Technical Efficiency of Shrimp Farming in Andhra Pradesh: Estimation and Implications

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ABSTRACT

Shrimp farming is a key subsector of Indian aquaculture which has seen a remarkable growth in the past decades and has a tremendous potential in future. The present studyanalyzes thetechnical efficiency of the shrimp famers of East Godavari district of Andhra Pradesh using the Stochastic Production Frontier Function with the technical inefficiency effects. The estimates mean technical efficiency of the farmers was 93.06 % which means the farmers operate at 6.94 % below the production frontier production. Age, education, experience of the farmers and their membership status in farmers associations and societies were found to have a significant effect on the technical efficiency. The variation in the technical efficiency also confirms the differences in theextent of adoption of the shrimp farming technology among the farmers. Proper technical training opportunities could facilitate the farmers to adopt the improved technologies to increase their farm productivity.

Key words: Shrimp farming, technical efficiency, Stochastic Production Frontier

INTRODUCTION

Coastal shrimp aquaculture in a traditional form existed in Indian sub-continent for many centuries. During eighties the shrimp farming enterprise picked momentum and became a popular farming practice among coastal farmers. It was in the 1990s, the economic liberalization process widened the scope of the commercial shrimp farming since it was arosean export oriented activity. The government schemes and programmes fueled the growth in subsequent years and the shrimp farming become a very important sub-sector of the fisheries domain. During the year 2013-14, Indiaexported shrimp worth Rs 19368 crores (MPEDA,2014). Shrimp farming is dependent on various factors like quality of the physical characteristics of the system, climatic conditions and essentially the quality of all the input resources that areused in the production process. Hence, the shrimp yield is a function of different factors. The variation in the yield and the factors responsible for the inefficiencies has to be studied in detail to improve the production and productivity of the farms and thus our farming systems can achieve maximumefficiency.

MATERIALS AND METHODS

In this study we have collected farm level cross sectional data from randomly selected 150 shrimp farmers of East Godavari district. A interview schedule was pretested and used to collect the information from the farmers. Stochastic production functionwas used to explain the variation in the shrimp yield.The stochastic frontier model has been widely used in measurement of performance of agriculture in developing countries where the data are often influenced by measurement errors and other stochastic factors such as weather conditions, diseases, etc (Aigner *et al*, 1977). The Technical Efficiency (TE) estimation has also been attempted by many researchers in aquaculture economics, majority of those studies are from Asian countries. (Shang *et al*. 1998;Sharma et al.1999; Iinuma et al. 1999; Sharma and Leung 2000; Irz and McKenzie 2003; Chiang *et al*. 2004; Dey *et al*. 2005; Singh *et al*. 2009; Alam *et al*. 2011; Rahman *et al*. 2011;).

To estimate the Technical Efficiency the Battese and Coelli (1995) model is widely adopted model due to its computational simplicity and ability to examine the effects of various farm specific variables of TEin an econometrically consistent manner. This model was employed in recent studies. Sharma and Leung (2000); Dey *et al*. (2000, 2005) ; Singh *et al*. (2009) ; Alam *et al*. (2011) have employed the FRONTIER 4.1 software, used Battese and Coelli (1995), to simultaneously estimate the parameters of the SPF and the TE models.

The stochastic frontier production function for cross-sectional data is specified as:

$$Yi=f(Xi;\ \beta)\ \exp\ (Vi - Ui) \qquad ...(1)$$

Where Y_i denotes the production for the *i* th farm (i = 1, 2, 3, ……, n), X_i is a 1 × k vector of the value of known functions of inputs of farm production and of other explanatory variables associated with the *i* th farm, β is a k × 1 vector of unknown parameters to be estimated, V_i's are random variables which are assumed to be independently and identically distributed $N(0, \sigma_v^2)$ and independent of the U_i's, U_i's are non-negative random variables associated with TE in production and are assumed to be independently distributed as truncations of the $N(Z_i\delta, \sigma_u^2)$ distribution.

Following Battese and Coelli (1995), U_i's can be represented as:

$$Ui=Zi\delta + Wi \qquad ...(2)$$

where Z_i is a 1 × p vector of variables which may influence efficiency of a farm, δ is a p × 1 vector of parameters to be estimated, W_i's are random variables defined by the truncation of the normal distribution with mean 0 and variance σ_u^2, such that the point of truncation is $Z_i\delta$, that is, W_ie" $Z_i\delta$. These assumptions are consistent with U_i being a non-negative truncation of the $N(Z_i\delta, \sigma_u^2)$ distribution (Battese and Coelli, 1995).

By using the maximum likelihood (ML) estimation procedure simultaneous estimation of the parameters of the stochastic frontier model is possible as in Eq. (1) and those for the technical inefficiency model in Eq. (2) the likelihood function and its partial derivatives with respect to the parameters of the model are given.(Battese and Coelli,1993).

The technical efficiency of production for the *i* th farm (TE_i) is defined as:

$$TE_i = exp\ \ (-U_i) = \frac{Y_i}{f(X_i;\beta) exp\ (V_i)} \qquad ...(3)$$

Given the model assumptions, the prediction of the TE's is based on the conditional expectation of the expression in (3).

Empirical model

The stochastic production frontier for shrimp farming in Andhra Pradesh can be estimated using the Cobb–Douglas functional form as specified below:

$$\ln Y_i = \beta_0 + \sum_{k=1}^{n} \beta_k \ln X_{ki} + V_i - U_i \qquad ...(4)$$

where subscript *i* refer to the *i*th farm in the sample; *ln* represents the natural logarithm; *Y* represents output and *X*'s are input variables defined earlier; b's are parameters to be estimated; *V* 's and *U*'s are random variables defined earlier. Maximum likelihood estimation of Eq. 4 provides the estimations for b's and variance parameters,

$$\sigma^2 = \sigma_y^2 + \sigma_u^2 \text{ and } \gamma = \sigma_u^2/\sigma^2$$

Following Battese and Coelli (1995), it is assumed that the technical inefficiency distribution parameter, U_i is a function of various operational and farm-specific variables hypothesized to influence technical inefficiencies as:

$$U_i = \delta_0 + \sum_{k=1}^{n} \delta_k Z_{ki} + W_i \qquad ...(5)$$

Where Z's are various operational and farm-specific variables, defined earlier; δ's unknown parameters to be estimated; and W_i's are also defined earlier.

It should be noted that the technical inefficiency model in Eq. 5 can only be estimated if the technical inefficiency effects, U_i's, are stochastic and have particular distributional properties Coelli and Battese, (1996). Therefore, it is of interest to test the null hypothesis for the absene of technical inefficiency effects, $\gamma = \delta o = \delta 1 = -- = \delta 9 = 0$ that technical inefficiency effects are nonstochastic, $\gamma = 0$ and that farm-specific factors do not influence the inefficiencies, $\delta 1 = -- = \delta 9 = 0$ under $\gamma = 0$; the stochastic frontier model reduces to a traditional average function in which the explanatory variables in the technical inefficiency model are accounted in the production function. These hypothesis and related null hypotheses can be tested using the generalized likelihood-ratio statistic λ given by:

$$\lambda = -2[\ln\{L(H_0)\} - \ln\{LH_1)\}] \qquad ...(6)$$

Where $L(H_0)$ and $L(H_1)$ denote the values of likelihood function under the null (H_0) and alternative (H_1) hypotheses, respectively. If the given null hypothesis is true, λ has approximately X^2 distribution or mixed distribution when the null hypothesis involves $\gamma = 0$.

Given the model specifications, the Technical Efficiency index for the i^{th} farm in the sample , defined as the ratio of observed output to the corresponding frontier output, is given by:

$$TE_i = \exp(-U_i) \qquad ...(7)$$

The prediction of TE is based on the conditional expectation of expression in Eq. (7) given the values of evaluated at the maximum likelihood estimates of the parameters of the stochastic frontier model (Battese and Coelli, 1988).

The frontier production for the i^{th} farm can be computed as the actual production divided by the TE estimate. The parameters for the stochastic frontier function in Eq. (4) and those of the technical inefficiency model in Eq. (5) are estimated simultaneously using the ML estimation method, using the computer program, FRONTIER 4.1 (Coelli, 1994).

Output and Input Variables

The variables corresponding to the output and input parameters involved in the stochastic production frontier function for the sample shrimp farmers in East Godavari district, Andhra Pradesh are given in Table 1. Water spread area, stocking density, quantity of feed, labour cost, cost of chemicals and fertilizers, cost of electricity and fuel are included in the SPF. The efficiency of farm might be affected by the farm specific variables that are mentioned in the Table 1. Based on the existing literature, the variables were chosen and the justification for their inclusion also elaborated.

RESULTS AND DISCUSSION

Farm Characteristics

Characteristics of the sample shrimp farms were presented in the Table 1. The average water spread area of the farms was found to be 1.06 ha. The farms stock an average of Rs391502 PL per ha that is equivalent to 39 PL per square meter. Shrimp were fed with commercial pellet feed, the average quantity of feed applied wasRs11251 kgs. The mean shrimp production ranged from Rs3128 kg/ha to Rs11326 kg/ha and the average production was Rs7846 kg/ha. The amount of labour used for production was expressed in terms of salaries and wages paid for permanent labour as well as hired labour utilized for specific activities such as pond preparation and other regular activities . The average labour cost is Rs51135/ha. Farmers use a variety of chemicals and fertilizers right from the stage of pond preparation to the harvest. The average cost of chemicals and fertilizers is Rs189507/ha. The average cost of electricity and fuel is Rs245036 / ha.

Parameter Estimates of the Inefficiency Function

In TE analysis, the dependent variable of the inefficiency model in Eq. (5) is defined in terms of the level of inefficiency; a farm-specific variable

Table 1: Specification of variables in the stochastic production frontier and technical inefûciency model for shrimp farming

Variable	Description	Unit
Y	Total shrimp production per hectare per year	kg
Variables in the production frontier		
X Ws	Water spread Area	Ha
X Pl	Quantity of post larvae stockedper hectare per year	Number
X Fd	Quantity of feed used per hectare per year	kg
X La	Labour cost per ha	Rs /ha
X Cf	Cost of chemicals and fertilizers applied per hectare per year	Rs /ha
X Cf&e	Cost of fuel and electricity consumed per hectare per year	Rs /ha
Variables in the inefficiency function		
Z Cd	Culture Duration	Days
Z Ag	Age of the shrimp farmers	Yrs
Z Ex	Experience of the shrimp farmers	Yrs
Z Ed	Education level of the shrimp farmers(Primary 1, Secondary 2 , Higher Education 3)	yrs
Z Oc	Shrimp farming as primary occupation (1 if yes , otherwise 0)	1, 0
Z Fa	Family size of the shrimp farmers	Persons
Z Rk	Risk Averse nature of the shrimp farmers (1 if yes, 0 otherwise)	0,1
Z Ea	Early technology adoption nature of the shrimp farmers (1 if yes, 0 otherwise)	0,1
Z Ls	Farm ownership (if leased then 1, otherwise 0)	1, 0
Z Me	Membership in shrimp Farmers Associations and societies (1 if yes, 0 otherwise)	1,0

Table 2: Summary statistics of the variables involved – East Godavari district

Name of the variable	Minimum	Maximum	Mean	Std Dev
Shrimp Yield (kg/ha)	3128	11326	7846	1826
Water Spread Area (ha)	0.45	1.6	1.06	0.27
Stocking Numbers (No/ha)	150000	550000	391502	98436
Feed (kg/ha)	4461	16343	11251	2462
Labour cost (Rs/ha)	19358	65987	51135	10265
Cost of Chemicals & Fertilizers (Rs/ha)	69194	26832	189507	44126
Cost of Electricity and Fuel (Rs/ha)	91410	407545	245036	60923
Duration of Culture (Days)	62	131	106.77	13.97
Age (Years)	29	65	44.21	8.56
Education (1 or 2 or 3)	1	3	1.87	0.63
Experience (Years)	7	25	13.13	4.62
Family size (No)	2	6	3.52	1.19
Occupation (0 or 1)	0	1	0.78	0.42
Ownership (0 or 1)	0	1	0.69	0.46
Membership (0 or 1)	0	1	0.55	0.5
Risk averse (0 or 1)	0	1	0.46	0.5
Early-adopt (0 or 1)	0	1	0.62	0.49

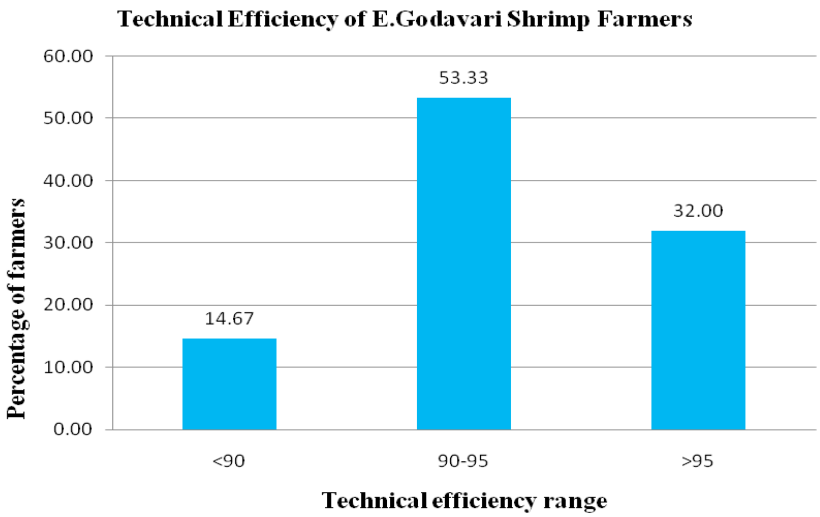

Fig. 1: Frequency distribution of technical efficiency for shrimp farmers in East Godavari district

associated with the negative (positive) coefficient will impact positively (negative) on TE.

From the results it is observed that experience and educational status of the farmers has significant positive effect on the TE of the farm. Age was found to be positively associated with the TE. These results suggest that farmers with higher experience and better education were taking proper farm management decisions which increased their TE. These results were also supported by the studies carried out by Dey et al. (2000), Alam et al. (2011), and Rahman et al. (2011). Apart from these variables early technology adopting nature, and membership with organizations were also found to be positively related with the TE. These variables were associated with the TE at 5 % significant level, whereas risk averse nature, family size, occupational status and ownership status were negatively associated with TE. Though family size, occupational status, duration of culture, ownership status were negatively related, the statistical significance was only at 10% level.

The estimated ã parameter associated with the variance in the stochastic production frontier model is found to be close to one and highly significant. Though the ã parameter cannot be interpreted as the proportion of the total variance explained by the Technical Efficiency effects, from the result it is inferred that Technical Efficiency effects do have a significant contribution to the variation of shrimp production in Andhra Pradesh.

Technical Efficiencies

Fig. 1 depicts the frequency distribution of the estimated TE scores for the sample shrimp farmers in East Godavari district. About 32 % of farmers have TE scores above 95%, while 53.33 % operate between 90 and 95%. About 14.67 % farmers operate at less than 90%. The mean TE level of shrimp farmers was found to be 93.06 %. Similar kinds of results were obtained by Reddy et al (2008) in a study in East Godavari district, where the estimated TE of shrimp farming was 93%. Studies conducted in other countries had lesser TE scores. For example, studies conducted in Bangladesh shrimp farming systems shows that the Technical Efficiency scores were found to be around 70 %. Haque (2011) found the Technical Efficiencyof shrimp culture to be 71%. Rahman et al (2011) concluded that the Technical Efficiency of shrimp culture at 68%.

CONCLUSIONS

From the study it is clearly evident that farmers were technically efficient and they could achieve 93.06 % of the potential yield in East Godavari. The reason for the higher TE was probably due to the better understanding of the production technology by the farmers. The semi intensive farming technology the farmers adopt is a superior production technology in which high quality commercial pellet feed is used to feed the shrimps and a variety of growth enhancers are also applied to the pond ecosystem during different stages of the growth cycle. The gap in the TE scores indirectly informs that there is still good scope to improve their production to achieve the potential yield. The main factors that contribute to the inefficiency were experience, education and age of the farmers. The early technology adopting nature and membership with organizations were positively relatedwith the TE. Family size, occupational status, duration of culture, ownership status was negatively related with TE. The study results imply that the gap in TE maybe attributed to thefarmers' personalitytraits. Valderrama et al (2014) suggests that the efficiency of the farms can be improved with proper technical training programs to farmerson Better Management Practices that will enable them toachieve better productivity further.

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