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Farm Specific Economic Efficiency of Fish Production in South Tripura District: A Stochastic Frontier Approach

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I

INTRODUCTION

Fish is an important item of food to almost all the people (about 95 per cent) of Tripura. The aqua-resources of Tripura include reservoirs, lake, river and rivulets (10,000 ha), ponds/tanks (9,072 ha) and mini barrages (4,270 ha). All these aqua-resources, however, encompass only 2.22 per cent of the total geographical area of the state of Tripura. There were about 93,870 fish farmers in the state during 2001-02. The present average production from culture fish in the state is very low (about 1,200 kg/ha/year), which needs to be increased up to 3,000 kg/ha/year to make the state self-sufficient in fish production (Sarkar, 2002).

The increase in production is possible only through improvement in productivity, which can be increased through one or a combination of factors, namely, technology, the quantities and types of resources used and the efficiency with which the resources are used. Of the various determinants, improvement in the efficiency of resources already at the disposal of the farmers is of great concern (Goyal *et al.,* 2006) and widely recognised by researchers and policy makers alike (Arsalanbod, 2005). An underlying premise behind efficiency estimation is that, if the farmers are not making efficient use of the existing technology, their efforts designed to improve efficiency would be more cost effective than introducing new technologies as a means of increasing agricultural output (Bravo-ureta and Evenson, 1994).

The economic efficiency (EE) is composed of technical efficiency (TE), which is connected to technology, refers to use the minimal possible combination of inputs for producing a certain output (input orientation) or to obtain maximum possible level of output (i.e., frontier output) at the given level of technology (output orientation). EE also includes allocative efficiency (AE) as Farrell (1957) called it price efficiency, which refers to optimal combination of inputs at given input prices, i.e., connected to market (Brummer *et al.,* 2002). Both TE and AE are important to achieve the overall economic efficiency in resource use, i.e., maximum profit at given level of technology and input prices.

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Keeping in view the importance of the estimation of farm specific efficiencies, in the present study, the farm specific EE under different categories of fish farms has been examined by estimating technical and allocative efficiencies in South Tripura district of Tripura state during 2004-05.

II

THEORETICAL FRAMEWORK

Stochastic Frontier Production (SFPF) and Cost Functions (SFCF)

The stochastic frontier modelling is becoming increasingly popular because of its flexibility and ability to closely combine the economic concepts with modelling reality. And, based on this, the model is employed in this study to provide the basis for measuring farm-level TE and AE, which are the basis for estimating the EE of fish farming in the study area.

The modelling, estimation and application of stochastic frontier production function to economic analysis assumed prominence in econometrics and applied economic analysis following Farrell's (1957) seminal paper, where he introduced a methodology to measure the TE, AE and EE of a firm.

According to Farrell, the TE is associated with the ability of a firm to produce on the isoquant frontier, while the AE refers to the ability of a firm to produce at a given level of output using the cost-minimising input ratios. Thus, EE is defined as the capacity of a firm to produce a pre-determined quantity of output at a minimum cost for a given level of technology (Bravo-ureta and Pinheiro, 1997).

However, over the years, Farrell's methodology had been applied widely, while undergoing many refinements and improvements. And of such improvement is the development of stochastic frontier model which enables one to measure firm level technical and economic efficiency using maximum likelihood estimate (a corrected form of ordinary least square – COLS). Aigner *et al.,* (1977) and Meeusen and Van de Broeck (1977) were the first to propose stochastic frontier production function and since then many modifications had been made to stochastic frontier analysis. The model used in this study is based on the one proposed by Battese and Coelli (1995) and Battese *et al.* (1996) in which the stochastic frontier specification incorporates models for the inefficiencies effects and simultaneously estimate all the parameters involved in the production and cost function models.

Model Specification

The stochastic frontier function model of Cobb-Douglas functional form is employed to estimate the farm level TE and AE of the farmers in the study area. The Cobb-Douglas functional form is used because of: (a) the functional form has been widely used in farm efficiency both for the developing and developed countries, (b) the functional form meets the requirement of being self-dual, allowing an examination of EE, and (c) Kopp and Smith (1980) suggested that the functional form has limited effects on empirical efficiency measurement.

The Cobb-Douglas production functional form which specifies the production technology of the farmers is expressed as follows:

$$Yi = f\,(Xi;\,\beta)\ \exp Vi - Ui$$

Where, Yi represents the production of the i-th farm, which is measured in kg; Xi represents the quantity of inputs used in the production. The Vis are assumed to be independent and identically distributed random errors, having normal N $(0, \sigma v^2)$ distributional and independent of the Uis. The Uis are technical inefficiency effects, which are assumed to be non-negative truncation of the half-normal distribution N $(\mu, \sigma u^2)$.

The TE of individual farmers is defined in terms of the ratio of observed output to the corresponding frontier's output, conditional on the level of input used by the farmers. Hence the TE of the farmer is expressed as:

$$TEi = Yi/Yi^* = f\,(Xi;\,\beta)\ \exp\,(Vi - Ui)\ /\ f\,(Xi;\,\beta)\ \exp Vi\ = \exp\,(-Ui)$$

Where, Yi is the observed output and Yi* is the frontier's output.

The cost frontier of Cobb-Douglas functional form which is the basis of estimating the AE of the farmers is specified as follows:

$$Ci = g\,(Yi,\, Pi\ \alpha)\ \exp\,(Vi + Ui);$$

Where, Ci represents the total input cost of the i-th farm; g is a suitable function such as the Cobb-Douglas function; Y_i represents production of the i-th farm; Pi represents input prices employed by the i-th farm in fish production and measured in Indian Rupees (INR); α is the parameter to be estimated, V_is and U_is are random errors and assumed to be independent and identically distributed truncations (at zero) of the N$(0, \sigma^2 v)$ distribution. Ui provides information on the level of allocative efficiency of the i-th farm. The AE of individual farmers is defined in terms of the ratio of the predicted minimum cost (Ci*) to observed cost (Ci) as follows:

$$AEi = Ci^*/Ci = \exp\,(Ui)$$

The farm-specific EE has been obtained as the product of TEi and AEi.

Given the assumptions of the above stochastic frontier models, the inference about the parameters of the model can be based on the maximum likelihood (ML) estimation because the standard regularity conditions hold. Aigner *et al.* (1977)

suggested that ML estimates of the parameters of the model can be obtained in terms of parameterisation $\sigma^2_u + \sigma^2_v = \sigma^2 s$ and $\lambda = \sqrt{(\sigma^2_u \div \sigma^2_v)}$. Battese and Corra (1977) replaced σ^2_u and σ^2_v with σ^2 (variance of composite term) = $\sigma^2_u + \sigma^2_v$ and $\gamma = \sigma^2_u \div (\sigma^2_u + \sigma^2_v)$. The parameter γ must lie between 0 and 1. In the case of $\sigma^2_v = 0$, γ would be equal to 1 and all the differences in error terms of the frontier production function are the results of management factors under the control of the producer (Coelli *et al.,* 1998). When $\sigma^2_u = 0$, γ would be equal to zero, which means all the differences in error terms of the frontier production function are the results of the factors that the producer has no control on them, i.e., random factors. This also implies the existence of a stochastic production frontier. γ close to 1 indicates that the random component of the inefficiency effects makes a significant contribution to the analysis of production system.

γ statistic is used for hypothesis testing concerning the existence of inefficiencies. If ($H_0 : \gamma = 0$) is rejected, it means that there are inefficiencies and the function could be estimated using ML estimation method. If H_0 is not rejected, ordinary least squares method gives the best estimation of the production function.

III

RESEARCH METHODOLOGY

Data and Sampling Design

The study is based on the primary cross section data collected from six villages (two villages each from Matarbari, Amarpur and Bagafa rural development blocks) of South Tripura district of Tripura state of India. South Tripura district contributed about 35 per cent of total culture fish production in Tripura during 2004-05. The rural development blocks and villages within the blocks were selected on the basis of water area under fish culture, i.e., top three blocks within the district and top two villages within the block. On the basis of the list of fish farms (showing pond area), the farms were post-stratified into two categories (category-I having pond area ≤ 0.32 acre and category-II having pond area > 0.32 acre) by using cumulative cube-root frequency method. A sample of 250 fish farms was proportionately allocated to both of the categories and then the selected villages, were drawn. In category-I, the number of farms selected was 157, whereas in category-II farms it was 93. Due to availability of inadequate information, 6 farms in category-I and 5 farms in category-II were dropped, hence the final sample retained was 239.

Method of Data Analysis

Descriptive statistics (mean and standard deviation) and stochastic frontier production and cost functions are used to analyse the technical and allocative efficiency, respectively, of the farmers. The farmer's economic efficiencies are estimated as the product of TE and AE.

The production technology of the farmers is assumed to be specified by the Cobb-Douglas frontier production function which is defined by:

$$\ln Y = \alpha + \beta_1 \ln X_1 + \beta_2 \ln X_2 + \beta_3 \ln X_3 + \beta_4 \ln X_4 + \beta_5 \ln X_5 + (V_i - U_i).$$

Where, Y = fish production (kg); α, β_1, β_2, β_3, β_4, β_5 = parameters to be estimated; X_1 = pond area (acre); X_2 = seed (No. of fingerlings); X_3 = feed (kg); X_4 = fertiliser (kg); X_5 = labour (man-days), V_i = random error having zero mean which is associated with random factors; U_i = one-sided inefficiency component; and ln = Natural Logarithmic value.

The Cobb-Douglas cost frontier function for the fish farmers is specified and defined as follows (Ogundai and Ojo, 2006):

$$\text{In } C = \alpha + \beta_1 \ln Y + \beta_2 \ln P_{X1} + \beta_3 \ln P_{X2} + \beta_4 \ln P_{X3} + \beta_5 \ln P_{X4} + (V_i - U_i).$$

Where, C = Input cost in INR; α, β_1, β_2, β_3, β_4, β_5 = parameters to be estimated; P_{X1} = average price of seed (INR per 100 No. of fingerlings); P_{X2} = average price of feed (INR per kg), P_{X3} = average price of fertiliser (INR per kg), P_{X4} = average wage rate (INR per man-day); INR = Indian Rupee; V_i, U_i and ln are as defined earlier.

The model is estimated through maximum likelihood method by using Limdep 7.0 software, which gives the estimates of parameters λ (= $\sqrt{(\sigma^2_u \div \sigma^2_v)}$), σ^2_u, σ^2_v, and σ. γ is estimated from the estimates of σ^2_u and σ^2_v as $\gamma = \sigma^2_u \div (\sigma^2_u + \sigma^2_v)$.

IV

RESULTS AND DISCUSSION

Average Pond Area, Fish Production and Yield

'Average pond area', 'average fish production per farm' and 'average fish yield' along with respective standard deviations and coefficient of variance are given in Table 1. It is clear from this table that the average pond area per farm is very low in category I farms as compared to category II farms resulting in lower average fish production per farm in the former category than that of the latter one. However, average fish yield in category I is significantly higher in category I farms than that of category II farms as evidenced by t-test. The variation in fish yield in the former category is lower than that in the latter category as given by coefficient of variation.

Overall, the average fish yield in the study area is very low (i.e., 584.25 kg per acre) as compared to the scientific composite fish culture (i.e., 1,000 kg per acre) (Anonymous, 2002). Average pond area and average fish production per fish farm are obtained at the levels of 0.35 acre and 216.59 kg, respectively in the study area.

TABLE 1. AVERAGE AREA, PRODUCTION AND FISH YIELD, CATEGORY WISE, SOUTH TRIPURA DISTRICT, TRIPURA, 2004-05

Item (1)	Pond size category (2)	Category I farms (3)	Category II farms (4)	All farms (5)
Pond area	Average area (acre/farm)	0.15	0.68	0.35
	Standard Deviation (acre)	0.07	0.59	0.44
	Coefficient of Variation (per cent)	46.67	86.76	125.71
Fish production	Average production (kg/farm)	91.20	431.76	216.59
	Standard Deviation (kg/farm)	66.95	919.50	582.22
	Coefficient of Variation (per cent)	73.41	212.96	268.81
Fish yield	Average (kg/acre)	624.71	514.82	584.25
	Standard Deviation (kg/acre)	429.02	362.98	408.64
	Coefficient of Variation (per cent)	68.68	70.51	69.94

Levene's test for equality of variances between fish yield in category I and II, F = 1.397, Level of Sig. = 0.0442.

t-test for equality of means between fish yield in category I and II, t = 2.1085 (unequal variances), level of significance = 0.0362 (2-tailed), df = 206.82.

Number and Composition of Fish Fingerlings Stocked

The composition of fingerlings stocked per acre and per farm along with the characteristics for species are depicted in Table 2. On the basis of percentage share in total seed stocked by the samplexd farms, Rohu is the most dominant fish species in all pond size categories. Mrigal, catla, and common carp are the other dominant fish species in the study area. Table 2 further reveals that the average number of fingerlings stocked per acre in category-I farms was significantly higher (1.73 times) than that in category-II farms as evidenced by the t-test for equality of means between number of fingerlings stocked per acre. The levels of fingerlings stocked per acre were more than three and two times in category-I and II farms, respectively, than that of scientific/recommended one, i.e., 3,000 per acre (Anonymous, 2002).

TABLE 2. PER CENT SHARES OF DIFFERENT FISH SPECIES STOCKED, CATEGORY WISE, SOUTH TRIPURA DISTRICT, TRIPURA, 2004-05

(Per cent to total fish fingerlings stocked)

Fish species ↓ Pond size category → (1)	Category I farms (2)	Category II farms (3)	All farms (4)
Rohu	31.32	31.57	31.52
Catla	19.34	17.20	17.91
Mrigal	21.58	24.01	23.26
Common carp	16.64	13.42	14.43
Silver carp	6.98	10.78	9.59
Grass carp	1.46	1.64	1.59
Bighead	1.75	1.14	1.30
Others	0.94	0.24	0.40
Average no. of fingerlings stocked per farm	1349	5042	2703
Average no. of fingerlings stocked per acre	10511	6082	8881
Recommended level of fingerlings to be stocked per acre			3000

Levene's test for equality of variances between average number of fingerlings stocked per acre in category I and II, F = 3.5613, level of significance = 0.0000.

t-test for equality of means between no. of fingerlings stocked per acre in category I and II, t = 4.5689 (unequal variances), level of significance = 0.0000 (2-tailed), df = 235.

Labour Use Pattern

The average labour use results in terms of man-days are given in Table 3. The average casual hired labour (C.L.) used in category-I farms was only 31.28 per cent to total labour (T.L.) use as against 76.88 per cent in category-II farms and 76.04 per cent in overall situation. This clearly shows that with the increase in the pond size, the per cent contribution of C.L. increases, whereas the reverse is true for family labour (F.L.). The results of the t-test for equality of means between labour used per acre in category I and II establishes that the average labour use (man-days per acre) in category I are significantly higher than that of in category II farms. On an average, 13.99, 24.18 and 17.74 man-days are engaged in category I, II and all farms, respectively.

TABLE 3. LABOUR USE PATTERN IN FISH PRODUCTION, CATEGORY WISE, SOUTH TRIPURA DISTRICT, TRIPURA, 2004-05

Pond size category →	Category I farms			Category II farms			All farms		
Activity ↓ Type of Labour → (1)	C.L. (per cent to T.L.) (2)	F.L. (per cent to T.L.) (3)	T.L. (man-days) (4)	C.L. (per cent to T.L.) (5)	F.L. (per cent to T.L.) (6)	T.L. (man-days) (7)	C.L. (per cent to T.L.) (8)	F.L. (per cent to T.L.) (9)	T.L. (man-days) (10)
Average labour use per farm	31.28	68.72	13.99	76.88	23.12	24.18	76.04	23.96	17.74
Average labour use per acre (man-days)			110.82			37.64			83.88

Levene's test for equality of variances between average labour use per acre in category I and II, F = 12.55, level of significance = 0.0000.

t-test for equality of means between labour use per acre in category I and II, t = 13.2312 (unequal variances), level of significance = 0.0000 (2-tailed), df = 188.

Note: C.L. = casual labour, F.L. = family labour and T.L. = total labour.

Feed, Fertilisers and Manure Use Pattern

The main inputs used in the study area are rice bran, oil cake, lime and cow dung. Large majority of fish farming households are found to be using cow dung and lime. A few (<8 per cent) of fish farming households are using chemical fertilisers (urea, SSP, DAP, MOP) and palette feed. The average quantities of these inputs used are presented in Table 4. The levels of material input use per acre are higher in category-I farms than that of category-II farms for all the inputs except chemical fertilisers and rice bran. The levels of chemical fertilisers used are very low due to the fact of very low proportion of farming households using these inputs (Table 4).

TABLE 4. AVERAGE QUANTITIES OF MATERIAL INPUTS USED IN FISH PRODUCTION, CATEGORY WISE, SOUTH TRIPURA DISTRICT, TRIPURA, 2004-05

(quantity in kg)

Category→	Category I farms		Category II farms		All farms	
Item↓	Per farm	Per acre	Per farm	Per acre	Per farm	Per acre
(1)	(2)	(3)	(4)	(5)	(6)	(7)
Rice bran	40.12	263.99	199.65	294.14	98.85	285.74
Oil cake	22.78	149.93	91.03	134.11	47.92	138.52
Palette feed	4.95	32.57	13.34	19.65	8.09	23.37
Lime	24.01	158.02	33.39	49.19	28.31	81.83
Cow dung	616	40537	1119	1649	699	2020
Urea	0.00	0.00	68.56	101.01	61.61	178.09
SSP	0.00	0.00	4.07	6.00	1.34	3.88
DAP	0.01	0.04	1.85	2.72	0.48	1.40
MOP	0.00	0.00	0.46	0.67	0.50	1.45

Summary Statistics of the Variables for Production and Cost Frontiers

The summary statistics of variables (mean and standard deviations) used for estimation of Stochastic Frontier Production Function (SFPF) and Stochastic Frontier Cost Function (SFCF) are given in Table 5. The total input cost, which is the dependent variable (C) for the estimation of SFCF, includes expenditure on seed, feed, fertilisers and manures, and labour.

TABLE 5. SUMMARY STATISTICS OF VARIABLES OF STOCHASIC FRONTIER PRODUCTION AND COST FUNCTIONS, FISH PRODUCTION, SOUTH TRIPURA, TRIPURA, 2004-05

	Category I farms		Category II farms		All farms	
Variable	Mean	Std. Dev.	Mean	Std. Dev.	Mean	Std. Dev.
(1)	(2)	(3)	(4)	(5)	(6)	(7)
Total fish production (kg)	91.20	66.95	431.76	919.50	216.59	582.22
Pond size (acre)	0.15	0.07	0.68	0.59	0.35	0.44
Total input cost (INR)	2883.31	2448.73	8595.74	17988.44	4986.64	11388.02
Quantity of seed ('00 No. of fingerlings)	13.49	9.54	50.42	124.16	27.03	77.52
Quantity of feed (kg)	67.85	173.93	304.02	631.42	154.81	421.70
Quantity of fertilisers and manures (kg)	639.95	429.03	1227.52	1323.21	790.99	947.19
Labour (man-days)	13.99	6.08	24.18	27.82	17.74	18.19
Average price of seed (INR per '00 No. of fingerlings)	96.38	78.77	67.88	47.51	85.88	70.18
Average price of feed (INR per kg)	5.82	2.58	4.92	2.28	5.49	2.51
Average price of fertilisers (INR per kg)	1.41	2.49	0.83	1.32	1.19	2.15
Average wage rate (INR per man-days)	65.17	12.50	63.98	11.15	64.73	12.01

The prices of various independent variables for SFCF are the weighted averages of the constituents of the aggregated input. For example, average price of fertilisers and manures is the weighted average (quantities used as weights) price of lime, cow dung, urea, SSP, DAP, MOP, etc. Similarly, average price of feed is the weighted price of rice bran, oil cake and palette feed.

Estimates of Stochastic Frontier Production Function (SFPF)

The maximum likelihood (ML) estimates of the SFPF are given in Table 6. All independent variables considered have positive significant coefficients up to 10 per cent level of significance (majority up to 1 per cent) (except β_4, which is non-significant up to 10 per cent level of significance in category-I farms), which indicate that there is a scope for increasing production of fish by increasing the level of these inputs. The estimated elasticities of production (value of coefficients in Cobb-Douglas type of function) of all the inputs are less than one, i.e., positive decreasing function to the factors. This indicates that the inputs allocation is in stage-II of the production surface (the stage of efficient factor usage).

TABLE 6. MAXIMUM LIKELIHOOD ESTIMATES OF THE STOCHASTIC PRODUCTION FRONTIER, FISH PRODUCTION, SOUTH TRIPURA, 2004-05

		Category I farms		Category II farms		All farms	
Variable (1)	Parameters (2)	Coeff. (3)	p-value (4)	Coeff. (5)	p-value (6)	Coeff. (7)	p-value (8)
Constant	α	3.3945 (0.4832)	0.0000	3.5653 (0.2502)	0.0000	3.5062 (0.2246)	0.0000
Area (acre per farm) (X_1)	β_1	0.5900 (0.0778)	0.0000	0.7994 (0.1074)	0.0000	0.6048 (0.0314)	0.0000
Seed (100 No. of fingerlings per farm) (X_2)	β_2	0.1065 (0.0305)	0.0005	0.0602 (0.0154)	0.0001	0.0777 (0.0107)	0.0000
Feed (kg per farm) (X_3)	β_3	0.0251 (0.0083)	0.0024	0.0178 (0.0086)	0.0372	0.0238 (0.0049)	0.0000
Fertiliser (kg per farm) (X_4)	β_4	0.0063 (0.0098)	0.5200	0.0605 (0.0265)	0.0224	0.0159 (0.0086)	0.0643
Labour (man-days per farm) (X_5)	β_5	0.8037 (0.1241)	0.0000	0.7564 (0.0594)	0.0477	0.7941 (0.0526)	0.0000
Lambda	λ	0.9714 (0.5768)	0.0921	1.8669 (0.7649)	0.0002	1.1389 (0.3776)	0.0026
Sigma	σ	0.5355 (0.0901)	0.0000	0.6214 (0.0713)	0.0000	0.5632 (0.0577)	0.0000
Gamma	γ	0.4855		0.7770		0.5646	
Sigma-squared(v)	σ^2_v	0.1476		0.0861		0.1381	
Sigma-squared(u)	σ^2_u	0.1392		0.3001		0.1791	
Log-likelihood function		-91.9676		-51.4590		-148.2874	
Returns to Scale*		1.5253		1.6943		1.5163	

Figures in parentheses are the standard errors, ln = Natural Logarithmic value, 1 acre = 0.4 hectare, p-value is the probability of significance.

*Returns to scale is the sum of significant $\beta$is. (up to .10 level of significance).

The ‘returns to scale’ are estimated at the levels 1.52, 1.69 and 1.52 in category I, II and all farms, respectively (Table 7), indicating prevalence of ‘increasing returns to scale’ in the study area. This shows that efforts should be made to expand the present scope of production to actualise the potential in it, that is, more of the variable inputs could be employed to realise more output.

Estimates of Stochastic Frontier Cost Function (SFCF)

The estimates of SFCF are presented in Table 7. The estimated values of all the parameters of price variables are found to be positive. All the coefficients are significant up to 10 per cent level of significance except for the variables namely average price of seed (P_{x1}) and average price of feed (P_{x2}) in category I farms, and average price of seed in the overall situation.

TABLE 7. MAXIMUM LIKELIHOOD ESTIMATES OF THE STOCHASTIC COST FRONTIER, FISH PRODUCTION, SOUTH TRIPURA, TRIPURA, 2004-05

		Category I farms		Category II farms		All farms	
Variable (1)	Parameters (2)	Coeff. (3)	p-value (4)	Coeff. (5)	p-value (6)	Coeff. (7)	p-value (8)
Constant	α	3.42425 (0.9276)	0.0002	-0.4749 (1.6338)	0.7713	2.8435 (0.7565)	0.0002
Production (kg) (Y)	β_1	0.4632 (0.0368)	0.0000	0.7651 (0.0613)	0.0000	0.5686 (0.0285)	0.0000
Average price of seed (INR per '00 No. of fingerlings (P_{x1})	β_2	0.0003 (0.0075)	0.9653	0.3784 (0.0747)	0.0000	0.0002 (0.0062)	0.9681
Average price of feed (INR per kg) (P_{x2})	β_3	0.0510 (0.0802)	0.5245	0.2591 (0.1307)	0.0474	0.1610 (0.0731)	0.0277
Average price of fertiliser (INR per kg) (P_{x3})	β_4	0.0604 (0.0273)	0.0270	0.1447 (0.0570)	0.0112	0.0873 (0.0256)	0.0007
Average price on labour (INR per man day) (P_{x5})	β_5	0.4438 (0.2242)	0.0477	0.5841 (0.3358)	0.0819	0.4138 (0.0026)	0.0000
Lambda	λ	2.1077 (0.070)	0.0000	1.8703 (0.5103)	0.0002	2.5869 (0.1720)	0.0161
Sigma	σ	0.6625 (0.0703)	0.0000	0.6154 (0.0667)	0.0000	0.7464 (0.0459)	0.0000
Gamma	γ	0.8162		0.7777		0.8700	
Sigma-squared(v)	σ^2_v	0.0807		0.0842		0.0724	
Sigma-squared(u)	σ^2_u	0.3583		0.2945		0.4847	
Log-likelihood function		-93.5917		-50.4444		-164.6142	

Figures in parentheses are the standard errors, ln = Natural Logarithmic value, INR = Indian Rupee, 1 acre = 0.4 hectare, p-value is the probability of significance.

Farm Specific Technical Efficiency

The estimated values of σ^2_u and σ^2_v indicate that the difference between the observed output and frontier output is not due to the statistical variability alone, but also due to technical inefficiencies of farms (Table 7). The estimates of γ indicate the presence as well as the dominance of inefficiency effect over random error in category-II and 'all farms'. However, in category I farms, random error effect is dominant over inefficiency effect. In category I farms, 48.55 per cent of the difference between frontier output and the observed output is primarily due to factors which are under the control of farms, i.e., due to technical inefficiencies. In category II and all farms, 77.70 and 56.46 per cent of the gap between frontier and actual output is due to technical inefficiencies.

A 'per cent' distribution of farms in decile ranges of farm specific TE along with minimum, maximum, mean and median TE in the two categories of sampled farms as well as for overall situation is depicted in Table 8. The results of the χ^2 test showed that the distribution of farms according to different TE levels in both of the farm categories is significantly different.

TABLE 8. DECILE RANGES OF FREQUENCY DISTRIBUTION, TECHNICAL EFFICIENCY (TE), SOUTH TRIPURA DISTRICT, TRIPURA, 2004-05

TE Level	(No. of farms as per cent to total farms)		
	Category I farms	Category II farms	All farms
(1)	(2)	(3)	(4)
<0.10	0.00	0.00	0.00
0.10-0.20	0.83	4.94	1.93
0.20-0.30	3.31	2.47	3.38
0.30-0.40	9.09	2.47	5.80
0.40-0.50	4.96	6.17	5.80
0.50-0.60	9.92	11.11	10.14
0.60-0.70	22.31	23.46	20.29
0.70-0.80	13.22	35.80	21.26
0.80-0.90	22.31	8.64	20.77
0.90-1.00	14.05	4.94	10.63
Total sample farms	151	88	239
Minimum TE	0.1968	0.1463	0.1681
Maximum TE	0.9964	0.9814	0.9995
Standard Deviation of TE	0.2020	0.1817	0.1965
Mean TE	0.6869	0.6543	0.6838
Median TE	0.6989	0.6991	0.7105

Calculated chi-square (χ^2) = 27.89, theoretical chi-square ($\chi^2_{0.01,\ 8df}$) = 20.09 (first two TE classes were combined).

The mean TEi in category I, II and all farms are estimated at the levels of 68.69, 65.43 and 68.38 per cent, respectively. This means if the average farmer in the study area belonging to category I, II and all farms is to achieve the TE of its most efficient counterpart, then he/she can realise 31.06, 33.33, and 31.59 per cent of incremental output, respectively. The corresponding figures for the most inefficient farmer belonging to category I, II and farms are obtained to be 80.25, 85.09 and 83.18 per cent respectively.

Internationally, the TE of fish farmers in Oyo State (Nigeria), by using SFPF approach was estimated to be varying between 6 to 61 per cent with a mean level of 24 per cent (Awoyemi *et al.,* 2003). Ara *et al.* (2004), by using same approach, estimated mean TE in three categories of fish farms, i.e., technical advice receiving, training receiving and normal fish farms, at the levels of 69, 86 and 61 per cent, respectively, in Rajshahi district of Bangladesh.

The frequencies of occurrence in decile range (Table 8) indicate that the highest number of farmers have TE between 0.60-0.70 and 0.80-0.90 in category I (22.31 per farm) and 0.70-0.80 in category II representing about 35.80 per cent of the sample farms. And 50 per cent of fish farms have the TE level below 69.89, 69.91 and 71.05 per cent of the respondents of category I, category II and all farms, respectively, as evidenced by the median TE.

Farm Specific Allocative Efficiency

The values of σ^2_u and σ^2_v obtained from SFCF, given in Table 7, reveals presence and dominance of allocative inefficiencies in fish production in the study area. The estimates of γ indicate that more than 77 per cent of the difference between observed cost and frontier cost is due to allocative inefficiencies.

A distribution of farms in 'per cent' terms in decile ranges of predicted AE is presented in Table 9. The χ^2 test of equality of proportions in category-I and II farms shows the frequency distribution of farmers in decile ranges is significantly different in both the categories. The highest number of farmers have AE between 0.60-0.70 in category I and 0.70-0.80 in category II representing about 20.16 and 27.27 per cent of the sample farmers, respectively. And the corresponding median AE levels were of 61.22, 50.64 and 57.44 per cent.

It can be estimated from the mean and maximum levels of AE that the average farmer belonging to category I, II and all farms can realise a 39.28, 35.75 and 42.53 per cent of cost saving, in that order, to attain the AE level of its most efficient counterpart. The corresponding figures obtained for the most inefficient farmers are 87.25, 88.59 and 95.71 per cent cost savings in the case of category I, II and all farms, respectively.

TABLE 9. DECILE RANGES OF FREQUENCY DISTRIBUTION, ALLOCATIVE EFFICIENCY (AE), SOUTH TRIPURA DISTRICT, TRIPURA, 2004-05

	(No. of farms as per cent to total farms)		
AE Level (1)	Category I farms (2)	Category II farms (3)	All farms (4)
<0.10	0.00	0.00	0.47
0.10-0.20	2.33	2.60	3.77
0.20-0.30	3.88	1.30	5.19
0.30-0.40	12.40	5.19	10.85
0.40-0.50	15.50	14.29	16.98
0.50-0.60	13.18	20.78	18.40
0.60-0.70	20.16	11.69	17.45
0.70-0.80	14.73	27.27	10.38
0.80-0.90	11.63	7.79	10.38
0.90-1.00	6.20	9.09	6.13
Total sample farms	151	88	239
Minimum AE	0.1251	0.1126	0.0429
Maximum AE	0.9811	0.9867	0.9982
Standard Deviation of AE	0.1985	0.1876	0.2078
Mean AE	0.5957	0.5143	0.5737
Median AE	0.6122	0.5064	0.5744

Calculated chi-square (χ^2) = 13.30, theoretical chi-square ($\chi^2_{0.01,\ 8df}$) = 13.39 (first two AE classes were combined).

It can be estimated from the mean and maximum levels of AE that the average farmer belonging to category-I, II and all farms can realise a 39.28, 35.75 and 42.53 per cent of cost saving, in that order, to attain the AE level of its most efficient counterpart. The corresponding figures obtained for the most inefficient farmers are 87.25, 88.59 and 95.71 per cent cost savings in the case of category-I, II and al farms, respectively.

Farm Specific Economic Efficiency

The farm specific EE has been estimated as the product of farm specific AE and TE. The 'per cent' distribution of fish farms is shown in Table 10. The distribution in both the categories of fish farms is found significantly different as confirmed by the χ^2 test. The mean and medium EE are found higher in category I farms (46.27 and 45.18 per cent, respectively) than in category II farms (36.31 and 34.51 per cent, respectively). The mean EE in overall farms is estimated at the level of 44.35 per cent.

TABLE 10. DECILE RANGES OF FREQUENCY DISTRIBUTION, ECONOMIC EFFICIENCY (EE), SOUTH TRIPURA DISTRICT, TRIPURA, 2004-05

EE Level (1)	(No. of farms as per cent to total farms) Category I farms (2)	Category II farms (3)	All farms (4)
<0.10	1.48	4.71	4.04
0.10-0.20	11.85	12.94	10.76
0.20-0.30	17.04	21.18	15.25
0.30-0.40	13.33	27.06	17.49
0.40-0.50	13.33	17.65	15.25
0.50-0.60	16.30	7.06	12.11
0.60-0.70	8.89	5.88	10.31
0.70-0.80	8.15	1.18	4.04
0.80-0.90	4.44	1.18	5.83
0.90-1.00	5.19	1.18	4.93
Total sample farms	151	88	239
Minimum EE	0.0744	0.0813	0.0072
Maximum EE	0.9983	0.9139	0.9939
Standard Deviation of EE	0.2346	0.1679	0.2329
Mean EE	0.4627	0.3631	0.4435
Median EE	0.4518	0.3451	0.4173

Calculated chi-square (χ^2) = 20.22, theoretical chi-square ($\chi^2_{0.01,\ 8df}$) = 20.09 (first two EE classes were combined).

There is scope to increase the profitability from fish farming of the average farmer belonging to category I, II and all farms by 53.65, 60.27 and 55.37 per cent, respectively, by reaching the EE level of the most efficient farmer. Correspondingly, the most inefficient farmer can increase his/her profitability by 92.55, 91.10 and 99.27 per cent in category I, II and all farms to match with the most efficient farmers EE level.

V

CONCLUSIONS

The study has used a stochastic efficiency decomposition frontier analysis to estimate and analyse the farm specific TE, AE and EE levels. The estimated mean TE, AE and EE are found to be lying at the levels between 0.6543-0.6869, 0.5143-0.5957 and 0.3631-0.4435, respectively. The corresponding median TE, AE and EE are estimated at the levels of 0.6989-0.7105, 0.5064-0.6122 and 0.3451-0.4518. The category I fish farms (≤0.32 acre of pond area) are found to be relatively more technical as well as allocative efficient, thus, economic efficient, than category II farms (>0.32 acre of pond area). The results of the study are consistent with "Sultz poor – but – efficient hypothesis" (Schultz, 1964).

The TE appeared to be more significant than AE as a source of gains in EE. The result of the analysis indicated that presence of TE and AE has effects on fish production as depicted by the estimated γ coefficient of the models, and by the predicted TE and AE within the farms.

The study, however, revealed that fish farmers of Tripura are yet to achieve their best. This has been confirmed by the presence of both AE and TE effects on their operations. Also, it is evident from this study that the EE of the farmers could be improved substantially and that AE constitutes relatively more serious problem than TE as judged by the average AE and TE levels estimated in the area.

The results, however, point to the importance of examining not only TE, but also AE and EE, when measuring productive efficiency with the aim of examining critically the role higher efficiency level can have on output in fish culture. The results of the study have further shown that any expansion in the use of any resources by the fish farmers would bring more than proportionate increase in their output, given the value of 'increasing returns to scale' obtained in production.

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