)	2.57	0.51	1	3
Method of application of feed (0 or 1)	0.97	0.17	0	1
Calamities (0 or 1)	0.76	0.425	0	1
Periodical netting (0 or 1)	0.86	0.348	0	1
Types of labor (0 or 1)	0.76	0.425	0	1
Types of organic fertilizer (1 or 2)	1.48	0.501	1	2
Types of feed (1 or 2 or 3 or 4)	2.33	0.58	1	4
Disease encountered (1 or 2 or 3 or 4 or 5 or 6 or 7 or 8 or 9 or 10 or 11)	3.44	2.089	1	11

Table 2. Summary statistics of variables involved in the stochastic production frontier and technical inefficiency models for carp pond culture in Kolleru Lake, Andhra Pradesh, India.

and based on that several approaches to efficiency assessment have been developed that can be classified into two broad categories viz. parametric and nonparametric frontier models. Frontier techniques have been widely used in determining the productive performance of farms which may be estimated either by stochastic frontier production function approach [18] or non-parametric linear programming approach known as data envelopment analysis (DEA). The stochastic frontier approach is preferred for assessing efficiency in agriculture because of the inherent stochasticity involved [19,20]. There are several reviews of the applications of the stochastic frontier approach in agriculture [21,22,]. Most of the analysis applications of frontier analysis in Asian aquaculture have used this approach [12-15,23,24]. There are two approaches for estimating the inefficiency models. These may be estimated with either a one step or a two-step process. For the two-step procedure the production frontier is first estimated and the technical efficiency of each farm is derived. These are subsequently regressed against a set of variables, which are hypothesised to influence the farm's efficiency. A problem with the two-stage procedure is the inconsistency in the assumptions about the distribution of the inefficiencies. In the first stage, the inefficiencies are assumed to be independently and identically distributed is order to estimate their values. However, in the second stage, the estimated inefficiencies are assumed to be a function of number farm specific factors, and hence are not identically distributed unless all the co-efficients of the factors are simultaneously equal to zero [20]. FRONTIER uses the ideas of Reifschneider and Stevenson [25] and estimates all of the parameters in one step to overcome this inconsistency. The inefficiency effects are defined as functions of farm specific factors (as in the two stage approach) but they are then incorporated directly into the maximum likelihood estimation.

The stochastic production frontier for sample carp producers of Kolleru Lake area is specified as follows taking into account the model developed and proposed by Aigner *et al.* [18].

$$LnY_i = \beta_0 + \sum_{k=1}^{8} \beta_k LnX_{ki} + V_i - U_i \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(1)$$

where subscript i refer to the i-th farm in the sample; Ln represents the natural logarithm; Y is output variable and Xs are input variables. The details of input and farm specific variables are defined in Table 1. βs are unknown parameters to be estimated; V_i is an independently and identically distributed N (0, σ_v^2) random error; and the U_i is a non-negative random variable associated with technical inefficiency in production, which is assumed to be independently and identically distributed and truncations (at zero) of the normal distribution with mean, μ_i and variance, σ_u^2 (|N (μ_i, σ_u^2)|). According to Battese and Coelli [26], the technical inefficiency distribution parameter, μ_i is defined as:

$$\mu_i = \delta_0 + \sum_{m=1}^{25} \delta_m Z_{mi} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(2)$$

where Zs are various farm-specific variables, defined and explained in Table-1. Summary statistics of farm specific variable are furnished in Table-2 and δs are unknown parameters to be estimated. Since the dependent variable in Equation-2 is defined in terms of technical inefficiency, a farm-specific variable associated with the negative (positive) coefficient will have a positive (negative) impact on technical efficiency [12].

Socio economic and demographic variables like religion, caste, age, number of children, education, experience in carp culture, primary occupation, ownership type are expected to have some impact on technical efficiency. Similarly farm specific variables like pond size, renovation, cost of assets, source of water, depth of water, source of seed, sources of advice taken, loan, harvesting technique, method of application of drug and feed, calamities faced, types of feed, types of organic manures applied, types of disease encountered, periodical biomass checking, types of labour engaged are also expected to have impact over technical efficiency affecting carp yield. Farm specific technical efficiency of the i-th sample farm (TE_i) is obtained using the relationship.

$$TE_i = \exp(-U_i) \ldots\ldots\ldots\ldots\ldots\ldots\ldots(3)$$

The prediction of technical efficiencies is based on the conditional expectation of expression in equation-3, given the model specifications [27]. The parameters for the stochastic production frontier model in equation-1 and those for the technical inefficiency model in equation-2 were estimated simultaneously using the maximum-likelihood estimation method (MLE) using an econometric computer program, FRONTIER 4.1 [28], that estimates the variance parameters of the likelihood function in terms of $\sigma^2 = \sigma_u^2+\sigma_v^2$ and $\gamma = \sigma_u^2/\sigma^2$

Results

Maximum livelihood estimates

The maximum likelihood estimates of the parameters for the stochastic frontier model and those for technical inefficiency model for carp culture farms of Kolleru Lake, Andhra Pradesh, India are produced in table-3.

The slope coefficient and output elasticities of inputs showed almost expected signs of the physical factors excepting water management cost used in the model. The elasticity of output for feed was found highest (0.2001) followed by organic manure (0.1411) and both coefficients are observed highly significant ($P<0.01$). This is indicative of the fact that both feed and organic manure have major influence on yield. Inorganic fertilizer, stocking weight, labour and lime have demonstrated positive impact but not proved to be statistically significant. Both chemicals and drugs and water management coefficient showed insignificant negative impact over yield. σ showed significant positive coefficient at one percent level of significance. The estimated values of σ_u^2 and σ_v^2 are found to be

	Parameter	Coefficient	Standard-error	T-ratio
Stochastic production frontier model				
Constant	β_0	1.2374793***	0.19531434	6.3358343
Organic manure (X_1)	β_1	0.14112453***	0.037727305	3.7406470
Inorganic fertilizer (X_2)	β_2	0.024032115	0.023807879	1.0094186
Lime (X_3)	β_3	0.033957713	0.026476323	1.2825691
Stocking weight (X_4)	β_4	0.026828252*	0.019799683	1.3549839
Chemicals and Drugs (X_5)	β_5	-0.014569666	0.017009698	-0.85655054
Feed (X_6)	β_6	0.20010391***	0.036975060	5.4118616
Labor (X_7)	β_7	0.011732542	0.011203558	1.0472157
Water management (X8)	β_8	-0.022573018*	0.011707627	-1.9280609
Technical inefficiency model				
Constant	δ_0	0.55002287	0.60348210	0.911415
Religion (Z_1)	δ_1	-0.085277684*	0.050847024	-1.6771421
Caste (Z_2)	δ_2	0.013630104*	0.0097874157	1.3926152
Age (Z_3)	δ_3	-0.00051804104	0.0013822222	-0.3747885
No of children (Z_4)	δ_4	0.0041073793	0.0084882335	0.4838909
Education (Z_5)	δ_5	-0.0016462576	0.0040847498	-0.4030253
Experience (Z_6)	δ_6	0.00022949786	0.0022022899	0.10420874
Primary occupation (Z_7)	δ_7	-0.027911207*	0.022389016	-1.2466473
Pond size (Z_8)	δ_8	-0.0026728321**	0.0011043401	-2.4202980
Renovation (Z_9)	δ_9	0.023636240	0.019656041	1.2024924
Asset cost (Z_{10})	δ_{10}	0.00000041221	0.0000010251	0.4020827
Ownership type (Z_{11})	δ_{11}	-0.037148235	0.033218818	-1.1182889
Source of water (Z_{12})	δ_{12}	-0.097534707**	0.040034542	-2.4362639
Depth of water (Z_{13})	δ_{13}	-0.0008716901	0.023454639	-0.0371649
Source of seed (Z_{14})	δ_{14}	0.030013137*	0.016411887	1.8287439
Sources of Advice taken (Z_{15})	δ_{15}	-0.0045832209	0.010281450	-0.4457757
Loan (Z_{16})	δ_{16}	0.021655156	0.024542989	0.8823357
Harvesting technique (Z_{17})	δ_{17}	0.059316720*	0.040854522	1.4519010
Method of application of drug (Z_{18})	δ_{18}	-0.015432842*	0.010162719	-1.5185742
Method of application of feed (Z_{19})	δ_{19}	0.0033167997	0.043048858	0.0770473
Calamities faced (Z_{20})	δ_{20}	-0.029885695*	0.018107579	-1.6504523
Periodical netting for biomass checking (Z_{21})	δ_{21}	0.068515871**	0.025246614	2.7138638
Types of labour (Z_{22})	δ_{22}	-0.042361853*	0.030499051	-1.3889565
Type of organic manure (Z_{23})	δ_{23}	0.0091244716	0.013217207	0.6903479
Type of feed (Z24)	δ_{24}	-0.019243984	0.016299137	-1.1806750
Disease encountered (Z_{25})	δ_{25}	-0.00026916853	0.0040550140	-0.0663799
	σ^2	0.0084153852	0.00077490850	10.8598440
	γ	0.99921654	1.3397727	0.74581048
	Log likelihood function	214.76039		
	LR test	63.053464		
	Mean TE	0.72608099		

***, **, * Significant at 1, 5 and 10 percent level of significance respectively

Table 3. Maximum-likelihood estimates of stochastic production frontier and technical inefficiency models for carp production in Kolleru Lake, Andhra Pradesh, India.

0.008408791 and 0.000006594 respectively indicating that technical inefficiency σ_u^2 is greater than the inefficiency caused by stochastic factor σ_v^2. These values indicate that the differences between the observed (actual) and frontier (potential) output are mostly due to inefficiency and not chance alone. If the value of γ equals zero, the difference between farmers yields and the efficient yield is entirely due to statistical noise. On the other hand, a value of one would indicate the difference attributed to the farmers' less than efficient use of technology i.e., technical inefficiency [26]. In the present case the estimated value of γ, which is the ratio of variance of farm-specific TE to total variance of output, is 0.9992 which suggest that 99.92% of error variation in output among the farms is due to technical inefficiency. This suggests the fact that the random component of the inefficiency effects does not make a significant contribution in the analysis. This result is identical with the observations of Hjalmarsson et al. [29], Coelli and Battese, [30], Kalirajan [31], Ali and Flinn [32] suggesting that technical inefficiency effects are important in explaining the levels and variations in carp yield in Kolleru Lake. The estimated value of λ was found be 35.71020897 which is positive and statistically significant confirming that the variance of farm specific error is much higher than the variance of the stochastic term error.

Estimation of technical efficiency

Frequency distribution of TE estimates for the stochastic frontier model is presented in Table 4. The results derived from the econometric estimation indicate that technical efficiency (TE) scores for fish farmers of Kolleru Lake ranged from 0.5051 to 0.9899 with a mean of 0.7260 and modal class is 0.6 to 0.7 (Table-4).

Efficiency score class	Number of farmers	% of farmer	Cumulative frequency of farmer
0.50 – 0.60	6	2.71	17
0.60 – 0.70	90	40.72	125
0.70 – 0.80	88	39.82	199
0.80 – 0.90	30	13.58	218
0.90 – 1.0	7	3.17	221
Total	221	100.00	--

Table 4. Frequency distribution of technical efficiency estimates for a stochastic frontier model.

Mean technical efficiencies of carp culture ponds of Nepal, India, Bangladesh and Pakistan are reported to be 0.676, 0.790, 0.738 and 0.740 respectively for semi-intensive and intensive carp farming and the respective values for extensive farming are reported to be 0.597, 0.502, 0.475, 0.625 [12] and between 0.11-1.0 [11]. In the present study it revealed that over 56% of the farmers operate with efficiency score greater than 0.7 and no farmer operate below the technical efficiency of 0.50.

Potential for technical efficiency improvement

The result furnished in the abovementioned section suggests that on average the farmers of Kolleru Lake area are able to obtain about 72.60% of potential output from the given set of production inputs. Therefore, in the short run there is a scope of increasing the productivity of carps by around 27.40% by adopting the technology and techniques used by best practice farms. Further, it is observed that if the average farmer in the sample was to achieve the TE level of its most efficient farmer counterpart then the average farmer could realize 26.7 percent cost saving [1 – (72.60/98.99)]. Similarly the most technically inefficient farmer may achieve cost saving of 48.9 percent [1 – (50.51/98.99)].

Determinants of Technical Efficiency

It is reported that Socio-economic, demographic, farm, environmental and non-physical factors are likely to affect the efficiency of operation of any farm [33]. Results of maximum likelihood estimates of the technical inefficiency model and determinants of technical efficiency are presented in Table-3. Altogether twenty-five nonphysical socio-economic, demographic and farm specific factors were included in the model to test the possible impact and association with the technical efficiency of aquaculture farms operating in the Kolleru lake area. The inclusion of variables was based on the belief that these might be relevant in model estimations. A close look at Table-3 reveals that of the twenty-five factors considered for technical efficiency model, socio economic and farm specific factors like religion, age, education, primary occupation, pond size, ownership type, source of water, depth of water, sources of advice taken, method of application of drugs, calamities faced, types of labour, types of feed and disease encountered have positive impact on technical efficiency. On the other hand caste, number of children, experience, renovation, asset cost, source of seed, loan, harvesting technique, method of application of feed, periodical netting for biomass checking and types of organic manure showed negative association with technical efficiency. Of all the farm specific factors showing positive impact mentioned above only pond size and source of water were found significant at ($p<0.05$) and types of labour, religion, method of application of drug, primary occupation and calamities are found significant at ($p<0.10$). Likewise of the variables showing negative impact only periodical netting for biomass checking is found highly significant ($p<0.01$), source of seed and harvesting technique and caste were found significant at lower level of significance ($p<0.10$) demonstrating the influence of these factors in efficiency of carp culture. In depth analysis of impact of pond size on TE performed and presented in Table 5 indicates that a consistent increase in mean TE with the size of the farm showing highest TE value of 0.7552

	Marginal (< 1 ha)	Small (1-2 ha)	Semi-medium (2-4 ha)	Medium (4-10 ha)	Large (>10 ha)
Mean TE	0.63525835	0.676256767	0.71594478	0.721440235	0.755257403
Standard Deviation	0.017217	0.077395	0.067207	0.07777	0.083428
Coefficient of Variation (%)	2.710266	11.44464	9.387159	10.77982	11.04634

Table 5. Relationship between pond sizes on TE level of carp farm in Kolleru Lake, Andhra Pradesh, India.

for aquaculture farms of size greater that 10 ha. This is at par with the popular belief that larger farms are capable to capture the economics of size and operates at higher efficiency levels compared to those of marginal and small farm. Pond area is estimated to have positive impact indicating large operations are technically more efficient than smaller ones [15]. Pond size is reported to have positive relationship on productivity [6]. Water is the primary essential component of all aquacultural activities and its importance has been reflected through significant positive impact on TE. Farmers those who have set up their farms by the side of irrigation canals facilitating regular intake and periodical discharge of water are found to operate with significantly higher mean technical efficiency of 0.7287 compared to those using water from other sources with a mean TE of 0.6648 (F_{cal}=5.57>F_{crit}=3.88). Types of labour employed also showed positive impact on TE. Farms employing permanent labour could utilize their services for timely operation of various farm activities reflecting significantly higher mean TE of 0.7354 compared to those employed casual labour as and when needed reflecting mean TE of 0.6957 (F_{cal}=10.11>F_{crit}=3.88). Majority of the farm were operated by farmers of Hindu religion who are influential and economically sound having in an advantageous position for mobilizing resources for timely investment in various aquacultural activities resulting in significantly higher TE of 0.7275 compared to other religion i.e. 0.6207 (F_{cal}=5.33>F_{crit}=3.88). Method of application of drug has also shown positive impact over TE. To combat disease, drugs were used either diluting in water or spraying in water or mixing with feed demonstrating estimated TE of 0.7292, 0.7237 and 0.6284 respectively and the differences among treatment were not found significant (F_{cal}=1.62<F_{crit}=3.04). Primary occupation was found to be significant at 10 percent level indicating that farmers doing fish farming as main activity showed significantly higher mean of 0.7359 compared to those of others showing mean TE of 0.6896 (F_{cal}=13.02>F_{crit}=3.88). This finding is at par with the observation of Sharma and Leung [13]. Impact of calamity on TE was found significant (p<0.10). One possible explanation may be that Kolleru Lake is located in the flood and cyclone prone areas of Krishna and Godavari districts of Andhra Pradesh. As a result farms affected by flood or cyclone were automatically flushed out of organic load and metabolic wastes those used to be accumulated due to regular use of inputs like organic manure and feed resulting in marginally higher mean TE of 0.7276 compared to a mean TE of 0.7210 of farms not affected by calamities during last five years of operation although the difference is not proved statistically significant (F_{cal}=0.27<F_{crit}=3.88).

In Kolleru lake area, it is observed that about 86% of farmers resort to periodical netting for biomass checking that has shown significant negative impact over TE, may be due to the fact that as a result of frequent netting, the shallow pond bottom of farms were disturbed resulting in turbidity for a prolonged period due to presence of muddy substances creating unfavourable environmental condition for the growth of cultivated species. Mean TE of 0.7898 demonstrated by farms those are not doing periodical netting is observed significantly higher compared to TE of 0.7157 by farms resorting to periodical netting (F_{cal}=25.18 > F_{crit}=3.88). Contrary to priori expectation, source of seed showed negative impact on TE at 10 percent level of significance thereby indicating that the on-farm seed production system does not improve the efficiency of aquaculture farms. On the other hand, those purchased seed from outside may be of superior quality. From survey it is found that about 66% of sample farmers stocked ponds procuring seed from outside sources and the rest of the farmers reared seed in their farms for stocking the culture ponds. Mean TE of 0.7351 shown by farms stocked procuring seed from outside compared to mean TE of 0.7215 shown by farms those stocked seed rearing in their own farm. Apparent differences in mean of the two groups are not statistically significant (F_{cal}=1.42 < F_{crit} = 3.88). Analysis of another important factor harvesting technique showed negative impact on TE. It reveals that 95% of sample farmers are resorting to single stocking and single harvesting technique wherein mean TE of 0.7631 was obtained compared to mean value of 0.7241 demonstrated by farm practicing single stocking and multiple harvesting or multiple stocking and multiple harvesting techniques.

However, the differences of TE between the two groups are not statistically significant (F_{cal}=2.47<F_{crit} = 3.38). In Kolleru lake general caste farmers used to be dependent on hired labour showed negative impact on TE. Mean TE of farms owned by SC, OBC and General Caste farmers are 0.7333, 0.7195 and 0.7276 respectively. But differences among castes are found not statistically significant (F_{cal}=0.33<F_{crit} = 3.04). The results indicate that the farm specific variables included in the technical inefficiency model contribute significantly to the explanation of the technical inefficiencies among sample carp farms of Kolleru Lake area.

Conclusion and Policy Implications

Enhancement of productivity is one of the most important aims of carp culture in India that contributes significantly towards food and nutritional security. The present analysis of data has given attention and focused on the issues of productivity enhancement through improvement of TE of the carp farming system with available existing resources and technology of the carp farmers of Kolleru Lake area, popularly known as Carp Pocket of India for regularly supplying quality protein particularly eastern states of India. The stochastic frontier estimate demonstrates the average technical efficiency of 72.60% indicating that there is scope for further increasing the output by 27.40% without increasing the levels of inputs. The use of stochastic frontier analysis enables ranking of the carp culture farms based on efficiency of yield of fish facilitating identification of the most efficient and inefficient farms across various carp farming system operating in the Kolleru lake area. The efficient farms may serve as a model farm for improving the efficiency of carp production in the kolleru lake area as well as throughout the whole country where the mean technical efficiency is reported to be lower [13] compared to the one reported in the present case. The empirical results suggest that there are immense possibilities to increase efficiency levels by extending culture operation in large size ponds, provision for supply of fresh water, application of drugs after diluting in water, employing labour on regular basis and leasing out the water bodies to farmers whose primary occupation is fish farming and educating the farmers to procure seed from reliable sources, proper harvesting technique and avoiding periodical netting. From the policy point of view, above mentioned farm specific variables are found to be most promising areas for action, suggesting that policy maker may look into the matter seriously for possible reforms to enhance the productivity without any additional input use. Further studies involving allocative cost and economic efficiencies are needed.

Acknowledgements

The author is thankful to Indian Council of Agricultural Research for sponsoring the project and financial assistance for carrying out the investigation. Thanks are due to all the Ex-Directors of Central Institute of Freshwater Aquaculture for providing necessary facilities and encouragement during the course of study.

References

1. FAO. State of World Aquaculture: 2006. FAO Fisheries Technical Paper. FAO. Rome. 2006.

2. Anon. Final Report of the project 'Technical innovations in aquaculture and its sustainability of farming system in Andhra Pradesh', Central Institute of Freshwater Aquaculture, Kausalyagnaga, Bhubaneswar-751002. 2002.

3. Roy AK, Sahoo KN, Saradhi KP, Saha GS. Aquaculture in Kolleru Lake area for socio-economic development. Environment and Ecology. 2001, 19(4): 927-931.

4. Roy AK, Sahoo KN, Saradhi KP, Saha GS. A socio economic study on aqua culturists of Eluru and Kaikalur Mandals of Kolleru Lake area of Andhra Pradesh. 2001. In: National conference on eco-friendly management of resources for doubling fish production strategies for 21 century (ed. Sinha M, Dhirendra Kumar, Katiha PK), pp. 176-179. Central Inland Capture Fisheries Research Institute (CICFRI), Barrackpore, during 22-23 December, 1999.

5. Roy AK, Saradhi KP, Sahoo KN, Saha GS. Statistics of carp culture in Eluru and Kaikalur Mandals of Kolleru Lake in Andhra Pradesh, India. In: The Fifth Indian Fisheries Forum Proceedings AFSIB, Mangalore and AoA, Bhubaneswar, India (eds. Ayyappan S, Jena JK, Joseph MM). 2002, PP. 409-411.

6. Roy AK, Sahoo KN, Saradhi KP, Saha GS. Farm size and aquaculture productivity relationship. Asian Fisheries Society. 2002, 15(2): 129-134.

7. Sahoo KN, Roy AK, Saradhi KP, Saha GS. Break even analysis of carp culture practice in Eluru Mandal – A Case Study. 2000. In: Proc. Fifth Indian Fisheries Forum (ed. Ayyappan S, Jena JK, Joseph MM), pp. 146. Central Institute of Freshwater Aquaculture, Bhubaneswar, India during 17–20 Jan 2000.

8. Sahoo KN, Roy AK, Saradhi KP, Saha GS. A study on marketing channels of fish produce of Kolleru Lake. Journal of Fisheries Economics and Development. 2001, 4(1):35-44.

9. Saradhi KP, Roy AK, Sahoo KN, Saha GS. On socio economic database management in Aquaculture. 2002. In: The Fifth Asian Fisheries Forum. Proceedings AFSIB, Mangalore and AoA, Bhubaneswar, India (Ayyappan S, Jena JK, Joseph MM), pp. 413-415.

10. Roy AK, Saha GS, Sarangi N. Socio-economic, educational and demographic profile of fish farmers of Kolleru Lake, Andhra Pradesh. 2006. In: Compendium of lectures on National Workshop Cum Training on Bioinformatics and Statistics

in aquaculture Research (ed. Roy AK, Sarangi N), pp.293-318. Central Institute of Freshwater Aquaculture, Kausalyagnaga, Bhubaneswar-751002, India, during 7–10 February, 2006.

11. Jayaraman R. Economics and technical efficiency in carp culture in Thanjavur District, Tamil Nadu State, India. In: Proceedings of 9th International Conference of the International Institute of Fisheries Economics and Trade, Trade, Tromso, July 8-11, 1998 (ed. A. Eide, T. Vassdal), pp. 71-82. Norwegian College of Fishery Science, Tromso, Norway. 1998.

12. Sharma KR, Leung PS. Technical efficiency of carp pond culture in South Asia: An Application of a stochastic meta-production frontier model. Aquaculture Economics and Management. 2000, 4(3-4): 169-189.

13. Sharma KR, Leung PS. Technical efficiency of carp production in India: A stochastic frontier production function analysis. Aquaculture Research. 2000, 31(12): 937-947.

14. Dey MM, Paraguas FJ, Bimbao GB, Regaspi PB. Technical efficiency of Tilapia growout pond operations in the Philippines. Aquaculture Economics and Management. 2000, 4(1-2): 33-47.

15. Iinuma M, Sharma KR, Leung PS. Technical efficiency of carp pond culture in peninsula Malaysia: an application of stochastic production frontier and technical inefficiency model. Aquaculture. 1999, 175(3-4): 199-213.

16. Greene WH. The econometric approach to efficiency analysis, In: The Measurement of Productive Efficiency (ed. H.O. Fried, C.A.K. Lovell and S.S. Schmidt), pp. 68-119. Oxford University Press, New York.

17. Farrell MJ. The measurement of productive efficiency. Journal of the Royal Statistical Society. Series A. 1957, 120(3): 253-281.

18. Aigner DJ, Lovell CAK, Schmidt PJ. Formulation and estimation of stochastic frontier. 1977, 6(1): 21-37.

19. Kirkley JE, Squires DE, Strand IE. Assessing technical efficiency in commercial fisheries: The Mid-Atlantic Sea Scallop Fishery. American Journal of Agricultural Economics. 1995, 77(3): 686-97.

20. Coelli TJ, Rao DSP, Battese GE. An introduction to efficiency and productivity analysis. USA: Kluwer Academic Publishers, USA. 1998.

21. Battese GE, Coelli TJ. Frontier production function, technical efficiency and panel data: with application to paddy farmers in India. Journal of Productivity Analysis. 1992, 3(1/2): 153-169.

22. Boris E. Pinheiro, Bravo-Ureta, Antonio E. Efficiency analysis of developing country agriculture: A review of the frontier function literature. Agricultural and Resource Economics Review. 1993, 22(1): 88-101.

23. Gunaratne, L.H.P. and P. S. Leung. 2001. Asian Black Tiger Shrimp Industry: A meta-production frontier analysis, In: Economics and Management of Shrimp and Carp Farming in Asia (ed. P.S. Leung, K. R. Sharma). Network of Aquaculture Centres in Asia-Pacific, Bangkok, Thailand.

24. Irz X, McKenzie V. Profitability and technical efficiency of aquaculture systems in Pampanga, Philippines. Aquaculture Economics and Management. 2003, 7(3-4): 195-211.

25. Reifschneider D, Stevenson R. Systematic departures from the frontier: A framework for the analysis of firm inefficiency. International Economic Review. 1991, 32(3): 715-723.

26. Battese GE, Coelli TJ. A model for technical inefficiency effects in a stochastic frontier function for panel data. Empirical Economics. 1995, 20: 325-332.

27. Battese GE, Coelli TJ. Prediction of firm-level technical efficiencies with a generalised frontier production function and panel data. Journal of Econometrics. 1988, 38(3): 387-399.

28. Coelli TJ. A guide to FRONTIER version 4.1: a computer programme for stochastic frontier production and cost function estimation. Department of Econometrics. Univ. of New England, Australia. 1994.

29. Hjalmarsson L, Kumbhakar SC, Heshmati A. DEA, DFA and SFA: A Comparison. Journal of Productivity Analysis. 1996, 7(2): 303-327.

30. Coelli TJ, Battese GE. Identification of factors which influence the technical inefficiency of Indian Farmers. Australian Journal of Agricultural Economics. 1996, 40(2): 103-128.

31. Kalirajan K. An econometric analysis of yield variability in paddy production. Canadian Journal of Agricultural Economics. 1981, 29(3): 283-294.

32. Ali M, Flinn JC. American Journal of Agricultural Economics. Profit efficiency among basmati rice producers in Pakistan Punjab. 1989, 71(2): 303-310.

33. Kumbhakar SC, Bhattacharya A. Price distortion and resource use efficiency in Indian agriculture: a restricted profit function approach. Review of Economics and Statistics. 1992, 74(2): 231-239.