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# Technical Efficiency of Fish Catch and Its Socio-Economic Determinants – A Study on Traditional Fishermen of Karimganj District of Assam

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**Abstract**
This paper has measured the technical efficiency of fish catch and its socio-economic determinants among traditional fishermen dwelling in the neighbourhood of the Shon Beel in Karimganj district of Assam, India. Empirical estimations are on the basis of primary data collected from a sample of fishermen during the peak fishing season of 2014. The study uses a log-linear stochastic production frontier with inefficiency effects where selected non-input socioeconomic variables are hypothized to explain variations in catch efficiency across fishing teams. The study finds that technical efficiency of fish catch at the fishing team level is influenced positively by experience and per –capita household expenditure. Non-fishing income, dependency ratio, and education are found to have a dampening effect on catch efficiency. The study opines that excessive fishing in the Sone Beel in recent years has necessitated greater catch effort to get the same quantity of catch. This is indicative of falling fish stock, premature catch, and consequently falling average size of catch irrespective of species.
**Keywords:** Fish catch, Technical Efficiency, Inefficiency Effects Model, Stochastic Production Frontier, Non-input Factors.
**JEL classification:** Q 22, C 21.

## 1. Introduction

For a long time, fishing has been regarded as one of the most important means of livelihood of thousands of households living in the neighborhood of the Sone Beel Haor in Karimganj district of Assam. The Sone Beel is the largest wet land and catchment area of the region. Numerous small rivers and canals in the region flow into the Sone Beel. The fisheries sector in Karimganj is almost entirely dominated by small scale, poor fishing households dwelling in the vicinity of the Sone Beel. In fact total fish catch in the Sone Beel can account for around 70 percent 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, pp. 27-28).

Most informed people in the region (that includes fishermen) have a perception that there has been over-crowding of catchers in the Sone Beel in recent years the due to the complete absence of entry restrictions during the peak fishing season. Moreover lack of modern skills, capital and knowhow prevents the fishing households to go beyond the traditional methods. With the scarce resources and growing fish demand, decision makers (policy makers and households) face the challenge of developing a sustainable small-scale fisheries sector, which can integrate socio-economic and environmental objectives in their planning decisions.

The key issues of concern as identified by the fishermen themselves include poor and inefficient fishing gears and vessels, lack of capital, poor fisheries management, limited access to larger markets (e.g. Silchar, Guwahati and Agartala) coupled with poor handling facilities, poor infrastructure and high post-harvest losses. Lack of alternative employment opportunities and rising number of fishing households have possibly been the main cause of over-crowding of catchers leading to over-exploitation of the resource and degradation of fish stock. Almost all fishing households around the Sone Beel continue to be trapped in poverty and this has been their status over generations. The key objective of planners and policy makers of the district and region is to create sufficient levels of non-fishing employment opportunities for fishing households so that no one is forced to take up fishing as the only livelihood. This would also address the problem of overcrowding in the Sone Beel.

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 (though they are different concepts) of fish catch with respect to catch-effort or labour time spent, along with the revenue earned from it and, (ii) the income from non-fishing occupation – say for example from agriculture and allied activities, or even from other petty businesses.

However the efficiency of fish catch may in turn depend on several factors that are not used as inputs by fishermen. In other words several non-input socio-economic factors may influence the efficiency of fish catch. These include health status (level of physical fitness and physical capability) of the fishermen, experience, knowledge and awareness, standards of living, indebtedness, understanding within the fishing team members and income sources other than fishing, e.g. agricultural or petty business income. Thus the present study also looks into how these non-input socio-economic variables influence the technical efficiency of fish catch.

A production frontier represents the minimum input bundles required to produce different levels of output. Not all producers are successful in producing the maximum output using given levels of inputs or are able to use the minimum levels of inputs to produce a target level of output for a given technology. Both are tantamount to production below the production frontier. In other words not all producers are technically efficient. The presence of inefficiency in the production process leads to four major consequences. First, it reduces the quantity of output for a given set of inputs. Second, some of the inputs will be either under-utilised or over-utilised. Third, it raises the cost of production. Finally, there will be a loss in profit. We classify efficiency into three categories, technical, allocative and scale. Technical efficiency refers to production of actual output relative to the frontier output for a given quantity of inputs. Allocative efficiency is related to producer's choice of optimal input combination. And finally, scale efficiency is a situation of choice of right quantity of output, where price and marginal cost of production are assumed to be equal.

The objectives of the study are summarized as follows.

1. To measure the technical efficiency of fish catch of traditional fishermen fishing in the Sone Beel.
2. To identify key non-input and socioeconomic factors that influences the technical efficiency of fish catch and to measure their marginal impacts.
3. To outline policy prescriptions aimed at raising technical efficiency of fish catch and improving overall quality of life of fishing households dependent on the Sone Beel.

## 2. Profile of the Study Area

The Sone Beel is the largest wet land of southern Assam. It is located in Karimganj district – one of the three districts of southern Assam. Southern Assam is also known as Barak valley as it is a flood plain generated by the river Barak due to its peculiar meandering nature.


**Figure 1**: District map of Assam (Source: www.mapsofindia.com)

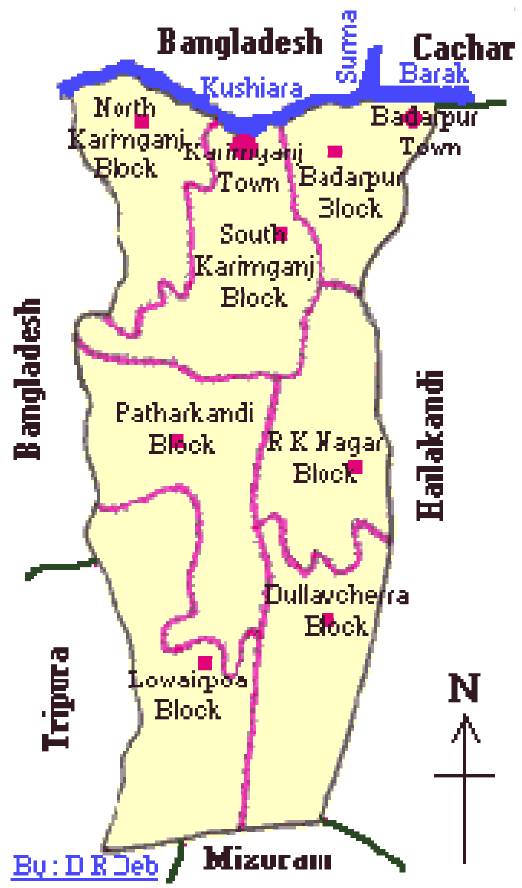


**Figure 2**: District map of Karimganj (Source: www.mapsofindia.com)

The study region is depicted in the above figures (maps). The geographical location of the district is between 92°15' - 92°35' east and 24°15' - 25°55' north. The district head quarter is 338 km away from the state capital Guwahati. As is evident from the map, Karimganj is a border district and shares international borders with Bangladesh both on the north and west. Kushiara, Longai, Singla, and Barak are the four major rivers of the district. As per the 2011 census the population of the district was 12, 17,000 with a literacy rate of almost 80 percent. Bengali is the major language of the district and the region and is officially recognized as the official language. The population density is 673 per square km. Sex ratio in the district is 961 females per 1000 males according to the latest census. Sone Beel is around 17 km away (south) from Karimganj town which is lies on the northern border of the district.

Sone Beel Fisherman's Co-operative Society Limited is perhaps the largest fishing society of Assam. Located in Karimganj District of southern Assam the society was established on February 14, 1975. It covers eight Gram Panchyats (GPs) namely, Anandapur, Gamaria, Nagendra Nagar, Bhairav Nagar, Nayatilla, Gandhi Nagar, Baruala, and Shaila Nagar. Among these, the three most important GPs from the point of view of fishing community concentration are Anandapur, Gamaria, and Nagendra Nagar.

At present the society consists of 4934 share holders who reside in the said region. All share holders belong to traditional fishing community. Fishing is the major or in many cases, the only source of income for the shareholders. In order to be a shareholder of this society a traditional fisherman residing in the region is required to register his name under this society. The society is structurally well constituted and has formally an elected President, a Vice President, a Secretary, and other officials. The executive members are authorized to run the society for a period of three years. In order to run the society a general body meeting is held every year. The society is entitled to issue permits to an individual for fish cultivation (planned culture) but these permits (fishing restrictions) are applicable only during the dry months of November to April each year. A person may be given fishing permits for the same area for a maximum period of five years at a single go. Since 2009-10 the maximum area limited for an individual permit holder is 4 bigha only. Annually the society pays a tax to the state government that amounts to nearly Rupees six lakhs every year.

The whole year is divided into two seasons – peak season and slack season. During peak season the wet land acts as a catchment area and hence water volume rises many folds. During peak season the fishermen are allowed free access to fishing and therefore are motivated to have maximum haul or catch as because no fishing permits are required during this period. During the peak season some major techniques of fish catch are applied. However during slack season the water body shrinks in size, fish stock is limited and the area under water is partitioned into a number of segments or sub-areas. There are almost 24 fishing areas which are located for fishing convenience. Free or open access fishing is not allowed during this period. These partitions or sub-areas vary in size from around 0.7 bigha to 4 bigha.

The principal techniques of fish catch in the Sone Beel are, (i) two or three catchers with a single boat, (ii) four to six catchers with two boats and (iii) eight to twelve catchers with motorized boats. The type of net varies across methods.

Quite a large number of studies on the nature, patterns and determinants of technical efficiency of fish catch among backward fishing communities in rural areas are reported in literature at the international level but similar studies at the national level are rare. A few influential works in the area of measurement of technical efficiency among backward fishing communities of developing countries in recent years are due to Sesabo and Tol (2008), Singh, Dey, Rabbani, Sudhakaran and Thapa (2009), Akanni (2008), Ekunwe and Emokaro (2009), Zen, Abdullah and Yew (2002), Squires, Grafton, Alam and Omar (2003), Rahman, Haque, Akhteruzzaman and Khan (2002) and Kompas, Che, and Grafton (2004) among many others.

## 3. Methodology and Data

### 3.1 Econometric Approach: The Stochastic Production Frontier

The present study uses the technical inefficiency effects model [originally due to Kumbhakar, Ghosh and McGuckin (1991)], and estimates the stochastic frontier and the inefficiency effects model parameters simultaneously, given appropriate distributional assumptions on the inefficiency random variable (Battese and Coelli, 1995). The simultaneous estimation of the stochastic production frontiers and models of technical inefficiency using maximum likelihood techniques have also been further developed by Reifschneider and Stevenson (1991), Huang and Liu (1994), and Battese and Coelli (1995). This approach has been applied empirically by Coelli and Battese (1996) and Battese and Broca (1997).

The present study follows a Kumbhakar *et al* (1991) approach to simultaneously measure the level of technical efficiency of the fishing team and to examine the impact of a few (selected) non-input factors on the level of technical inefficiency of fishermen dependent on the Shon Beel of Karimganj District on the basis of primary data. Exact description of all relevant variables used in the study is essential.

The variables along with their units of measurement for estimation of the trans-log production frontier model are as follows. Since the catch is heterogeneous inside the team and obviously across teams output (Y) is measured in terms of rupee value of fish caught per week by the fishing team. Labour input is measured in terms of total number of man-days spent per week by the fishing team. Length of the fishing vessel and length of net in metres capture the capacity of the fishing gears used by the team. Depreciation is ignored. The dimension index calculation methodology for computing the UNDP HDI is applied to labour, boat and net to find the team level labour index, boat index and the net index. Simple mean of these three indexes is taken as the catch effort index E in the present study. E rises in value if at least one component rises other things remaining the same.

The non-input variables that influence fish catch efficiency are listed along with their units of measurement, (i) **education** measured by the average years of schooling of the team, (ii) average age of team members (proxy for **experience**), (iii) **physical standards of living** as captured by the sum of average per capita plinth area index and monthly per capita expenditure index (both calculated as per the UNDP dimension index formula), (iv) **existing loans**, and (v) **non-fishing income** of all team members taken together. The following econometric model is used to fulfill the desired objectives.

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

$$\ln y_i = \ln f(x;\beta) + v_i - u_i \qquad (1.1)$$

$$u_i = \gamma' z_i + \varepsilon_i \qquad (1.2)$$

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 (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 $\varepsilon_i$. Inserting equation (1.2) in (1.1) gives the single stage production frontier model

$$\ln y_i = \ln f(x_i;\beta) + v_i - (\gamma z_i + \varepsilon_i). \qquad (1.3)$$

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 $\varepsilon_i$ 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 $\varepsilon_i$. 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 $\gamma_1$, 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 can be statistically tested. Finally if $u_i$ and $v_i$ are independently distributed, all parameters of equation (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 $\mu$, with only one change. Constant mode $\mu$ is now replaced by the variable mode $\mu_i = \gamma' z_i$, so that the log likelihood function is

$$\ln L = constant - \frac{N}{2}\ln(\sigma_v^2 + \sigma_u^2) - \sum_{i=1}^{N} \ln \Phi\left(\frac{\gamma' z_i}{\sigma_u}\right) + \sum_{i=1}^{N} \ln \Phi\left(\frac{\mu_i^*}{\sigma^*}\right) - \frac{1}{2}\sum_{i=1}^{N}\left(\frac{(e_i + \gamma' z_i)^2}{\sigma_u^2 + \sigma_v^2}\right) \qquad (1.4)$$

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

and the $e_i = \ln y_i - \ln f(x_i;\beta)$ are the residuals obtained from estimating equation (1.1) simply by OLS. The log likelihood function of (1.4) 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

$$E(u_i / e_i) = \mu_i^* + \sigma^* \frac{\phi(\mu_i^* / \sigma^*)}{\Phi(\mu_i^* / \sigma^*)} \qquad (1.5)$$

or

$$M(u_i / e_i) = \begin{cases} \mu_i^* & if \ \mu_i^* \geq 0 \\ 0 & otherwise. \end{cases} \qquad (1.6)$$

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 $\varepsilon_i$ bounded below by the variable truncation point $-\gamma' z_i$. Battese and Coelli (1995) have verified that this new distributional assumption on $\varepsilon_i$ is consistent with the distributional assumption on $u_i$ that $u_i \sim N^+(\gamma' z_i, \sigma_u^2)$. We assume a log-linear production function in value of output and catch effort index $E$ to specify the underlying technology.

$$\ln f(x;\beta) = \beta_0 + \beta_e \ln E \qquad (1.7)$$

Here the left hand side represents total value of fish catch of the team per week during peak fishing season in rupee terms.

Further $\gamma' z_i = \gamma_1 + \gamma_2 z_{2i} + \gamma_3 z_{3i} + \gamma_4 z_{4i} + \gamma_5 z_{5i} + \gamma_6 z_{6i}$ (1.8)

Where, the $z_i$'s are firm specific non-inputs variables which may influence the technical efficiency of fishermen of the fishing team. Specifically,

$z_{2i}$ = average age of members the fishing team (years), as a proxy for **experience**.

$z_{3i}$ = **education** of the fishermen as measured by average number of years of formal schooling.

$z_{4i}$ = average **standard of living index in the team**,

$z_{5i}$ = **non-fishing income** of the team,

$z_{6i}$ = average existing **loans** of the team,

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,
$LR = -2ln\,[L(H_0) / L(H_A)]$

where $L(H_0)$ and $L(H_A)$ are the values of the likelihood function (optimum) under the null and alternative hypotheses respectively. But since the hypothesized value of $\lambda$ lies on the boundary of the parameter space it is difficult to interpret the test statistic. It can be shown that the *LR* statistic follows a mixed $\chi^2$ distribution that asymptotically approaches $\chi^2$ 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 absent in the model. The Battese and Coelli (1995) inefficiency effects model was adopted.

3.2 Data

The study is based on primary data. First random selection of 347 fishermen was done from the cooperative society register. The data is collected in a household level socio-economic survey (during the peak seasons). All catchers are found to be concentrated in 3 Gram Panchayats surrounding the Sone Beel Haor. The data is collected using a well structured pretested schedule by employing the direct interview method. The total sample size (fishing households) covered in the present study is 350. This is just less 5% of the population size as because all fishermen are not registered. Detailed information on fishing effort, fish catch (physical and nominal), fishing equipments, asset holding patterns, food and nutritional status, health status, alternative occupation and earnings from them, existing loans with sources, and all relevant socioeconomic information was collected through the survey. The data consists of 166 fishermen with single boats, 94 fishermen with two boats, and 87 fishermen with two motorized boats. Exact population distributions of fishing teams according to method of catch are unknown.

## 4. Empirical Results

**Table 1. Distribution of Fishermen and Fishing Teams across Catch Methods***

| **Categories of fishing team** | Catchers (teams) |
|---|---|
| Single Boat and Two Catchers | 166 (83) |
| Two Boats with 3 Catchers | 13 (4) |
| Two Boats with 4 Catchers | 29 (7) |
| Two Boats with 6 Catchers | 19 (3) |
| Two Boats with 8 Catchers | 33 (4) |
| Two Motorized Boats with 8 Catchers | 87 (11) |
| Total sample of fishermen (catchers) | 347 (112) |

*No. of fishing teams are given in parenthesis. **Source**: Primary data.

Table 1 shows distribution of Fishermen and Fishing Teams across Catch Methods during the peak season. During peak season the wet land acts as a catchment area and hence water volume rises many folds. During peak season the fishermen are allowed free access to fishing and therefore are motivated to have maximum haul or catch as because no fishing permits are required during this period. During the peak season some major techniques of fish catch are applied. Some major technique of fish catch methods is highlighted in table1 and numbers of fishing teams are given in parenthesis. Here technical efficiency is measured on fishing teams and not individual catchers.

**Table 2. Average Catch Composition According to Species**

| **Fish Types**[ǂ] | **Weight of Catch (kg)** | |
|---|---|---|
| | Single Boat | Paired Boats |
| Tengra (Batasio batasio) | 1.5 | |
| Pabda (Ompok pabo) | 1.8 | 3.1 |
| Moka | 2.6 | |
| Kajri | 1.7 | |
| Punthi (Puntius chola) | 2.9 | 7.5 |
| Bele (Glossogobius giuris) | 2.1 | |
| Koi (Anabas testudineus) | 0.7 | |
| Khoira | 1.9 | |
| Shol ( Channa striata) | 1.1 | |
| Shingi/magur (Gagata youssoufi) | 1.5 | |
| Kharish | 2.3 | 2.6 |
| bacha | 0.7 | |
| Rohu (Labeo rohita) | | 8.7 |
| Katla (Catla catla) | | 7.2 |
| Boal (Wallago attu ) | 1.4 | 4.4 |
| Aar (Sperata aor) | 1.6 | 3.9 |

[ǂ] **scientific names are provided in parenthesis.** ***Source***: Authors' estimates based on primary data.

Table 2 shows average catch composition of Fish species in single boat and paired boat is recorded in kg. According to Fish diversity in Sone Beel of Assam, 69 species of fishes belonging to 49 genera under families and 11 orders have been recorded in Sone Beel (Devashish Kar et al., 2006). However some common types fishes with their scientific name provided in the parenthesis generally found in Sone Beel Lake. There are average number of small fish species such as *moka, puthi, tengra, shol* catches by using gill net and non net fishing inputs for fish trap like cylindrical drum trap, vertical slit trap (locally called dari and kati) popularly used in South Asian Countries (Northeast India, Bangladesh, Mekong and others). While large quantity (kg) of big fishes like (*Rohu, Katla, Boal, Aar)* etc. are being caught by using seine net or drag net by the paired boat teams.

**Table 3. Counting Boat Sightings and Arrival in the Sone Beel during Survey Week**

| **Date** | **Sightings at 6:00 AM** | **Arrival at 7:00 AM** |
|---|---|---|
| 23.07.2013 | 49 | 52 |
| 24.07. 2013 | 57 | 49 |
| 25.07. 2013 | 42 | 56 |
| 26.07. 2013 | 56 | 63 |
| 27.07. 2013 | 61 | 48 |
| 28.07. 2013 | 54 | 39 |
| 29.07. 2013 | 78 | 58 |

***Source***: Authors' estimates based on primary data.

Table 3 presents the number of counting boat sightings and arrival in the Sone Beel during Survey Week. The observation has been done from fish-landing sites during the survey week and found that almost 50 to 60 fishing teams with their boat landed in the fish-landing sites. The total crewmembers ranges from two to four persons appear for selling and grading to the fish auctions (called *macher arath*, i.e., the whole sale trading and transaction place). The number of fish auctions appearing in the landing site is 3 to 4 and this number is fluctuating depending on fish transaction. However, only 2-3 auctions are regularly and continuously in activity.

**Table 4. Summary Statistics of all Variables**

| Variables | Min. | Max. | Mean | S.D. |
|---|---|---|---|---|
| Age (years) | 31 | 39 | 34.4 | 9.78 |
| Existing Loans (Rs) | 1900 | 9100 | 6755 | 43.89 |
| Education (years) | 4 | 7 | 5.7 | 3.26 |
| Non-fishing income (Rs/month) | 1250 | 5800 | 3890.55 | 38.87 |
| SOL Index | 0.29 | 0.90 | 0.68 | 0.98 |
| Per capita Food Expenditure (Rs/month) | 460 | 1340 | 870.65 | 51.02 |
| Per capita Living Area (sqft) | 48 | 64.14 | 58.33 | 22.36 |
| Output (Rs/week) | 2340 | 8750 | 5567.9 | 59.32 |
| Net (meters) | 29.00 | 62.00 | 39.67 | 27.65 |
| Boat (meters) | 3.90 | 7.1 | 5.11 | 8.6 |
| Labour (man-hours/week) | 32 | 115 | 69.45 | 68.99 |
| Catch Effort Index (E) | 0.49 | 0.94 | 0.77 | 1.01 |

**Source**: Author's estimates based on primary data.

**Descriptive statistic:** The descriptive statistics of variables for the production frontier estimation are presented in Table 4. The result revealed that the average total value of fish caught (obtained by adding cash receipt from selling of fish on weekly) is 2340 with a standard deviation of 59.32. The large value of standard deviation implies that the fishers are operating at different number of fishing gears and this tends to influence their output levels. The minimum value of boat length is 3.90 m, while maximum was 7.10 m. The mean length of boat is 5.11 m with a standard deviation of 8.6 m. The variability in length of boat measured by the minimum, maximum values and confirm by standard deviation may be due to the high cost of fishing gears in study areas. The average monthly non fishing income of fish catchers earning from agriculture or allied activities is recorded as 3890.55 with standard deviation 38.87 which implies that there is a considerable variability of non fishing income across fishing teams. The average age of the farmers was 34.4 years with a standard deviation of 9.78 years. This shows that most farmers are relatively middle aged people. The average year of schooling was 5.7 with standard deviation of 3.26, showing that most of the farmers attended at least a Primary School. The physical standards of living (SOL) index as captured by the sum of average per capita plinth area index and monthly per capita expenditure index is 0.68. Catch-effort Index (E) is measured by simple mean of labour index, boat index and the net index is taken as the catch effort index in the present study. The mean value of catch effort index is 0.77 which is positively influence on fish caught. E rises in value if at least one component rises other things remaining the same.

**Table 5. Maximum Likelihood Estimates of Parameters of Log-linear Production Frontier** (n = 112)

| Coefficients of | Estimated Value | *t*- Value |
|---|---|---|
| Constant | 1.096 | 1.008 |
| *Ln(E)*^ | 0.039 | 2.890 |
| **Variance parameters** | | |
| $\sigma^2 = \sigma_v^2 + \sigma_u^2$ | 0.035 | 8.005* |
| $\lambda = \sigma_u / \sigma_v$ (Aigner *et al* 1977) | 0.359 | 2.500* |
| $\sigma_v^2$ | 0.031 | |
| $\sigma_u^2$ | 0.004 | |
| *Log Likelihood* | -1.110 | |
| 3rd Central Moment of OLS Residuals | -79.011 | |
| *OLS Log Likelihood* | -10.805 | |
| LR Stat [λ = 0] (5% Critical $\chi^2$=8.01) | 19.39* | |

**Source**: Author's estimation based on primary data. ^E= (effort index multiplied by 100)
*: Statistical significance at 5 %.

**Stochastic frontier production analysis:** The maximum likelihood estimates of the log-linear stochastic frontier production function of sample fishing teams across catch methods (no. teams) in the study area are presented in Table 5. This suggests that the fishing teams are operating below the output oriented frontier and that the traditional response function, i.e. ordinary least square is not an adequate representation of data in the study. This is also confirmed by the estimated value of the variance parameter, λ, which is statistically different from zero. The null hypothesis that there is no inefficiency in the fishing team of all methods of Sone Beel region is rejected at 5 percent level of significant. Furthermore, elasticity of output with respect to effort index is positive but low at 0.039.

**Table 6. Estimated Coefficients of the Inefficiency Effects Variables**

| **Coefficients of** | **Estimated Value** | ***t*- Ratios** |
|---|---|---|
| Constant | 0.006 | 1.991* |
| Age (experience) | -0.256 | -1.819* |
| Dependency ratio | 1.956 | 2.658* |
| Education | 0.007 | 1.008 |
| Non-fishing income | 3.476 | 1.033 |
| Household expenditure PC | -0.90 | -1.901* |

**Source**: Authors' estimates based on primary data. *: Statistical significance at 5 %.

**The inefficiency model estimates**: The stochastic frontier production function inefficiency analysis result depicted in table 6. The coefficients in the inefficiency model indicated that age and physical standards of living (as measured by per capita household expenditure) is estimated to be positive and significant. This result suggests that increasing these variables will decrease technical inefficiency i.e. increase technical efficiency. This means that old catchers are technically more efficient than the younger ones this is due to the technical knowledge of fish catch. The coefficient of non fishing income in the technical inefficiency is estimated to be positive but insignificant; the incomes from other than fishing activities accruing to fishers have a negative impact on technical efficiency. The percapita house holds expenditure which gives an approximate measure on physical conditions and overall standard of living positively influence on technical efficiency. The coefficients dependency ratio and education have negatively influence of technical efficiency.

**Table 7. Distribution of Technical Efficiency of all Teams (n = 112)**

| TE(%) intervals | Frequency | Distribution (%) |
|---|---|---|
| 40-50 | 8 | 7.14 |
| 50-60 | 13 | 11.61 |
| 60-70 | 23 | 20.54 |
| 70-80 | 31 | 27.68 |
| 80-90 | 23 | 20.54 |
| 90-100 | 14 | 12.50 |
| **Total** | **112** | **100** |
| **Mean TE** | 73.03 | |
| **Max. TE** | 93.45 | |
| **Min. TE** | 45.88 | |
| **S.D.** | 27.78 | |

**Source**: Authors' estimates based on primary data.

**Technical efficiency scores analysis:** The frequency distributions of technical efficiency scores are also presented in Table 7. The result indicates that about 78 % of fishermen are operating at 80% or more technical efficiency levels. Furthermore, about 60.72 % of fishing teams across all methods are operating at a technical efficiency level of 70 % or more. Also about 39.29 % of the fishing teams are operating at technical efficiency level of 60 % or less. The results further reveal that technical efficiency for all teams ranges between 45.88-93.45 percent with a mean technical efficiency of 73.03 percent. 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.

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**Table 8**. **Distribution of Technical Efficiency of Single Boat and Paired Boat Teams**

| **TE (%)** | **Frequency (n = 83)** | **Distribution (%)** | **Frequency (n = 29)** | **Distribution (%)** |
|---|---|---|---|---|
| 40-50 | 9 | 10.84 | 1 | 3.45 |
| 50-60 | 15 | 18.07 | 5 | 17.24 |
| 60-70 | 14 | 16.87 | 9 | 31.03 |
| 70-80 | 21 | 25.30 | 5 | 17.24 |
| 80-90 | 17 | 20.48 | 7 | 24.14 |
| 90-100 | 7 | 8.43 | 3 | 10.34 |
| **Total** | **83** | **100** | **29** | **100.00** |
| **Mean TE** | 70.66 | | 74.48 | |
| **S.D.** | 22.45 | | 31.33 | |

**Source**: Authors' estimates based on primary data

Users of single boats (83) have a mean technical efficiency of 70.66 per cent while the same for paired boat users is substantially higher at 74.48 per cent (29) presented in tables 8. This result indicates that paired boat users are technically more efficient as their fishing equipments and labour effort gives maximum potentialities of carrying large quantity of output. Whereas the same for single boat users are compare ably less efficient of carrying potential level of output.

## 5. Summary and conclusions

The estimated results reveal that catch experience and physical standards of living positively (as measured by per capita household expenditure) influence the technical efficiency positively while non-fishing income, dependency ratio and education have dampening effects on the same. Elasticity of output with respect to effort index is positive but low at 0.039. From the inefficiency model it is observed Education is found to have an insignificant effect on efficiency. The mean technical efficiency of all catchers is estimated at 73.03 per cent. Users of single boats (83) have a mean technical efficiency of 70.66 per cent while the same for paired boat users is substantially higher at 74.48 per cent (29). The study is of the opinion that excessive fishing in the Sone Beel in recent years has necessitated greater catch effort to get the same quantity of catch. This is indicative of falling fish stock, premature catch, and consequently falling average size of catch irrespective of species. Most fishermen are unwilling to stay in this occupation although it has been their traditional occupation. The key reasons cited are, (i) falling fish population in the Sone Beel which has leads to higher effort for same or sometimes lower catch, (ii) low offer price faced during sale of catch and (ii) attraction towards other non-fishing occupations that are physically less involving.

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