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Technical Efficiency of Freshwater Aquaculture and its Determinants in Tripura, India

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Abstract

Freshwater aquaculture is an important and promising sector of the economy of Tripura State. The biophysical potential for growth in freshwater aquaculture in the state is still far from exhaustion and a faster development is required to meet the growth in demand for fish. This paper has assessed the level of technical efficiency and its determinants of small-scale fish production in the West Tripura district of the state of Tripura, India. The study is based on the cross-sectional primary data collected from 101 fish farmers through a multi-stage random sampling method. The paper has employed stochastic production frontier approach, and has followed both one-stage and two-stage procedures to analyze the determinants of TE. The TE ranges between 0.21 and 0.96 with mean of 0.66 and median of 0.71. The study has revealed the Cobb-Douglas form of stochastic frontier production function is more dependable than that of translog form under the farming conditions in the West Tripura district of Tripura state. One-stage procedure with technical inefficiency model gives reliable estimates of coefficients of stochastic frontier production function than that of two-stage procedure. Seed quality has been found as an important determinant of TE. The study has suggested that the state government needs to play a role to ascertain the supply of quality fish fingerlings at adequate time and quantity to the farmers in the study area.

Introduction

Freshwater aquaculture is an important and promising sector of the economy of the Tripura state in India. Over the years, production of freshwater aquaculture has grown significantly, from 14,172 tonnes in 2003-04 (Singh, 2006) to 30,840 tonnes in 2007-08 (Govt. of Tripura, 2009). The biophysical potential for the growth of freshwater aquaculture in the state is still far from exhaustion and a faster development is required to meet the growth in demand for fish. The average productivity of freshwater aquaculture in Tripura was 1,931 kg/ha/yr in 2007-08, and it must attain a minimum level of 3,000 kg/ha/yr by 2010-11 to meet the growing demand. The main objective of the Perspective Plan (2004-2008) of the Department of Fisheries, Government of Tripura, was to bridge the gap between demand and supply of fish, and attain self-sufficiency in fish production by 2010-11 (Government of Tripura, 2009a). This can be done by (i) adopting new technology, (ii) enhancing the use of inputs, and (iii) increasing the efficiency of farming operations.

Efficient farms either produce more output than others for a given set of inputs or produce a given output with minimum level of inputs. Improvement in farm economic efficiency (EE) is an important factor of productivity growth in areas like Tripura where resources are scarce. A study of the level and determinants of production efficiency can provide some of the information needed by policymakers to improve productivity of freshwater aquaculture in Tripura.

In recent years, a few studies have been conducted to analyze the level and determinants of farm level economic efficiency in the freshwater aquaculture sector at all-India level (Sharma and Leung, 2000; 2000a; Dey *et al.*, 2005). But, no such studies have

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been conducted in the state of Tripura. Singh (2005; 2008) has studied the farm–specific economic efficiencies in the South Tripura district, but has not analyzed the factors affecting efficiencies.

The economic efficiency is composed of technical efficiency (TE) and allocative efficiency (AE); TE reflects the ability of a farm to obtain maximum outputs from a given set of inputs, and AE reflects the ability to use the inputs in optimal proportions given their respective prices (Farell, 1957). Though both the TE and AE are important to achieve the overall economic efficiency in resource use, the TE is more important for areas like Tripura where use of farm-produced inputs (not purchased from the market) is highly prevalent (Singh, 2006; 2008). Moreover, there is skepticism about the credibility of allocative efficiency estimates in the peasant economies (Barrett, 1997). While TE estimation does not require information on prices, estimation of AE does. Given that household-specific failures in markets for input and output are the distinguishing characteristics of low-income agriculture like aquaculture in Tripura, the relevant notion of AE might differ from farmer to farmer, with many crucial variables like fundamentally unobservable shadow prices.

Against this background, the main objective of this paper is to assess the level of technical efficiency and its determinants of small-scale fish production in the West Tripura district of the state of Tripura, India. The West Tripura district has 5017.48 ha of culturable water area, which accounts for about 23.70 per cent of the total culturable water area in the state (Singh, 2006). The results are expected to provide inputs to various stakeholders for productivity gains in fish culture by improving technical efficiency in the study area.

Methodology and Data

Theoretical Framework

In microeconomic theory, a frontier refers to a bounding function (e.g., production function, cost function, profit function). Since the publication of seminal article of Farrell (1957) on efficiency measurement and the subsequent development of several approaches to efficiency and productivity measurements, frontier techniques have been widely used in determining the farm-level efficiency in developing-countries agriculture[1]. The most basic method of TE estimation is to map a production frontier (statistically or non-statistically, parametrically or non-parametrically), find the locus of maximum output levels associated with given input levels, and estimate farm-specific TE as a deviation from the fitted frontier. Among different major approaches followed to measure and estimate efficiency, the stochastic frontier production function approach involving econometric estimation of parametric function (Aigner *et al.*, 1976 and 1977; Meeusen and Broeck, 1977) and non-parametric programming, known as data envelopment analysis (DEA) (Charnes *et al.*, 1978), are the most popular. The stochastic frontier approach is considered more appropriate for assessing TE in a developing-country agriculture, where data are often heavily influenced by measurement errors and other stochastic factors such as weather conditions, diseases, etc. (Fare *et al.*, 1985; Kirkley *et al.*, 1995; 1998; Jaforullah and Delvin 1996; Coelli *et al*., 1998; Dey *et al.*, 2005). Several recent studies have applied stochastic frontier technique for determining efficiency in aquaculture in the developing Asian countries (Gunaratne and Leung, 1996; 1997; Jayaraman, 1998; Sharma and Leung, 1998; 2000; 2000a; Iinuma *et al.*, 1999; Sharma, 1999; Sharma *et al*., 1999; Bimbao *et al.*, 2000; Dey *et al.*, 2000; 2005; Irz and McKenzie, 2003; Singh, 2008).

There are two approaches to analyze determinants of technical efficiency or inefficiency. The traditional approach, which has been used for investigating the relationship between efficiency and various socio-economic variables, is estimating a stochastic production frontier at the first stage, which provides the basis for measuring farm-level TE. Then, a second stage analysis (Lingard *et al*., 1983; Bravo-Ureta and Pinheiro, 1993) is performed where separate two-limit Tobit equations for TE are estimated as a function of various attributes of the farms/farmers in the sample. This is usually referred to as a two-stage procedure. Several economists have, however, criticized this procedure (Battese *et al*., 1989; Kumbhakar *et al*., 1991;

[1] For comprehensive surveys of the frontier literature, the readers are referred to Bauer (1990), Green (1997) and Coelli *et al.* (1998). Ali and Byerlee (1991), Battese (1992), Bravo-Ureta and Pinheiro (1993) and Coelli (1995) have provided excellent review of the application of production frontier approach in agriculture.

Reifschneider and Stevenson, 1991; Battese and Coelli, 1995). They argue that the socio-economic variables should be incorporated directly into the estimation of production frontier model because such variables may have a direct influence on the production efficiency. In recent years, the Battese and Coelli (1995) model for technical inefficiency effects has become more popular because of its computational simplicity and ability to examine the effect of various farm-specific variables of technical efficiency in an econometrically consistent manner. Many recent papers (e.g., Battese *et al*., 1996; Wilson *et al*., 1998; 2001; Yao and Liu, 1998; Sharma and Leung, 2000; Dey *et al*., 2000 and 2005) have used the FRONTIER 4.1 software, developed by Coelli (1996) following Battese and Coelli (1995), to simultaneously estimate the parameters of the stochastic production frontier and the technical inefficiency model. In spite of criticisms, many studies still use two-stage approach; Simar and Wilson (2007) have mentioned about 800 published articles and working papers that have followed two-stage approach for measuring efficiency.

Keeping in view the advantages of stochastic production frontier approach, we have also employed the same to obtain the farm-specific technical efficiency estimates. We have applied both, the two-stage procedure and one-stage procedure (i.e., simultaneous estimation of stochastic production frontier and technical inefficiency effect model) to analyze the determinants of TE. In the two-stage procedure, we have used Error Component Model (ECM) in the first stage to obtain farm-specific technical inefficiency, and then have regressed these predicted technical inefficiencies on farm- and farmer-specific variables (Z variables as defined below) using Tobit model. The Tobit model has been used because the technical inefficiency indices lie between 0 and 1, i.e. dependent variable is truncated (Thiam *et al*., 2001; Brazdik, 2006). In the technical inefficiency effect model (TIEM), the μ_i (measure of inefficiency in frontier models) is defined by Equation (1):

$$\mu_i = \delta_0 + \sum_{j=1}^{n} \delta_j Z_{ij} \qquad \ldots(1)$$

where, Z_{ij} is the vector of farm- and farmer-specific characteristics.

Empirical Model

A stochastic production frontier (SPF) function was specified which related the fish production as a function of inputs used. Assumption about the functional form is an important consideration in the specification of an econometric model. Past studies on technical efficiency utilizing stochastic frontier approach have used either Cobb-Douglas (CD) or the transcendental logarithmic (translog) functional forms. When the second order and the interaction terms in translog are restricted to zero, then the resulting functional form represents a Cobb-Douglas form. The translog and Cobb-Douglas models are specified as per Equation (2) and (3), respectively:

$$\ln Y_i = \beta_0 + \sum_{j=1}^{9} \beta_j \ln X_{ij} + \sum_{j=1}^{9}\sum_{k=1}^{9} \beta_{jk} \left(\ln X_{ij} \times \ln X_{ik}\right) + \nu_i - \mu_i \qquad \ldots(2)$$

$$\ln Y_i = \beta_0 + \sum_{j=1}^{9} \beta_j \ln X_{ij} + \nu_i - \mu_i \qquad \ldots(3)$$

where, Y is the fish production, X_js are the inputs, subscripts 'i', 'j'/'k' denote the i^{th} farm and j^{th}/k^{th} inputs, ν_i is independent and identically distributed random-errors having normal distribution $N(0, \sigma^2_v$ and independent of $\mu_{i,}$, μ_i is the technical inefficiency effects, and βs are the parameters to be estimated. The variance parameters σ^2_u and σ^2_v are expressed in terms of parameterization: $\sigma^2_\mu + \sigma^2_v = \sigma^2$ and $\gamma = \sigma^2_\mu/\sigma^2$; γ can take values from 0 to 1, where 0 implies that the random component of model is due to noise whereas $\gamma = 1$, implies that the random component of model is entirely due to inefficiency.

The independent variables (X_js) included in the model were pond area, lime, cow dung, chemical fertilizers, rice bran, oil cake, health care, fingerlings stocked, and labour used.

The technical inefficiency (TI) function was specified as per Equation (4):

$$TI_i = \mu_i = \delta_0 + \sum_{j=1}^{9} \delta_j Z_{ij} \qquad \ldots(4)$$

where, Z_{ij} is the vector of farm- and farmer-specific characteristics, which include marketed surplus, family non-farm income, family farm income, source of fingerlings, experience of the operator, training in fisheries, and education level of the farmer.

We have used FRONTIER 4.1 software to estimate one-stage procedure (joint estimation of SPF and TIEM) and stage 1 of the two-stage procedure (ECM). We have estimated stage 2 of the two-stage procedure (Tobit model) by using STATA 10 sofware.

Data

The study is based on the cross-sectional primary data collected from the West Tripura district of Tripura state (India) during 2003-04. A multi-stage random sampling method was used to collect data from the fish farmers. Three out of the 16 rural development blocks of West Tripura district, namely Melahgarh, Bishalgarh, and Mohanpur, were selected for the study. From each selected block, 40 fish farming households were considered for the study. Due to inadequacy of data on 19 sampling units, only 101 fish farmers were included in the study.

Results and Discussion

Table 1 presents the salient of features of inputs and output variables involved in the stochastic production frontier and of farm-specific variables included in the technical inefficiency function. The average pond area per household was 0.58 acres (Table 1) and more than 73 per cent of the farming households were having 0.60 acres (Singh, 2007). About 98 per cent of these fish farmers were following polyculture of carps. Rohu (*Labeo rohita*) was the most dominant fish species constituting more than 25 per cent of the total fish production, followed by mrigal (*Cirrhinus mrigala*) (23%), common carp (*Cyprinus carpio*) (18%), catla (*Catla catla*) (17%) and silver carp (*Hypophthalmichthys molitrix*) (16%) (Singh, 2006). Lime, cow dung, rice bran and oil cake were the important material inputs used by more than 65 per cent fish farming households in the study area. The farmers were found utilizing multi-sources for procuring fish fingerlings, but fish traders/commission agents

Table 1. Description of variables used in the stochastic frontier production function and technical inefficiency function

Variable	Variable symbol	Parameter	Mean values
Output variable			
Fish production (kg/farm)	Y		338.01
Input variable			
Pond area (acres/farm)	X_1	β_1	0.58
Lime (kg/farm)	X_2	β_2	65.47
Cow dung (kg/farm)	X_3	β_3	694.48
Chemical fertilizers (kg/farm)	X_4	β_4	27.95
Rice bran (kg/farm)	X_5	β_5	273.96
Oil cake (kg/farm)	X_6	β_6	86.35
Health care (Rs/farm)	X_7	β_7	38.37
Fingerlings stocked (No. /farm)	X_8	β_8	4198.0
Labour (humandays/farm)	X_9	β_9	26.32
Farm-specific variables affecting TE			
Marketed surplus (kg/farm)	Z_1	δ_1	43.45
Family non-farm income (Rs/year)	Z_2	δ_2	39219.0
Family farm income (Rs/year)	Z_3	δ_3	33174.0
Source of fingerlings (if commission agent then ‘1’, otherwise ‘0’)	Z_4	δ_4	
Source of fingerlings (if private then ‘1’, otherwise ‘0’)	Z_5	δ_5	
Source of fingerlings (if government then ‘1’, otherwise ‘0’)	Z_6	δ_6	
Experience of the operator (year)	Z_7	δ_7	10.24
Training in fisheries (if farmer got technical training then‘1’, otherwise ‘0’)	Z_8	δ_8	
Education of the farmer (year)	Z_9	δ_9	6.74

Source of fingerlings ‘Owned’ has been used as control variable for Z_4 to Z_6 dummy variables.

Table 2. LR test statistics for comparison of functional forms and distributions of ì$_i$

Model	Test for Cobb-Douglas vs. Translog		Test for half normal vs. Truncated	
	Half normal	Truncated	Cobb-Douglas	Translog
Stochastic production frontier with technical inefficiency effect model (one-stage procedure)	47.4818 (0.3718)	50.0338 (0.2804)	0.0000 (1.0000)	2.5520 (0.1102)
Stochastic production frontier - error component model (stage 1 of two-stage procedure)	46.1321 (0.4252)	50.4978 (0.2653)	2.4266 (0.1193)	1.9391 (0.1638)
Critical $\chi^2_{0.10,\ldots df}$ =	57.486 (45 df)		2.706 (1 df)	

Note: Figures within the parenthesis are levels of significance for LR test statistics

were the most important source, catering fingerling needs of about 61 per cent farmers in the study area. The majority of ponds were not excavated for the purpose of fish culturing, but were the results of digging out soil for constructing houses. These ponds were multipurpose (bathing, cleaning kitchen utensils, etc.). Most of the farmers were culturing fish for home consumption, but some were selling the produce only to cater their monetary needs. The marketed surplus was about 69 per cent of the total produce. Singh (2006; 2007) has described the fish production system in the West Tripura district and in his study (Singh, 2008) on farm-specific economic efficiency has provided details about fish production system in this district.

For the stochastic production function analysis, all output and input variables are measured on per farm basis. We have not found any major multicollinearity problem in using total inputs per farm and areas of ponds as explanatory variables. This specification also enabled us to examine economies of scale associated with the size of operation. The system under investigation being polyculture of fish, a stochastic multiple output distance function could have been considered for this study. But, it was not used due to the fact that not all farmers cultured the same combination of species (i.e., presence of zero-valued observations).

Model Specification Tests

The functional form has a discernible impact on estimated efficiency (Koop and Smith, 1980; Ahmad, and Bravo-Ureta, 1996). Studies using the Cobb–Douglas functional form yield significantly lower average TE indices than those relying on the translog specification, which implies that more restricted functional forms lead to lower average TE (Thiam *et al*., 2001). Therefore, the formal tests of alternative models, functional forms, and alternative distributions of μ_i in the stochastic frontier production models are warranted.

We have used generalized likelihood-ratio test[2] (LR test) to study the specification of stochastic frontier production function (Cobb-Douglas versus translog functional forms of the model, and half normal versus truncated distributions of μ_i) under both one-stage and two-stage procedures (Table 2). We have tested the null hypothesis (H_0): ln (H_0) = ln (H_1) against the alternate hypothesis (H_1): ln (H_0) < ln (H_1), where ln(H_0) is the log-likelihood function of CD form (restricted frontier) and ln (H_1) is the log-likelihood function of translog form (unrestricted frontier) and the LR test failed to reject our null hypothesis for the both one-stage as well as two-stage procedures (Table 2). It is important to mention that coefficients of most of the square and interaction terms used in the translog model were non-significant, and also the elasticity estimates from the model were unrealistic. This could be attributed to the biologically unplausive interactions used in the model.

To compare the distribution of μ_i, the null hypothesis (H_0): ln (H_o) = ln (H_1) was tested against the alternate hypothesis (H_1): ln (H_o) < ln (H_1), where ln(H_o) is the log-likelihood function of half normal distribution of μ_i (restricted frontier) and ln (H_1) is the

[2] The generalized likelihood ratio test statistics is defined as:g = – 2[ln (H_0) – ln (H_1)], where, ln (H_0) is the log-likelihood function of a restricted frontier model as specified by null hypothesis H_0; and ln (H_1) is the log-likelihood function of unrestricted model (alternate hypothesis). The test statistic (λ) has a χ^2 or a mixed χ^2 distribution with degrees of freedom equal to the difference between the parameters involved in H_0 and H_1.

log-likelihood function of truncated distribution of μ_i (unrestricted frontier). We did not find any evidence against our hypothesis of 'no difference' (i.e., H_o).

It is, however, not theoretically correct to compare the stochastic frontier models across two procedures (one-stage vs. two-stage) on the basis of log likelihood function. It is because of the fact that the log likelihood function of one-stage procedure contains the effect of inefficiency function also. However, one-stage procedure has advantages over the two-stage procedure as discussed in the 'theoretical framework' section of the paper. Therefore, we have focused our discussion on one-stage procedure of Cobb-Douglas functional form and half normal distributions of μ_i. However, we have presented the results of two-stage procedure also with the same functional form for a comparison.

Parameter Estimates of Stochastic Production Frontier

Table 3 depicts the maximum likelihood estimates of stochastic production frontier for Cobb-Douglas form under half-normal distribution of μ_i. The positive significant coefficient of pond area shows the existence of economies of scale in the study area. Singh (2008) has also obtained similar results for the South Tripura district of Tripura state. However, given the purpose of fish culture in the study area (particularly for subsistence), small size of ponds, and fragmented holdings, it may not be feasible to exploit the economies of scale arising from farm size.

Other variables having positive significant coefficients were fingerlings stocked, labour and lime (except for lime in ECM), which indicate that there is potential of increasing fish production through raising the levels of these inputs. The estimated elasticities of production (which are given by value of coefficients in Cobb-Douglas form) for these inputs were less than 1, i.e., positive decreasing function to the factors. This indicates that the allocation of these inputs was in stage-II of the production surface (the stage of efficient factor usage). The coefficient of cow dung in ECM showed its overuse in the study area.

The estimated value of γ indicates (Table 3) that the difference between the observed output and frontier output was not due to the statistical variability alone, but was also due to technical inefficiencies of fish farmers. The values of γ shows the presence as well as dominance of inefficiency effects over random-error effect in the two-stage procedure, while in the one-stage procedure, random-error effect was higher than inefficiency effects.

Technical Efficiency Estimates and Distribution of Farms

Table 4 presents the decile ranges of farm-specific TE frequency distribution along with mean, median,

Table 3. Maximum likelihood estimates of the stochastic production frontier, Cobb-Douglas form, West Tripura, Tripura: 2003-04

Model parameter	One-stage procedure with technical inefficiency model			Two-stage procedure-error component model		
	Coeff.	S.E.	p-value	Coeff.	S.E.	p-value
Intercept (β_0)	4.9174	0.6906	0.0000	5.0946	0.4061	0.0000
Pond area (acres/farm) (β_1)	0.5192	0.0746	0.0000	0.6563	0.0430	0.0000
Lime (kg/farm) (β_2)	0.0209	0.0120	0.0840	0.0051	0.0097	0.6008
Cow dung (kg/farm) (β_3)	-0.0098	0.0101	0.3338	-0.0346	0.0120	0.0049
Chemical fertilizers (kg/farm) (β_4)	-0.0057	0.0087	0.5132	-0.0052	0.0070	0.4625
Rice bran (kg/farm) (β_5)	-0.0004	0.0127	0.9729	0.0171	0.0145	0.2397
Oil cake (kg/farm) (β_6)	-0.0058	0.0123	0.6386	0.0101	0.0057	0.0797
Fish health care (Rs/farm) (β_7)	0.0063	0.0111	0.5722	0.0033	0.0064	0.6053
Fingerlings stocked (No. /farm) (β_8)	0.1958	0.0703	0.0064	0.2329	0.0486	0.0000
Labor (mandays/farm) (β_9)	0.0300	0.0144	0.0404	0.0485	0.0150	0.0008
σ^2	0.2954	0.0941	0.0022	1.2932	0.1434	0.0000
γ	0.4858	0.1503	0.0017	0.6872	0.0000	0.0000

S.E. = Standard error

Table 4. Decile ranges of technical efficiency frequency distribution, West Tripura district, Tripura: 2003-04

(% to total number of farms =101)

TE range (%)	One-stage procedure with technical inefficiency model	Two-stage procedure-error component model
0-10	0.00	4.67
10-20	0.93	13.08
20-30	10.28	10.28
30-40	4.67	17.76
40-50	7.48	14.95
50-60	11.21	8.41
60-70	17.76	10.28
70-80	17.76	7.48
80-90	19.63	6.54
90-100	10.28	6.54
Total	100.00	100.00
Mean TE (%)	0.6658	0.4746
Median TE (%)	0.7166	0.4361
Maximum TE (%)	0.9613	0.9993
Minimum TE (%)	0.2125	0.0463

maximum and minimum TE scores. The mean TE efficiency estimated was 0.67 in the case of one-stage procedure and 0.47 for two-stage procedure. The results are in line with the estimates of TE by using half-normal Cobb-Douglas form in the South Tripura district of Tripura state (Singh, 2008). The mean TE estimates and distribution of farms in decile ranges obtained through two procedures (one-stage vs. two-stage) were significantly different (Table 5).

Determinants of Technical Inefficiency

In the two-stage procedure followed to determine factors influencing TE, Tobit model was used at the second stage to explain the variations in the technical inefficiency scores (obtained from ECM in the first stage) related to farmer/farm-specific factors. In the one-stage procedure, the model determines the influence of farmer/farm-specific factors on technical inefficiency simultaneously. Table 6 presents the estimates of the coefficients of factors influencing technical inefficiency (*Z* variables are given in Table 1) obtained from both the procedures (two-stage and one-stage).

Table 5. Tests for equality of variances and means of TE, and distribution of farms in TE decile ranges

(Level of significance)

Test	One-stage procedure	Two-stage procedure
F-test (equality of variances)	0.0485	0.3257
T-test (equality of means, 2-tail)	0.0000	0.0000
χ^2–test (similarity of frequency distributions)	0.0000	0.0000

Amongst the factors considered, the coefficient of experience of the operator in fish culturing was significant and positive in both the models (Table 6). In general, as farmer's experience increases, so do his skills in optimally allocating the resources at his/her disposal. The more experience a farmer has, the higher is his output and higher is the technical efficiency (Revilla-Molina *et al*., 2009). However, findings of the present study are not in line with this statement. The positive sign of coefficients asserts that this variable has negative effect on TE. Onu *et al.* (2000), Fasasi (2007) and Raphael (2008) have also found similar results. The experience and age of the farmers are positively correlated, and a majority of farmers were above 40 years of age in the study area. There was a negative correlation between the age of a farmer and the education level (a majority was having primary or lower education) and between his age and income (majority belonged to low-income group). Farmer's age influences the farm practices directly or indirectly through labour, management and knowledge. Young and middle-aged farmers were more willing to adopt a new technology. Older farmers were conservative, risk averse, and, therefore, were less likely to embark on new technology (Temu, 1999). However, this hypothesis needs to be tested. In the present study, inaccessibility of new techniques/technology to the experienced farmers would be the plausive explanation. Inaccessibility to new techniques/technology may be because of low income, low education level and/or traditional mindset (conservative, risk averse, etc.).

Another important determinant of TE was the seed quality, which in the case of fish culture depends heavily on the source. The most important source supplying fish fingerlings to the farmers was the middlemen in the study area. They were supplying fish fingerlings as different species mix. But, species mix as well as quality including size were uncertain (Singh, 2008).

Table 6. Determinants of farm-specific technical inefficiency, West Tripura district, Tripura: 2003-04

Parameter	One-stage procedure Technical inefficiency model			Two-stage procedure Tobit model		
	Coeff.	S.E.	p-value	Coeff.	S.E.	p-value
Constant	2.8763	1.0088	0.0053	0.5092	0.0475	0.0000
Marketed surplus (kg/farm) (δ_1)	-0.0156	0.0780	0.8416	-0.0003	0.0004	0.4360
Family non-farm income (Rs/yr) (δ_2)	0.0141	0.0189	0.4581	0.0000	0.0000	0.0240
Family farm income (Rs/yr) (δ_3)	-0.2168	0.1116	0.0550	0.0000	0.0000	0.0310
Source of fingerling (if commission agent then ‘1’, otherwise ‘0’) (δ_4)	-0.4378	0.3031	0.1519	-0.1873	0.0361	0.0000
Source of fingerling (if private then ‘1’, otherwise ‘0’) (δ_5)	-0.6719	0.6191	0.2805	-0.3261	0.0525	0.0000
Source of fingerling (if government then ‘1’, otherwise ‘0’) (δ_6)	-2.8066	1.0677	0.0100	-0.3091	0.0666	0.0000
Experience of the operator (years) (δ_7)	0.1306	0.0786	0.0998	0.0077	0.0013	0.0000
Training in fisheries (if farmer got technical training then ‘1’, otherwise ‘0’) (δ_8)	-0.1445	0.3370	0.6690	-0.0473	0.0314	0.1360
Education of the farmer (years) (δ_9)	-0.0040	0.0167	0.0810	-0.0054	0.0027	0.0450

S.E. = Standard error

Farmers had to depend on this source because of their inaccessibility to government hatcheries or inadequacy of fingerling supply from the government hatcheries. Amongst the prevailing sources of fingerlings (i.e., commission agent, private hatcheries, government hatcheries, owned), the level of TE was higher in cases of farmers purchasing fingerlings from the government (Table 6). The government hatcheries provided fingerlings with better species mix as well as of superior quality.

Family non-farm income was another variable having negative influence on the technical efficiency (technical inefficiency model). This has been reported in other sectors of agriculture also. For instance, Lindara *et al*. (2006), while studying the technical efficiency in spice-based agroforestry sector in Sri Lanka, have found negative effects of off-farm income on TE.

Education negatively affected the technical inefficiency, supporting the hypothesis of Schultz (1964) (Table 6) that education increases the ability to perceive, interpret and respond to new events and enhances farmers’ managerial skills, including efficient use of agricultural inputs.

Conclusions

The study has revealed that there is potential for increasing fish production in the West Tripura district of Tripura state by increasing the levels of pond area, fingerlings stocked, labour and lime. But, given the farming conditions, it may not be feasible to harness the economies of scale observed in the study area.

The results of TE analysis have indicated the presence of TE has effects on fish production, as depicted by the estimated ‘γ’ (=0.48) parameter of the model, and by the predicted TE within the farms. The TE has been found to range between 0.21 and 0.96, with mean value of 0.66 and median value of 0.71. However, it is important to mention that the realized production frontier is lower than that of potential production frontier (frontier by following scientific recommendations), because none of the sample fish farmers has been found following the recommended practices. Therefore, the results of the study have been interpreted cautiously.

The study has revealed that the Cobb-Douglas form of stochastic frontier production function is more dependable than that of translog form under fish farming conditions in the West Tripura district of Tripura state. The study has further revealed that one-stage procedure with technical inefficiency model gives reliable estimates of coefficients of stochastic frontier production function than that of error component model, i.e., stage 1 of two-stage procedure.

Seed quality, which has been surrogated by fingerlings source, is an important determinant of TE. The TE, and thereby fish production, can considerably be improved in the West Tripura district if the supply of fish fingerlings from the government hatcheries is increased. Unlike other parts of India where aquaculture is well-developed, private hatcheries in the state of Tripura have not fully developed. Therefore, the state government needs to play a role to ascertain the supply of quality fish fingerlings at proper time and in adequate quantity to the farmers.

Awareness about scientific techniques of fish culture and cost-effective technology would play an important role in increasing fish productivity, particularly in fish farms operated by the experienced/aged farmers (> 40 years) in the area.

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