

Should Sustainability of Fish Stock Be Prioritised Over Catch Efficiency – A Study on Traditional Fishermen in Karimganj District of Assam

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Abstract
Sone Beel, the largest wet land of southern Assam is the home of traditional fishermen who are dependent solely on fishing for their livelihood. No fishing permits are required in the Sone Beel during the peak fishing season, and as such there is open access to fishing during this period. This paper estimates technical efficiency of fish catch and its non-input determinants using a stochastic production frontier with inefficiency effects. A sample of 165 fishing teams operating during the monsoon of 2013, were chosen for this purpose. The study suggests that experience in fishing has a positive influence on technical efficiency while education and income from sources other than fishing have depressing effects on the same. Uncontrolled fishing in the area during peak fishing seasons is the consequence of overdependence on fishing. There is no institutional mechanism in place to check the rampant use of dense nets that lead to massive loss of non-fish species in the water body. Thus immediate policy intervention may check loss of fish stock and aquatic species in the region, and can help in restoration of the ecological balance in the Sone Beel.
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JEL classification: C 21, Q 22.

1. Introduction and Objectives

For a long time, fishing has been regarded as one of the most important means of livelihood of thousands of households living in the neighbourhood of the Sone Beel in Karimganj district located in the southern part of Assam. The Sone Beel is the largest wet land and catchment area of the region. The fisheries sector in Karimganj is almost entirely dominated by small scale, poor fishing households dwelling in the vicinity of the Sone Beel. The Sone Beel accounts for a considerable share of the total fresh water fish catch of the district (***Source***: Comprehensive District Agricultural Plan Report of 2011-12, District of Karimganj, Government of Assam). People in the region (that includes fishermen) already have a perception that there is over-crowding of catchers in the Sone Beel. In all probability, this is due to the complete absence of entry restrictions during the peak fishing season (the monsoon months) and the lack of alternative livelihoods. Moreover lack of modern catch methods, capital shortage and technical knowhow prevents the fishing households to go beyond the traditional methods. With rapidly rising catch, falling fish stock and growing fish demand, the sector faces the challenge of developing a sustainable small-scale fisheries sector, which can integrate socio-economic and environmental objectives in their planning decisions.

The major concerns as identified by the fishermen themselves include, (i) poor and inefficient fishing gears and vessels, (ii) lack of financial capital, (iii) poor fisheries management, (iv) limited access to major markets of the region (e.g. Silchar, Guwahati and Agartala) on account of poor communications, (v) poor handling facilities, and finally (vi) high post-harvest losses, and above all (vii) over-concentration of fishermen. Lack of alternative employment opportunities and rising number of fishing households have possibly been responsible for over-crowding of catchers, ultimately leading to over-exploitation of the resource and degradation of fish stock in the Sone Beel. Almost all fishing households around the Sone Beel continue to be trapped in poverty and this has been their status over generations.

Since, the principal occupation of people residing around the Sone Beel is fishing, standard of living of the fishing household is indisputably linked with, (i) the productivity and efficiency of fish catch with respect to catch-effort or labour time spent, (ii) the revenue earned and, (iii) the income from non-fishing occupation if any – say for example from agriculture and allied activities, or even from other petty businesses. However the efficiency of fish catch depends on several factors that are not used as direct inputs by fishermen. These include health status (physical fitness and physical capability) of the fishermen, experience, knowledge and awareness regarding fishing in the area, indebtedness, understanding within the fishing team members and income sources other than fishing, e.g. agricultural or petty business income. Unfortunately in a remote and backward pocket of southern Assam, collection of detailed information on all these factors from fishermen is practically challenging even with a dedicated team of field surveyors.

Influential works on the application of stochastic production frontiers to assess inefficiencies in agricultural and industry include Battese and Coelli (1992), Coelli and Battese (1996) and Kong, Marks and Wan (1999). The pioneering study on technical efficiency in fisheries is due to Onumah and Acquah (2010) use a single –stage modeling stochastic frontier approach to examine technical efficiency and its determinants of aquaculture farms and extend the scope of the analysis to explore interactive effects of farm specific variables on efficiency of production. In a seminal paper, Adinya, Offem and Ikpi (2011) compared technical efficiency of mandarin fish and clown fish production in Cross River State, Nigeria. The result showed that the sum of elasticity for mandarin fish and clown fish were found to be 1.36 and 1.25, respectively implies that both production systems were operated in inefficient stage (technically inefficient). The result also showed that fish farmers' educational level, access to credit, farm size and feed positively influenced their levels of efficiency in mandarin fish and clown fish production systems in Cross River State. Ekunwe and Emokaro (2009) examined the technical efficiency of catfish farmers in Kaduna metropolis Kaduna State, Nigeria using the stochastic frontier production function analysis. Some of the variables of interest such as fingerling, labour and pond size were efficiently allocated as their estimated coefficient value range between zero and one. Gender, household size and education were found to be negatively related to technical efficiency while experience and age were found to be positively related to technical efficiency. The result also showed that the return to scale was 0.664 which gives an indication that the farmers are in stage II of catfish production in the study area.

Onumah, Brummer and Horstgen-Schwark (2010) examined the productivity of hired and family labour and determinants of technical inefficiency of fish farms in Ghana. Evidence from the estimated model indicated that family labour, hired labour, feed, seed, land, other costs and extension visit have a reasserting influence on fish farm production. Findings also show that family and hired labour used for fish farming production in Ghana may be equally productive. The combined effects of operational and farm specific factors (age, experience, land, gender, pond type and education) influence technical inefficiency although individual effects of some variables may not be significant.

Till date, no studies are reported in literature on the productivity and efficiency of fish catch in the Sone Beel in particular and Assam (or even North-eastern India) in general. In fact systematic studies on efficiency of fish catch in traditional fishing and its socio-economic determinants in India are rare. The present study is thus a pioneering attempt to measure the technical efficiency of fish catch among single boat using traditional fishermen fishing in the Sone Beel in Karimganj district of Assam. Three selected non-input factors such as experience in fishing (years), education (years spent in formal schooling) and income from other sources (measured in Rupees per month) are hypothised to explain variations in technical efficiency levels across fishing teams. The study takes the fishing team as the unit of analysis for stochastic production frontier analysis. This paper is presented in the following sections. After a brief introduction to the problem in section 1, a concise overview of the study region is presented in section 2 followed by methodological and data related issues in section 3. Empirical findings and its analyses are presented in section 4 with summary and conclusions in section 5. Throughout the text the words catchers and fishermen have been used alternatively to mean the same thing.

2. The Sone Beel

The Sone Beel is the largest wet land of southern Assam. It is located between 92°24'50" – 92°28'25" East and 24°36'40" – 24°44'30" North in Karimganj district of Assam (a major state in northeastern India) and falls in a valley geologically called syncline. The physiography of the district consists of small hillocks intervened by wide low valleys. The hillocks have northeast – southwest and northeast – south southwest trend near the Borail range and north – south trend towards south away from the Borail range. Notably, Sone Beel, the biggest `Beel' (wetland) in Assam is situated in between two hill ranges, viz., the Badarpur-Saraspur range and the Chowkirmukh-Dohalia range. The maximum length and breadth of the wetland at Live Storage Level (LSL) are measured at 12.5 km and 3.9 km respectively during June to September. Interestingly, these values reduce to 4.07 km and 2.22 km respectively at its Dead Storage Level (DSL) during December to April. The area of Sone Beel at LSL is 3458.12 hectares while at DSL, the area diminishes to only 409.37 hectares. Thus, there is enormous variation of water volume in the Sone Beel across the monsoon and winter months. The length of the shoreline is measured at 35.4 km while mean depth is 0.29 metres [Kar *et al*. (2006)]. Sone Beel can be approached from either the district of Karimganj or Hailakandi, the nearest major urban location being the district Head Quarter town of Hailakandi. Hailakandi town is located approximately 20 km to the east of the Sone Beel and is road-way connected. Due to the proximity of Hailakandi town, majority of fish caught in the Sone Beel is marketed in Hailakandi.

3. Models, Methodology and Data

3.1 The Stochastic Production Frontier with Inefficiency Effects

In order to measure technical efficiency (TE) at the fishing team level along with its non-input determinants, the present study adopts a Cobb-Douglas stochastic frontier model with inefficiency effects following Battese and Coelli (1995). In other words the stochastic production frontier and the inefficiency effects parameters are simultaneously estimated, given appropriate distributional assumptions. This was originally proposed by Kumbhakar *et al.* (1991), Reifschneider and Stevenson (1991), and Haung and Lui (1994). Battese and Coelli (1995) is an improvement over the previous methods as it is based on panel data. Moreover this one-stage maximum likelihood approach is statistically consistent with the Kumbhakar *et al.* (1991) approach and leads to more efficient inference with respect to the parameters (Coelli and Battese, 1996). The approach has been applied empirically by, Coelli and Battese (1996), Battese and Broca (1977).

Acceptably, a Cobb-Douglas form restricts the flexibility of the fish catch technology by imposing the elasticity of scale to be constant and the elasticity of input substitution to be unity. The trans-log production function often creates practical problems in estimation. First with several inputs there is an obvious loss of degrees of freedom (incorporation of log of inputs, square of log of inputs and cross product of log of inputs). Second there is the obvious econometric risk of muticollinearity among the various explanatory variable columns. Although its parameters may be estimated by Seemingly Unrelated Regression Equations (SURE) method, it is ineffective in estimating the stochastic production frontier parameters which requires direct estimation of the production frontier.

The stochastic production frontier developed separately by Aigner, Lovell and Schmidt (1977) and Meeusen and van den Broeck (1977) decomposes the error term of the usual econometric production function model into a white random noise component and a one sided inefficiency random component. For the present, we assume a cross-sectional stochastic production frontier model (specified in Kumbhakar *et al,* 1991) as

$$\ln y_i = \ln f(x;\beta) + v_i - u_i \tag{3.1.1}$$

$$u_i = \gamma' z_i + \varepsilon_i \tag{3.1.2}$$

The random noise component in the production process is introduced through the error component v_i which is $iid\ N(0,\sigma_v^2)$ in equation (3.1.1). The second error component which captures the effects of technical inefficiency has a systematic component $\gamma' z_i$ associated with the firm specific variables and exogenous variables along with a random component ε_i. Inserting equation (3.1.2) in (3.1.1) gives the single stage production frontier model

$$\ln y_i = \ln f(x_i;\beta) + v_i - (\gamma' z_i + \varepsilon_i) \tag{3.1.3}$$

The condition that $u_i \geq 0$ requires that $\varepsilon_i \geq -\gamma' z_i$ which does not require $\gamma' z_i \geq 0$ for each producer. It is now necessary to impose distributional assumptions on v_i and ε_i and to impose the restriction $\varepsilon_i \geq -\gamma' z_i$ in order to derive the likelihood function.

Kumbhakar *et al* (1991) imposed distributional assumptions on v_i and u_i and ignored ε_i. They assumed that $u_i \sim N^+(\gamma' z_i, \sigma_u^2)$ i.e., the one-sided technical inefficiency error component has truncated normal structure with variable mode depending on z_i. It is still not necessary that $\gamma' z_i \geq 0$. If $z_{1i} = 1$ and $\gamma_2 = \gamma_3 = \cdots\cdots \gamma_Q = 0,$ this model collapses to Stevenson's (1980) truncated normal stochastic frontier model with constant mode γ_1, which further collapses to the Aigner, Lovell and Schmidt (1977) half normal stochastic frontier model with zero mode if $\gamma_1 = 0.$ Each of these restrictions are statistically tested. Finally if u_i and v_i are independently distributed, all parameters of equation (3.1.1) can be estimated by using maximum likelihood estimation method. The log likelihood function is a simple generalization of that of Stevenson's (1980) truncated normal model having constant mode μ, with only one change. Constant mode μ is now replaced by the variable mode $\mu_i = \gamma' z_i$, so that the log likelihood function is

$$\ln L = constant - \frac{N}{2}\ln(\sigma_v^2+\sigma_u^2) - \sum_{i=1}^{N}\ln\Phi\left(\frac{\gamma' z_i}{\sigma_u}\right) + \sum_{i=1}^{N}\ln\Phi\left(\frac{\mu_i^*}{\sigma^*}\right) - \frac{1}{2}\sum_{i=1}^{N}\left(\frac{(e_i+\gamma' z_i)^2}{\sigma_u^2+\sigma_v^2}\right)$$

-------------- (3.1.4)

where $\mu_i^* = \frac{\sigma_v^2\,\gamma' z_i - \sigma_u^2\, e_i}{\sigma_v^2+\sigma_u^2}$, $\sigma^{*2} = \frac{\sigma_v^2\,\sigma_u^2}{\sigma_v^2+\sigma_u^2}$

and $e_i = \ln y_i - \ln f(x_i;\beta)$ are the residuals obtained from estimating equation (3.1.1) simply by OLS. The log likelihood function of (3.1.2) can be maximized to obtain ML estimates of $(\beta,\,\gamma,\,\sigma_v^2,\,\sigma_u^2)$. These estimates can then be used to obtain producer specific estimates of technical efficiency, employing the Jondrow, Lovell, Materov and Schmidt (1982) approach to find the best point estimates of technical efficiency. These estimates are either

$$E(u_i/e_i) = \mu_i^* + \sigma^*\frac{\phi(\mu_i^*/\sigma^*)}{\Phi(\mu_i^*/\sigma^*)} \tag{3.1.5}$$

Or

$$M(u_i/e_i) = \begin{cases}\mu_i^* & if\ \mu_i^* \geq 0\\ 0 & otherwise.\end{cases} \tag{3.1.6}$$

Once technical efficiency has been estimated, the effect of each exogenous or environmental variable on technical efficiency can be calculated from either $[\partial E(u_i/e_i)/\partial z_{ik}]\ or\ [\partial M(u_i/e_i)/\partial z_{ik}]$. Battese and Coelli (1995) model is an improvement over the Kumbhakar *et al* (1991) model as, (i) it is based on panel data and (ii) the non-negativity requirement $u_i = (\gamma' z_i + \varepsilon_i) \geq 0$ is modeled as $\varepsilon_i \sim N(0,\sigma_\varepsilon^2)$ with the distribution of ε_i bounded below by the variable truncation point $-\gamma' z_i$. Battese and Coelli (1995) verified that this new distributional assumption on ε_i is consistent with the assumption on u_i that $u_i \sim N^+(\gamma' z_i,\sigma_u^2)$. We assume a Cobb-Douglas production function with 3 inputs to specify the underlying technology. All the three inputs are mentioned below.

$$\ln(Y_i) = \ln\beta_0 + \beta_1\ln L_i + \beta_2\ln B_i + \beta_3\ln N_i + (v_i - u_i) \tag{3.1.7}$$

Here (3.1.7) is the Cobb-Douglas technological specification assuming three inputs – labour (L), boat (B) and net (N). Exact description of all relevant variables used in the study is imperative. The list of variables with their units of measurement for the Cobb-Douglas production frontier model (3.1.7) is listed in (3.2.1) section. The list of variables with their units of measurement for the inefficiency effects model is outlined below.

Further $\gamma' z_i = \gamma_1 + \gamma_2\, z_{2i} + \gamma_3\, z_{3i} + \gamma_4\, z_{4i}$ (3.1.8)

where, the z_i's are firm specific non-input variables which may influence the technical efficiency of fishermen. Specifically, z_{2i} is the experience (EXP) of the fishing team members as measured by the average number of years spent by the catchers in fishing; z_{3i} is education (EDU) of the catchers as measured by the average number of years of formal schooling and z_{4i} captures non-fishing income (NFI) at the fishing team level from agriculture and allied activities during slack season.

Testing the null hypothesis no technical inefficiency is important. The null hypothesis of no technical inefficiency can be tested by applying the Likelihood Ratio Test. The likelihood ratio test is based on the likelihood ratio statistic (LR) defined as,

$$LR = -2\ln[L(H_0)/L(H_1)] \tag{3.1.9}$$

Where, $L(H_0)$ and $L(H_1)$ are the optimum values of the likelihood function under the null hypothesis (no technical inefficiency or OLS) and alternative hypothesis (presence of technical inefficiency under the Aigner *et al.* 1977, Normal– half-Normal error specification) respectively. But since the hypothesized value of λ (which equals σ_u / σ_v) lies on the boundary of the parameter space it is difficult to interpret the test statistic. It can be shown that the *LR* statistic in (3.1.9) follows a mixed χ^2 distribution that asymptotically approaches χ^2 distribution with degrees of freedom equal to the number of restrictions imposed in the model (Coelli, 1995). Similar is the test of the hypothesis that inefficiency effects are totally absent in the model. To test that null hypothesis of no inefficiency in the data, which is equivalent to setting $\lambda = 0$ the Kodd and Palm (1986) critical values for relevant degrees of freedom are used. All estimations are done using the software package *FRONTIER 4.1* for WINDOWS (Coelli, 1996).

3.2 Variable Construction and Measurement

In the present study output (Y_i) is basically rupee value or money value of catch at the fishing team level (converted to monthly figures, i.e. Rs per month) recorded at the time of sale. The three inputs labour, boat and net are all measured physically. This is not a technical or statistical problem as the same method is applied across all fishing teams in the sample. Labour (L), a flow input, is measured in terms of labour hours per month for the i^{th} team. For instance members of a team comprising of 2 members may each spend 5 hours daily on fish catch implying that for this team daily labour hours spent is 10. If this team engages in fishing 5 days per week then weekly labour hours spent by this team equal 50 or in other words monthly labour hours equal approximately 200.

Fishing tools and equipments play the role of fixed capital or durable capital equipments. These are stock variables or stock inputs in contrast with labour which is a flow input. Boat size (B) in terms of length of the boat (in meters) is taken as a proxy physical measure of boat strength or boat capacity. Arguably in open access fishing net is a heterogeneous input like boat as because net density or gapping may vary across catchers. For the fishing teams of Sone Beel included in the present sample, the nets are almost of identical density or gapping and do not differ much across teams. Thus length of net (N) in meters is taken as a proxy measure of net capacity for each team. In sum, the production function for the present study models monthly output in value terms (value of catch per month) as the outcome of catch effort due to labour (L), boat (B) and net (N). Effort Index is not constructed. Depreciation of fixed inputs like tools and equipments (i.e., boat and net) is ignored.

3.3 Survey Methods and Data

Data for the present study is completely primary in nature and is based on information collected between July and September 2013, from Sone Beel fishing boat-landing sites. Fishing in the Sone Beel is officially managed by the Sone Beel Fishermen Cooperative Society (established in 1975). A new set up for the management of market transactions related to fish catch that includes auctioning and bidding (called *Machher Arath*, i.e., the whole sale trading and transactions place) was formed in July 2012. Under this newly formed institution, fish catchers and sellers sell their daily catch indirectly through a formal bidding system. The number of fish auctions observed in the landing sites are 3 to 4 and this number fluctuates depending on the season. However, only 2 – 3 auctions are found to be active and functional on a regular basis. It was further observed that this system of fish bidding helps fishermen to get better prices for their daily catch. However, catchers are charged with five percent of the value of their daily catch as fee on account of participation in the organized bidding under the *Machher Arath*.

The necessary information was collected from selected single boat using fishermen from the Sone Beel fish-landing sites employing the direct interview method. A well structured pretested survey schedule was used that focused specifically on sale and quantity of catch, labour hours spent, fishing equipments, socio-economic features etc. The face-to-face interviews were conducted in collaboration with four literate volunteers (selected to carry out field survey) from the fishing community. Two enumerators having satisfactory working experience in the field (graduates) helped the volunteers along with the local members (involving with Sone Beel Fishermen Cooperative Society) in the survey work. These volunteers have had regular contacts with fishing households dwelling around the Sone Beel. Around 50 to 60 fishing teams with their boat usually land in the fish-landing sites between 6 – 7 AM during the peak fishing season. The crew members engaged in selling and grading of fish in the auctions, varies from two to four persons. In view of the unorganized nature of the transactions activity, data collection was challenging, especially when fishermen were uninterested in facing the interview. Lack of willingness to cooperate was perhaps due to the excessive workload and physical stress and strain associated with catch and sale of fish during the peak working hours during (6 – 8 AM). Expectedly, the fishermen are extremely busy over their respective transactions during peak hours and are hardly in a position to face interviews. Time and place had to be suitably chosen so as to undertake an uninterrupted interview with the single boat using fishing team members. Strictly speaking, under such circumstances, random sampling (and even systematic sampling) is difficult if not impossible.

As per secondary data collected from Sone Beel Fisherman's Cooperative Society office, the total number of registered fishermen under the society is 4934. These people belong to traditional fishing community.

Three distinct types of fishing teams are commonly observed in the Sone Beel – (i) paired boat with 6 to 8 catchers, (ii) Single boat with 2 to 3 catcher (net users). The present study focuses on technical efficiency measurement of this two varieties of fishing teams.

No official statistical records on the number of fishing boats currently engaged in fishing in the Sone Beel are available. According to a' priory information (based on unofficial sources), there could be total of number of 50-60 paired boat fishing teams (each team comprising of 6 to 8 catchers), out of which approximately 20 are found to operate on a daily basis. The total number of single boat using teams with 2 to 3 catchers could be around 400, out of which 149 are selected for the present study. The total number of catchers using single boats may go up to 500. Out of these, there are some who use some traditional inputs as fish traps like cylindrical drum traps, vertical slit traps (locally known as *dori* and *kathi*). The non-net using catchers are excluded from the present study. Thus in a nutshell the types of catchers along with the subsample sizes in the present study are as follows: (i) single boat using team catchers with 2 to 3 members (149), (ii) paired boat using team catchers with 6 to 8 members (16). Thus total sample size of teams in the present study is 149 + 16, i.e. a total of 165 teams.

Because of the flow nature of the population in the boat landing sites, strictly random sampling could not be conducted. For the present study a convenient large sample of 149 single boat using fishing teams comprising of 2 to 3 members is chosen. The sample size is quite large relative to the size of the population (i.e., 149 out of 400, which is around 37 percent) and thus small sample bias may be ruled out. The sample size was fixed using the following formula when population size is not exactly known. $n = Z^2 . s^2/d^2$ where n is the minimum sample size to be chosen, Z is the value of the standard normal distribution function at 0.05 level, s is the population standard deviation of the variable, and d is acceptable standard error of the mean of the variable of interest – value of fish catch in this case. Since exact size of the population is not known, s is fixed through a pilot survey. Specifically, $s = \acute{s} . \sqrt{\acute{n}/(\acute{n}-1)}$ where n' is the sample size for the pilot survey, and s' is the standard deviation of value of catch computed from the pilot survey. Clearly the smaller is d the larger is the minimum sample size needed for statistically robust estimation and inference.

Labour effort is heterogeneous across fishing teams as because 87 fishing teams in the sample (out of 149 fishing teams), have 3 catchers while the rest, i.e., 62 fishing teams have 2 catchers per team. In other words there are 87 times 3 plus 62 times 2, or a total of 385 catchers in the sample of 149 single boat fishing teams. For paired boats teams in the sample (out of 16 fishing teams), 9 fishing teams have 6 catchers while the rest, i.e., 7 fishing teams have 8 catchers per team. In other words there are 9 times 6 plus 7 times 8, or a total of 110 catchers in paired boat teams. The skippers were interviewed for necessary information on key production function related variables such as value of catch, labour hours spent, and fishing tools and equipments like nets and boat. Moreover data on certain non-input factors as, experience in fishing, years of formal schooling and income from sources other than fishing were collected through the personal interview. Interview was not possible during the fish auction hours due to large and spontaneous gathering and outcry. The surveyors had to tailor interview time and place according to the convenience of the catchers. The availability of the fishermen during busy working hours was the other key concern.

In short the interviews were conducted just after sales of fishes when the catchers were relatively free and away from crowded gatherings. Interviewing became a lot easier when participants could relax and feel comfortable. Interviews were carried out in usual places of gathering and hang-outs such as tea stalls adjacent to the transaction sites. The respondent of each team was mainly the skipper or boat owner who provided precise information regarding fishing practices of his team. Open ended discussions centered around vessel use, fishing duration, quantity of daily catch, types of fish, income, and even on their respective household conditions. Discussions also focused on overall constraints faced by fishers. The sample is non-random in nature.

4. Empirical Results and Analysis

The summary statistics of all variables used for the production frontier estimation along with the inefficiency effects variables are presented in Table 1. From the figures in Table 1 it is evident that there is substantial variation in the outputs and inputs across catchers. Value of fish caught ranges between Rs. 5000 and Rs 130000 per team per month. Labour hours also very significantly across fishing teams. Length of net could be a distinguishing factor in determining size of catch as because variability of net size is very high across teams. Age, education and experience exhibit smaller variability across fishing teams.

Although variation in boat size is small, it could be a significant factor in determining catch effort. Finally non fishing income is an important indicator of dependence on fishing. Higher levels of non fishing income may be indicative of a shift from fishing to other occupations. Usually fish catch using traditional method is physically involving and physical fitness of each catcher is vital from the view point of efficient functioning of the team. The average age of catchers is below 34 years which is perhaps appropriate at the team level. Although experience ranges between 1 and 33 years, mean years of experience is below 7 years. It is possible that this is just sufficient for productive fish catch as catchers are acquainted to the system since childhood.

Table 1. Summary Statistics of all Variables

Variables	Min.	Max.	Mean	S.D.	C.V.
Value of fish caught (Rs./month)	5000	130000	33981.82	24382.24	0.72
Labour (man-hours/month)	100	1200	370.7121	218.51	0.59
Net (meter)	30.48	548.64	198.91	112.67	0.57
Boat Size (meter)	3.66	9.75	5.50	1.44	0.26
Age of catchers (year)	25	61	33.71	6.27	0.18
Experience (year)	1	33	6.17	5.22	0.78
Education (year)	0	8	4.83	1.99	0.41
Non Fishing Income (Rs/month)	1000	6000	3193	863.34	0.27

Source: Author's estimates based on primary data.

The types of fish commonly found and caught by fishermen in the Sone Beel in recent times are, tengra (*Batasio batasio*), punthi (*Puntius chola*), bele (*Glossogobius giuris*), koi (*Anabas testudineus*), shol (*Channa striata*), shingi/magur (*Gagata youssoufi*), rohu (*Labeo rohita*), katla (*Catla catla*), boal (*Wallago attu*), and aar (*Sperata aor*).

Most of the fishes enlisted above fall under small species. These are usually caught by using gill nets and some other traditional non-net fishing equipments in form of fish traps like cylindrical drum traps, vertical slit traps (locally known as *dori* and *kathi*) popularly used in northeastern India (including Bangladesh, and northern Myanmar region). The bigger sized fish like (*rohu, katla, boal, aar* etc) are caught by using seine net or drag net primarily by the paired boat teams.

The ordinary least squares estimates of the Cobb-Douglas model are first presented along with heteroscedasticity test of OLS residuals. Table 2 presents the ordinary least square (OLS) estimates of Cobb-Douglas production function for the sample of 165 single and pair boat teams. As seen from the *t* values, all the coefficients including the intercept are statistically significant. The R^2 value is almost 77 percent which means 77 percent of the total variation in logged value of catch can be accounted for by the logged values of three inputs labour (L) boat (B) and net (N). The overall regression is clearly significant as the F value is substantially large.

Table 2. OLS Estimates of Cobb-Douglas Production Function (N=165)

Dependent Variable: *ln* (Y)

Variable	Coefficient	Std. Error	t-Stat.	Prob.
C	3.91	0.34	11.65	0.0000
ln L	0.56	0.13	4.32	0.0000
ln B	0.68	0.24	2.83	0.0052
ln N	0.38	0.07	5.46	0.0000
R-squared	0.774	Mean dependent var		10.19
Adjusted R-squared	0.770	S.D. dependent var		0.73
S.E. of regression	0.35	Akaike info criterion		0.75
Sum squared residuals	19.48	Schwarz criterion		0.82
Log likelihood	-57.84	Hannan-Quinn criter.		0.78
F-statistic	184.42	Durbin-Watson stat		1.35

Source: Author's estimates based on primary data using EVIEWS 8.

Notes: 1. Y is rupee value of fish catch per month at the fishing team level.

2. *ln* denotes natural logarithm.

Moreover White's heteroscedasticity test confirms that the null hypothesis of homoscedasticity is accepted at 16 percent (table 3) which is desirable.

Table 3. White's Heteroskedasticity Test

Null Hypothesis: OLS Residuals are Homoscedastic

F-statistic	1.48	Prob. F(13,135)	0.1615
Obs*R-squared	13.02	Prob. Chi-Square(13)	0.1617
Scaled explained SS	12.48	Prob. Chi-Square(13)	0.1877

Source: Author's estimates based on primary data using EVIEWS 8.

Table 4 presents the maximum likelihood estimates of the Cobb-Douglas production frontier model assuming the Aigner *et al* (1977) Normal-half normal error structure.

Table 4. Cobb-Douglas Stochastic Production Frontier Estimates under Normal – Half-normal Error Structure (ALS, 1977)

	OLS		MLE	
Variables	**Coefficient**	**t-ratio**	**Coefficient**	**t-ratio**
Constant	3.909 (0.34)	11.66**	4.83 (0.32)	14.87**
ln Labour	0.554 (0.13)	4.30**	0.524 (0.10)	4.98**
ln Boat	0.684 (0.24)	2.86*	0.603 (0.19)	3.02**
ln Net	0.378 (0.07)	5.47**	0.34 (0.06)	5.57**
Variance Parameters				
$\sigma^2 = \sigma_v^2 + \sigma_u^2$			0.29 (4.45)	6.60**
σ_v^2			0.02	
σ_u^2			0.27	
$\gamma = \sigma_u^2 / (\sigma_u^2 + \sigma_v^2)$ (Battese and Corra, 1977)			0.93 (0.03)	27.69**
Log Likelihood Value	-57.807 (OLS)		-49.878 (MLE)	
LR Test of the One-Sided Error (H_0: $\gamma = 0$)			15.856	

Source: Author's estimates based on primary data using *FRONTIER 4.1* for Windows.

Notes: **1**. Test for $\gamma = 0$ follows mixed chi-square distribution with critical value found in table 1 of Kodde and Palm (1986) is 2.706 for 1 degree of freedom. **2**. (*) and (**) indicate that coefficients are statistically significant at the 0.05 and 0.01 levels respectively. **3**. Standard errors are given in parentheses. 4. *ln* is natural logarithm.

Most of the coefficients are highly significant and very similar to the OLS estimates of table 3. But more importantly variance parameters of the stochastic frontier model $\sigma^2 = \sigma_v^2 + \sigma_u^2$ and $\gamma = \sigma_u^2 / (\sigma_u^2 + \sigma_v^2)$ are statistically significant [Battese and Corra (1977) parameterization]. The likelihood ratio test for the absence of the one sided error (which is tantamount to an OLS regression model, assuming γ=0) reveals that computed *LR* statistic of 15.856 far exceeds the Kodde and Palm (1986) critical value for 1 degree of freedom (tabulated value being 2.706). The estimated value of γ is 0.93 and is statistically different from zero at 1 percent level of significance. This suggests that ordinary least squares or the average production function is an inappropriate statistical specification for describing the underlying relationship between inputs and output in case of single boat using fishing teams operating in the Sone Beel of Assam. Furthermore, this suggests that about 93 percent of variation in value of catch is as a result of technical inefficiency rather than due to random factors beyond the control of catchers.

Table 5. Cobb-Douglas Stochastic Production Frontier : Normal half-Normal and Normal - Truncated Normal Error Models Compared

Variables	Normal half-Normal Coefficient	Normal half-Normal t-ratio	Truncated Normal Coefficient	Truncated Normal t-ratio
Constant	4.83 (0.32)	14.87**	4.81 (0.32)	14.98**
ln Labour	0.524 (0.10)	4.98**	0.52 (0.10)	5.13**
ln Boat	0.603 (0.19)	3.02**	0.59 (0.19)	3.02**
ln Net	0.340 (0.06)	5.57**	0.34 (0.06)	5.76**
Error Distribution Parameters				
μ (Stevenson,1980)	NA	NA	-0.13 (0.47)	25.79**
$\sigma^2=\sigma_v^2+\sigma_u^2$	0.29 (4.45)	6.60**	0.33 (0.17)	2.04*
σ_v^2			0.02	
σ_u^2			0.33	
$\gamma=\sigma_u^2/(\sigma_u^2+\sigma_v^2)$	0.93 (3.37)	27.69**	0.93 (0.03)	25.79**
Log Likelihood Value	-49.878		-49.826	
LR statistic for absence of one-sided error (*df*)	15.856 (*df*, χ^2=1,095=2.706)		15.96 (*df*, χ^2=2,095=5.138)	

Source: Author's estimates based on primary data using *FRONTIER 4.1* for Windows.
Notes: 1. Test for gamma=0 follows mixed chi-square distribution with critical value found in table 1 of Kodde and Palm [1986]. 2. * and ** indicate statistical significance at the 0.05 and 0.01 level respectively.
3. NA, not applicable. 4. Standard errors are in parentheses.5. 'ln' is natural logarithm. 5. μ represents constant mode of the Stevenson (1980) truncated normal error.

Table 5 presents the maximum likelihood estimates of the Cobb-Douglas stochastic production frontier with normal – truncated normal error structure. The normal – half normal model results are also presented in the same table for quick comparison. μ, the constant mode of the truncated normal error distribution is negative but statistically insignificant thereby suggesting that the Aigner *et al* (1977) normal – half normal error specification is statistically more appropriate. Other estimates are hardly any different.

Table 6. Cobb-Douglas Stochastic Production Frontier with Inefficiency Effects

Variables		MLE Coefficient	MLE t-ratio
Constant		4.765 (0.32)	14.75**
ln Labour		0.563 (0.10)	5.39**
ln Boat		0.670 (0.20)	3.33**
ln Net		0.288 (0.06)	4.71**
Technical Inefficiency coefficients			
Constant		-2.95 (2.21)	-1.33
Experience		-0.005 (1.42)	-0.39
Education		0.09 (0.043)	2.08*
Non Fishing Income		0.33 (0.26)	1.26
Error variance parameters			
$\sigma^2=\sigma_v^2+\sigma_u^2$		0.24 (0.091)	2.66**
σ_v^2		0.02	
σ_u^2		0.22	
$\gamma=\sigma_u^2/(\sigma_u^2+\sigma_v^2)$ (Battese and Corra, 1977)		0.924 (0.041)	22.67**
Log Likelihood Value	-57.807 (OLS)	-44.266 (MLE)	
LR Test of the One-Sided Error [Kodd-Palm (1986) $\chi^2_{0.05,5}$ = 10.371]	27.081		

Source: Author's estimates based on primary data using *FRONTIER 4.1* for Windows.
Notes: 1. Test for gamma=0 follows mixed chi-square distribution with critical value found in table 1 of Kodde and Palm [1986]. 2. * and **indicate statistically significant at the 0.05 and 0.01 level respectively. 3. Standard errors are in parentheses. 4. *ln* is natural logarithm.

Table 6 presents the maximum likelihood estimates of the Battese and Coelli (1995) technical inefficiency effects model. The production function parameters are all positive and significant which is economically meaningful and desirable. The estimates of the production function parameters are found to vary only slightly across frontier and OLS models. The coefficients of the technical inefficiency variables are of profound economic importance in the present context. The constant γ_1 (equivalent to δ_0 as per Battese and Coelli, 1995 specification) is negative but statistically insignificant. The coefficient of experience is negative implying that higher the number of years of experience in fishing, lower is the technical inefficiency, or, higher is the level of technical efficiency. However the *t*-value is insignificant at 5 percent level. The coefficient of education on the other hand is positive and statistically significant at 5 percent implying that higher the number of years of formal education of the catcher the lower the level of the technical efficiency. This is expected as because, higher is the educational attainments, lower would be the attention or focus on traditional (or ancestral) occupation, i.e. fishing, and hence greater would be the focus on non-fishing earning avenues. Formal education can hardly raise traditional fishing skills. On the contrary it is likely to reduce the levels of fishing skills. Spending more years in school also implies lesser exposure to traditional occupation during childhood years, hence resulting in lower fishing skills. Furthermore, higher the number of years of schooling lower is the catch experience (correlation coefficient between education and experience in table 2 is -0.40 which is statistically significant) for the present sample of fishermen which is anticipated. Thus formal education may adversely affect fishing skills through lower experience as well as shift of focus to non-fishing earning avenues. Incidentally, around 31 percent catchers in the present sample have non-fishing occupations during the slack season. The rest are either unemployed or rely on very scanty fish catch during winter months when the water body goes dry.

The coefficient of experience is negative thereby implying that higher the experience in fish catch higher is the technical efficiency which is expected and economically desirable. However non-fishing income or income from sources other than fishing has a dampening impact on technical efficiency. In other words, as non-fishing income of the team members rises, the technical efficiency of the team falls. As attention is diverted to other sources of income beyond fishing (say agricultural labour, non-agricultural day labour, petty businesses, among few others), fishing is no longer reckoned as primary occupation. So, dependence on fishing for livelihood falls, and arguably catch efficiency falls as catchers take fishing less seriously with growing non-fishing income. Expressed otherwise, dedicated fishermen who have little or no non-fishing income are technically more efficient.

Generalized likelihood-ratio tests of various null hypotheses involving restrictions on parameters of the composed error distribution as well as that of the production function are presented in table 8. The first null hypothesis is formally expressed as $\gamma = \gamma_1 = \gamma_2 = \gamma_3 = \gamma_4 = 0.$ This implies that there is no technical inefficiency among the fishing teams and naturally no inefficiency effects. Here γ captures the proportion of error variance due to the inefficiency random variable u_i out of total variance $(\sigma_u^2 + \sigma_v^2)$. If the inefficiency random variable u_i is absent, σ_u^2 and γ are both reduced to zero, the only error is the white random noise and thus the model is simply an OLS. Thus under the above restriction the frontier model reduces to ordinary least squares. As seen in table 8, the computed LR statistic far exceeds the Kodd and Palm (1986) critical values implying that both the first and the second null hypotheses are rejected at 5 percent level.

Table 7. Likelihood Ratio Tests of Restrictions on Production Frontier Parameters

Null hypothesis	Log Likelihood function under H₀	Log Likelihood function under H₁	Likelihood Ratio Statistic (λ)	df	5% Critical value (χ^2)	Decision
1. $\gamma = \gamma_1 = \gamma_2 = \gamma_3 = \gamma_4 = 0$ (No inefficiency, no Inefficiency Effects)	-57.807 (OLS or symmetric error)	-44.266 (Inefficiency Effects)	27.082	5	10.371	Rejected
2. $\gamma = 0$ (One sided inefficiency random error is absent or OLS)	-57.807 (OLS)	-49.878 Normal/Half-Normal Error	15.858	1	2.706	Rejected
3. $\mu = 0$ (Normal –Half Normal)	-49.878 (Normal –Half Normal Error)	-49.826 Normal-Truncated Normal Error	0.104	1	3.84	Accepted
4. $\gamma_1 = \gamma_2 = \gamma_3 = \gamma_4 = 0$ (Normal-Half Normal Error)	-49.878 (Normal/Half-Normal Error)	-44.266 (Inefficiency Effects)	11.224	4	9.49	Rejected
5. $\gamma_2 = \gamma_3 = \gamma_4 = 0$ (Truncated Normal)	-49.826 Normal-Truncated Normal Error	-44.266 (Inefficiency Effects)	11.12	3	7.81	Rejected
6. $\beta_1 + \beta_2 + \beta_3 = 1$ (CRS technology)	-56.252 Under restriction $\beta_1 = 1 - \beta_2 - \beta_3$	-49.878 No Restrictions $\beta_1 + \beta_2 + \beta_3 \neq 1$	12.748	1	3.84	Rejected

Source: Author's estimates based on primary data using *FRONTIER 4.1* for Windows.
Notes*:* 1.The critical values for the first and second null hypotheses are obtained from Table 1 of Kodde and Palm (1986*)*. 2. *df* implies (degrees of freedom).

Thus OLS (which estimates the average production function) would be statistically inappropriate to specify the stochastic functional relationship between inputs and output. Acceptance of the frontier model also implies that technical inefficiency exits among the fishing teams. The third null hypothesis tests whether the one-sided inefficiency random error follows normal – half normal distribution (Aigner *et al.* 1977) as against the alternative of normal – truncated normal distribution with constant mode μ (μ is same as the constant $r_1$used here or δ_0 of the Battese and Corra, 1977 parameterization). As the LR statistic falls short of the critical chi-square value the null hypothesis of normal-half normal error structure is accepted. The fourth null hypothesis tests for the presence of normal-half normal error structure against the alternative of the full Battese and Coelli (1995) inefficiency effects in the one sided errors. The computed LR statistic just exceeds the critical 5 percent value implying that the null hypothesis of Aigner *et al.*(1977) error structure is rejected and the alternative of the Battese and Coelli (1995) inefficiency effects is accepted. In other words experience, education and non-fishing income jointly influences technical efficiency of the fishing team. The fifth null hypothesis is nested in the fourth and asserts that experience, education and non-fishing income jointly does not influences technical efficiency of the fishing team (the constant γ_1 is just left out). In fact this is equivalent to testing the null hypothesis of normal – truncated normal error against the alternative of Battese and Coelli (1995) inefficiency effects. The fifth null hypothesis is rejected at 5 percent implying that normal – truncated normal error is rejected and the inefficiency effects (i.e., experience, education and non-fishing income jointly influences technical efficiency) is accepted.

Finally the sixth null hypothesis tests for the presence of constant returns to scale technology against the alternative of increasing returns to scale (in view of the fact that the sum of the partial input elasticities adds up to 1.52) under the framework of Cobb-Douglas stochastic production frontier with inefficiency effects. The sixth null hypothesis is rejected thereby meaning that the underlying technological relationship between inputs and output exhibits increasing returns to scale (IRS). The microeconomic interpretation of returns to scale in the present context needs to be done with caution. Fixed input like the boat is on the one hand indivisible and is surely impractical to multiply (say double) on the other. One can however imagine a certain percentage increase in boat size. Again, given the boat size and number of catchers, there exists an optimum net size (length) which is most suited for catchers. Other things unchanged, a rise in net size would create difficulties in catch and would lead to lower team level efficiency. Thus a practical interpretation of the IRS finding could be that, 'if boat size, man hours and net length are increased by a certain φ percent, the catch would rise by more than φ percent'. However the practical relevance or field level relevance of the IRS finding may still seem doubtful. In sum, the most significant finding seems to be that the inefficiency effects model best suits the data and the inefficiency effects variables such as experience, education and non-fishing income influence technical efficiency both jointly as well as individually.

Table 8. Distribution of Technical Efficiency of all Teams (N = 165)

TE(%) intervals	Frequency	Distribution (%)
20-30	02	1.21
30-40	10	6.06
40-50	21	12.73
50-60	22	13.33
60-70	18	10.91
70-80	36	21.82
80-90	43	26.06
90-100	13	7.88
Total	165	**100**
Mean TE	68.18	
Max. TE	96	
Min. TE	23	
S.D.	17.69	

Source: Author's estimates based on primary data using *FRONTIER 4.1* for Windows.

The frequency distributions of technical efficiency scores are also presented in Table 8. The result indicates that the overall level of efficiency ranges from 23 to 96 percent with a sample mean technical efficiency of 68.18 percent. About 33.94 percent of fishermen are operating at 80percent or more technical efficiency levels. Also about 33.33 percent of the fishing teams are operating at technical efficiency level of 60 percent or less. Furthermore, about 66.67 percent of fishing teams across all methods are operating at a technical efficiency level of 70 percent or more. This suggest a relatively high technical efficiency level existing in the fishing teams across all methods, pointing to a frightening level of exploitation and a wide range of efficiency level existing in the fishing teams.

4.1 Sustainability Issues

Coming to the specific issues related to sustainability, several problem areas were identified during the survey. First, boats used by catchers are not registered with the Fisherman's Co-operative Society. There is no boat identification number assigned. In other words there is no formal mechanism in place to keep track of the exact population of boats. Since there is no control on fishing during the monsoon months, the exact number of boat on the water cannot be enumerated. Assignment of a boat identification number or a registration number is the key to control over fish catch. Obviously there is no log book or log sheet to formally record who exactly are fishing at any point of time. The suggestion is that the society must maintain a record of the total population of boats operating on the one hand and number of boats in operation during a 24 hour period on the other. The state fishery department must ration the labour time (say 4 days a week) spent by each fishing team so that even during the peak season anyone and everyone is not allowed free access.

Second, there is a government regulation in place regarding the exact gapping of the nets to be using in fishing but it is almost always violated. In other words there is no check or control over the type of nets used. It is the indiscriminate use of the dense net that is responsible for loss of non-fish species – especially small species in the Sone Beel. Thus there has to be regular surveillance by some government appointed dedicated and trained team to keep a check on the use of unapproved nets. The catchers are tempted to use unapproved nets in an attempt to harvest more using the same labour time. But in doing so they disturb the overall ecological balance of the water body which ultimately affect the fish population adversely.

Third, because of the open access nature of fishing any boat can travel to any corner of the Beel and there is no demarcated or well defined area or enclosure for fish breeding. This is a biologically crucial aspect as because fish population can be restored or even grown by demarcating an area within the Sone Beel for fish breeding. Since there is no dedicated breeding ground at present stock depletion is most likely if there is over fishing. Fishing boats should not be allowed to enter the breeding area. Protecting the breeding area could be the most significant step in restoring fish stock. This in turn would raise the catch levels and hence revenue earned without raising labour time.

5. Summary and Conclusions

5.1 Summary of the Study

This paper has measured technical efficiency of fish catch among traditional fishermen living in the neighbourhood of the Sone Beel, in Karimganj district of southern part of Assam. The Sone Beel is the largest wet land and catchment area of the region. Two methods of fish catch are most commonly observed in the Sone Beel – fishing teams with single boats having two or three catchers and paired boats having six to eight catchers. The latter are fewer in numbers. A stochastic production frontier with inefficiency effects is estimated on the basis of cross-sectional primary data on fishing inputs as boat, net and labour and value of catch. A convenient large sample of 165 single and pair boat using fishing teams is chosen. The sample size was determined by means of an appropriate sample size determination formula (when the population size is unknown). A pilot survey was first conducted in the study area for this purpose. The sample size is almost 37 percent of the unofficially and informally known population. Likelihood ratio tests suggest that the Battese and Coelli (1995) inefficiency effects model appropriately describes the underlying relationship between inputs and output. The mean technical efficiency is around 68 percent. Experience in fishing is found to have a positive influence on technical efficiency while formal education and income from other sources have dampening influences on the same.

Now, two key areas of concern that emerge from the present study are, (i) socio-economic backwardness (that includes poverty for obvious reasons) of the catchers or fishermen, and (ii) declining fish population or fish stock in the water body even during peak seasons in recent years. For obvious reasons these two issues are related. Higher the level of socio-economic backwardness among the traditional fishing community, higher is the dependence on fishing for livelihood. With low levels of education, alternative occupation and employment opportunities are also low. Thus a majority of households are rather forced to remain in the traditional occupation which in this case is also the ancestral occupation. A relative small percentage of catchers are engaged in non-fishing activities during the slack season, which implies that the majority are either unemployed or are forced to depend on very scanty fish catch during winter months. This raises their socio-economic distress levels substantially. Naturally, higher the accumulation of catchers during a given time point, higher would be the catch levels (over fishing) finally resulting stock depletion and loss of aquatic species.

During the survey it was revealed that almost 94 percent of the respondents do not have access to a hygienic sanitary toilet. Moreover almost 96 percent of the respondents depend on dug wells for their drinking water needs. Some were even found to consume pond water. Alarmingly 81 percent of the catchers' households were found to have 4 to 5 children. None of the catchers were found to have crossed the secondary educational level. Paradoxically 99 percent of the respondents were found to be using mobile phones. Regarding overcrowding of fishermen, around 87 percent catchers felt that there are more catchers currently fishing in the Sone Beel than what it should have been. Around 69 percent felt that they had to take up fishing as their primary occupation not by choice but rather by compulsion. Most catchers are not confident about other occupations as they are mostly unskilled in any non-fishing work. Almost all respondents felt that uncontrolled fishing in the area during peak fishing seasons is the consequence of overdependence on fishing. The immediate goal for planners and policy makers of the district and region would be to create sufficient levels of non-fishing employment opportunities for fishing households so that no traditional fishing household is forced to take up fishing as the only livelihood. This would address the issue of overcrowding and overfishing in the Sone Beel thereby checking the loss of fish stock and aquatic species in the region.

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