Chapter Two

REVIEW OF LITERATURE

Ever since the econometric formulation of the stochastic production frontier for measurement of economic efficiency (by Aigner, Lovell and Schmidt, 1977), a vast amount of empirical research has been conducted on the measurement of technical, allocative and scale efficiency in various fields of economic activities as agriculture (including all types of farming, plantations, poultry, cattle breeding and aquaculture etc.), fishing (marine, sweet water, and inland) industry, banking and finance, educations (both primary and higher), sports along with a few other newly emerging areas.

In fact, a very large volume of research already exists on the applications of the stochastic production frontier for measurement of technical efficiency in fishing (in its various forms) in different parts of the world. Unfortunately, as the following section seems to indicate, only a handful of such applications of stochastic production frontier exist in India. In other words, applications of the stochastic production frontier for measurement of technical efficiency of fish catch in India (marine or inland water) are very few compared to the volume of international studies in this area. The present chapter deals with an extensive review of existing literature in the fields of both the concepts and techniques of measurement of technical efficiency and also its applications in fish catch and fish production activities. Thus broadly, two categories of works are reviewed. In section 2.1, the first relates to historical development of the

conceptual framework of economic efficiency and the technicalities of econometric measurement. This starts with theoretical and empirical contributions of the late nineteen seventies. Farrell's celebrated work on the decomposition of technical and allocative efficiencies are developed in detail in the chapter on methodology (Chapter 3). Then in section 2.2, the second kind of reviews is on the most significant empirical contributions in the field of measurement of technical efficiency in the field of fishing areas. Influential contributions both in India and abroad are reviewed. And lastly in section 2.3, the literature gap in this area justified the necessity and importance of the present research undertaking. This chapter provides important theoretical (conceptual) and empirical inputs for the present study on technical efficiency measurement of fish catch in Karimganj district of Assam.

2.1 Theoretical Development of the Stochastic Production Frontier

The concept of stochastic frontier analysis (SFA) originated with two joint papers published almost simultaneously by Aigner, Lovell and Schmidt (1977) and Meeusen and van den Broeck (1977). The two papers were very similar in their approaches. In the same year a third paper on stochastic frontier analysis was developed by Battese and Corra (1977). These three original SFA models shared a composed error structure and each was developed in a production frontier context. The model can be expressed as $y = f(x; \beta).\ exp\ \{v\text{-}u\}$, where y is a scalar output, x is a vector of inputs and β is a vector of technology parameters. The first error component $v \sim N(0, \sigma_v^2)$ is intended to capture the effects of statistical noise, and the second error component $u \geq 0$ is intended to capture the effects of technical efficiency. Thus producers operate on or below their stochastic production frontier $f(x; \beta).\ exp\ \{v\}$ according as $u = 0$ or $u > 0$. Meeusen and van den Broeck (1977) assigned an exponential distribution to u. Battese and Corra (1977) assigned a half normal distribution to, and Aigner, Lovell

and Schmidt (1977) considered both distributions on u. The parameters to be estimated include β, σ_v^2 and a variance parameter σ_u^2 associated with u. Either distributional assumption on u implies that the composed error ($v - u$) is negatively skewed and statistical efficiency requires that the model be estimated by using maximum likelihood method. After estimation an estimate of mean technical efficiency in the sample was provided by $E(-u) = E(v - u) = -\sigma_u\sqrt{\frac{2}{\pi}}$ in the normal-half normal case and by $E(-u) = -\sigma_u$ in the normal-exponential case.

Jondrow, Lovell, Materov and Schmidt (1982) proposed that either the mean or the mode of the conditional distribution [$u_i / v_i - u_i$] would provide estimates of the technical inefficiency of each producer in the sample. This procedure of obtaining producer specific estimates of technical efficiency have greatly enhanced the appeal of stochastic frontier analysis. The half normal and exponential distributions assigned to the one sided inefficiency error component are single parameter distributions. More flexible two parameter distributions for the inefficiency error component were also introduced. Greene (1980a, and b) proposed a gamma distribution and Stevenson (1980) proposed both gamma and truncated normal distributions for the inefficiency error component. Even a more flexible distribution, namely, the four parameters Pearson family of distributions, was proposed by Lee (1983).

Reversing the sign on *u,* a methodology for estimating a stochastic cost frontier model along with firm specific cost inefficiency was first developed by Schmidt and Lovell (1979, 1980). However a deterministic cost frontier model was constructed and estimated by Forsund and Jansen (1977). Greene (1980b) and Stevenson (1980) introduced two parameter distributions for the one sided error component. Decomposition of cost inefficiency was essential. Schmidt and Lovell (1979)

decomposed the estimates of u into estimates of the separate costs of technical and allocative inefficiency for the Cobb- Douglas cost function case. However, Kopp and Diewert (1982) obtained the decomposition of cost inefficiency for the more general trans-log case although econometric difficulties with their decomposition remain even today. Schmidt (1985-86), Bauer (1990), Greene (1993), and Cornwell and Schmidt (1996) present comprehensive surveys on the development of the stochastic cost frontier in recent years.

Kalirajan and Shand (1992) measured technical efficiency which is central to measuring the firm's performance. The measurement of technical efficiency has proved difficult and complex, and the literate provides a range of methodologies. This paper reviews the various methodologies for measuring technical efficiency and offers a comparison between established methods of measurements. The discussion is literary with less mathematical jargons and equations. The objective of this paper is not to be exhaustive, but to be up-to date and to provide a significant discussion on some of the core methods of measuring technical efficiency.

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).

Several studies have used a two step approach to determine the sources of inefficiency or factors that affect farm level technical inefficiency. In the first step a stochastic frontier model is estimated by maximum likelihood method and farm specific technical inefficiencies are calculated under the assumption that the technical inefficiency effects are identically distributed. In this step it is ignored that technical inefficiency is a function of farm specific and exogenous variables. Once farm level technical inefficiencies are estimated it is regressed in the second stage on a set of farm specific factors (or characters) and/or exogenous factors beyond the farm's direct control but which may explain inter-farm variation in technical inefficiency. These factors typically are not inputs but may affect the way inputs are organized in production. In this step either logit or probit models are used.

The application of the logit or probit in the second step contradict the assumption of identically distributed inefficiency effects in the stochastic frontier model since predicted efficiencies are assumed to have a functional relationship with farm specific variables and exogenous variables. In the second stage the estimated technical inefficiency effects are modeled as a function of some farm specific and exogenous factors. This implies that inefficiency effects are not identically distributed unless the coefficients of the farm specific factors are simultaneously equal to zero (Kumbhakar and Lovell, 2000).

The problems of this two stage method can be addressed using a one stage formulation of Kumbhakar, Ghosh and McGuckin (1991). They specified the technical inefficiency effects and estimated the stochastic frontier and inefficiency effects simultaneously by using maximum likelihood method, given appropriate distributional assumptions on the inefficiency component. Kumbhakar *et al.,* (1991) model was developed for cross-sectional data. Reifschneider and Stevenson (1991)

and later, Huang and Liu (1994) also developed the one stage formulation based on cross-sectional data. Battese and Coelli (1995) developed a model similar to Kumbhakar *et al.,* (1991) but for panel data. The present study follows a Kumbhakar *et al.,* (1991) approach to simultaneously measure team level technical efficiency of the fishing teams of Sone Beel fishermen and to test the impact of a few non-input (or selected socio-economic) factors on the level of technical inefficiency on the basis of primary data. Important empirical applications in the agrarian sector are reviewed in the next section.

2.2 Literature on Efficiency Measurement in Fisheries

Numerous studies on the measurement of efficiency in fishing, i.e., fish catch, as well as that in planned fisheries are available in literature. Among developing countries, a substantial amount of literature is available on efficiency measurement in fishing in African and South East Asian Nations (e.g., Nigeria, Ghana, Malaysia, Indonesia, Iran and India). Among developed nations, similar studies have been conducted in Mexico, Spain, Australia, Norway and Sweden. Comparison across studies becomes difficult due to heterogeneous factors. While some works are done on open access fishing others focus on restricted fishing with clearly defined property rights. Moreover some studies focus on marine fishing while others focus on inland fishing. Comparability becomes difficult even across fishing in rivers (which is a flowing water body) and fishing fresh water lakes and large ponds as the two create different types of challenges for catchers. Yet another common form of fish production is by means of fish culture in partitioned ponds and planned tanks or reservoirs. This is a problem of a different type.

In case of Nigeria, Adinya, Offem and Ikpi (2011) compared technical efficiency of mandarin fish and clown fish production in Cross River State, Nigeria. The study was based on primary data collected through a multi stage random sampling techniques. Data collected were analyzed using descriptive statistics and stochastic frontier function that incorporated inefficiency effects that were estimated. In this study Cobb-Douglas production function was fitted to the frontier model for fish production systems of the two species. The result showed that there exists technical inefficiency in both mandarin fish and clown fish production systems in Cross River State. The determinants of technical efficiency showed that fish farmers' educational level, access to credit, farm size and feed positively influenced their levels of efficiency. In this study emphasis was given on determinant like extension visit dummy that may enhance level of technical efficiency in both the production systems. Extension agents should train fish farmers on improved production technique while banks should give loans to fish farmers and strictly monitor all loan beneficiaries to ensure loan repayment. The study also recommended efficient policy formulation and implementation that would encourage fish farmers and unemployed youth in Cross River State to join fish producers cooperative to enable them to obtain loans at low interest rate from banks for increasing their capital base for higher output.

Ajao (2011) analysed the technical efficiency of fishery sector for earthen and concrete ponds in Oyo State on the basis of primary data collected by using multi stage sampling procedure. The unit of study was fish farmers from two agricultural zones, i.e., from earthen fish farmers and from concrete fish farmers. The study used multi-stage Data Envelopment Analysis (DEA) to analyse the technical efficiency of earthen and concrete ponds under the Constant Return to Scale (CRS) and Variable Return to Scale (VRS) specifications. In order to identify the determinants of earthen

and concrete ponds inefficiency, a tobit analysis was conducted on the efficiency indices and suspected correlates of inefficiency. The overall technical efficiency estimates obtained under the CRS and VRS specifications for concrete pond fish farmers were found to be considerably high. The study found substantial inefficiencies in earthen and concrete ponds in the area with earthen ponds being more inefficient. The study further showed that only four farms were fully efficient under the CRS for the earthen pond fish farmers, while just 11 were fully efficient under the VRS from earthen pond fish farmers. Also under CRS for concrete pond fish farmers five farms were fully efficient while under VRS for concrete pond fish farmers 47 were fully efficient.

Inoni (2007) conducted a study to improve the efficiency of resource utilization in pond fish production in Delta State, Nigeria, using a production function approach. Primary data was used to estimate allocative efficiency in pond fish production. Study was conducted on a cross section data using a multi-stage sampling procedure. In this study the efficiency of resource utilization in pond fish production was measured using power production function and allocative efficiency was measured by value of marginal product to marginal factor cost. Finally log-linearised regression model was used to estimate the factors influencing output in pond fish production. Results indicated that factors such as pond size, feeds, fingerlings, and labour were positive and significant determinants of output in pond fish production while the influence of labour was negatively effect on the same. The index of resource-use efficiency revealed that fish farmers were not only inefficient in the allocation of productive resources, but grossly over-utilized feeds, fingerlings, fixed costs, and labour. The factor like pond size was however, under-utilised with an allocative efficiency index of 3.22. Given the under-utilisation of pond size, strategies aimed at increasing farm

size would thus significantly improve efficiency of utilisation of other resources. This, in addition to enhanced access to current technical and price information by farmers, would raise output and net returns in small-scale fish farming enterprises. The study emphasizes that in order to improve efficiency in resource allocation in pond fish production there should be access to current technical and price information for farmers, and the Delta State government should facilitate this as a part of policy.

Ekunwe and Emokaro (2009) examined the technical efficiency of catfish farmers in Kaduna metropolis Kaduna State, Nigeria using the stochastic frontier production function. Primary data were obtained through the use of well structured questionnaire. The simple random sampling technique was used to select sixty farmers who were drawn from the list of Agricultural Development Programme contact farmers in four Local Governments Areas that structure the study area. Descriptive statistics were used to analyze the socioeconomic characteristics of catfish farmers while the stochastic frontier production function analysis was used to determine the technical efficiency of the farmers. Results showed that the estimated mean technical efficiency was of 85.4 percent. 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. The inefficiency factors such as gender, household size and education were found to be negatively influence on technical efficiency while experience and age were found to be positively related on the same. It is further showed that the return to scale was 0.66 which gives an indication that the farmers are in stage II of catfish production in the study area.

Esmaeili and Mohamad Omrani (2007) estimated the three types of efficiency on fishermen viz, technical, allocative and economical efficiency of selected fishermen in Hamoon Lake southeastern of Iran. The study was based on primary data collected

from among Sistanian fishermen by using structured questionnaire. The method of measuring theses efficiency was based on DEA approach. The average technical efficiency of selected sample, using DEA approach was calculated at 82.7 percent. The allocative and economic efficiencies were low at 75.5 and 62.7 percent, respectively. Additionally, two components of technical efficiency including net technical efficiency and scale efficiency were also calculated. Regarding that economic inefficiency results from both technical and allocative inefficiencies, so the harvests would perform economically efficient by rising technical and allocative efficiencies. Although, differences in efficiency among vessels were small in this study, vessels which their skippers participated in extension classes and those who did not have financial problem were more efficient. In addition, bigger capacity vessels technically and economically were more efficient.

Onumah, Brummer and Horstgen-Schwark (2010) examined the productivity of hired and family labour and determinants of technical inefficiency of fish farms in Ghana. A modified Cobb-Douglas stochastic frontier production function which accounts for zero usage of family and hired labour was applied to cross-sectional data of 150 sample farmers. The study found that the values of coefficient estimated for all production inputs were positive. The results reveal that family labour, hired labour, feed, seed, land, other costs and extension visit have a reasserting influence on fish farm production. The study also showed 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. Mean technical efficiency was estimated to be 79 percent. Given the present state of technology and input level, the possibility of

enhancing production could be achieved by reducing technical inefficiency by 21 percent through adoption of practices of the best fish farm. The study suggested that Government policy should also focus on ensuring easy accessibility of bank loans especially to young and small farms to expand their operations. The study recommended further work to specify a stochastic frontier model which permits a more general structure. A more comprehensive study could also be considered using panel data to analyse technical change and time varying inefficiency.

Hassanpour, Ismail, Mohamed and Kamarulzaman (2011) conducted a study to measure factors affecting technical change of productivity growth in rainbow trout aquaculture in Iran. The study considered the socio-economic factor for analysing the factors affecting technical change in trout aquaculture. A two-stage estimation procedure for this analysis was applied. The Malmquist index was employed to measure the productivity and technical change in the first stage, while the pooled logit and tobit models were performed in the second stage so as to ascertain factors affecting the technical change or innovation improvement. The study was conducted to utilize panel data of 207 trout farms in the country over a five-year period from 2003 to 2007. The results of this study revealed that the total factor productivity (TFP) growth of rainbow trout farming in the aquaculture sector was substantially formed from technical efficiency change rather than technical change or innovation improvement. Hence, Iran still has adequate scope improving the TFP growth in the trout aquaculture, and this could be done by shifting its production frontier through improving innovation and development of new technologies. Based on the marginal effects analysis derived from the pooled logit/tobit regression, the factors that mostly affected technical change positively were suitability of water temperature, extension workshop and educational level of the manager. Conversely, the negative factors

included the governmental insurance coverage, pond size and being government tenure, such as public companies and cooperatives. The study conclude that there was a need for the government to intervene, guide and coordinate the various actions adopting the newest and latest technologies and allowing developed countries to invest in trout aquaculture in the country.

Jayaraman (1999) conducted a study to measure economic and technical efficiency in Carp Culture of forty randomly selected fish farmers in the Thanjavur district, Tamil Nadu, India, covering a total area of 26.59 ha. The district was chosen purposively since it is the only district in which carp culture in owned dug-out ponds is widely practiced. Further, homogenity in terms of aqua-ecological, soil and climatic conditions, and others were available in the district. Total Variable Cost (TVC) included all items of variable costs like inputs, and interest on variable cost at 4.5 percent p.a. Total Fixed Cost (TFC) included interest on capital costs at 10 percent p.a. and depreciation at 10-15 percent p.a. of various farm implements. Total income included sale proceeds of fish and other farm income. Total income minus total cost gave net income. Percentage and budgeting analyses were employed to analyze the data. For measure of efficiency stochastic production frontier model was used. The results showed that all the functions had good fit and were valid for interpretation with the expected positive for all coefficients having an R^2 value of 0.87. All the functions showed increasing returns to scales. The study revealed that 21 ponds (52.50 percent) realised the maximum possible yield obtained by the most progressive farmer in the study sample. The remaining 19 ponds could enhance their yield, and technical efficiency by increasing appropriate use of the inputs recommended in due course of time. The study concluded that there is a possibility to improve the level of technical efficiency if farm specific constraints are removed and the existing

technology is fully adopted. It further suggested that regular contact with extension agencies and participation in training programmes would become necessary to obtain the optimal input combination and optimize net income from carp culture so that the farming operations become economically sustainable.

Charles, Ayuba and Malo (2011) conducted a study to examine the Net Farm Income, profitability index and technical efficiency of artisanal fishing in five natural lakes in plateau state, central Nigeria, with a view to examining the level of exploitation of captured inland fisheries as a renewable resource. The study was based on primary data collected from 110 sample fishermen selected from Polmakat, Shimankar, Deben, Janta and Pandam lakes using multi-stage sampling technique. Technical efficiency was measured by using stochastic frontier production function. The mean technical efficiency of 83 percent was obtained, indicating that the sample fishermen were relatively efficient in allocating their limited resources. The result of the analysis indicated that 72 percent of variation in the fishermen output was as a result of the presence of technical inefficiency effects in fishery, showing a potential of about 17 percent chance for improvement in technical efficiency level. Among the determinants of inefficiency effects model variables such as experience, extension contact and educational status were found to influence the technical efficiency positively. The study suggested that in open access fishery resources excessive effort of fish catch may lead to depletion of stock. Therefore, increased efficiency at the aggregate level would thus only possible if fishing effort and catch are limited. Therefore government should adopt measures to limit entry.

Singh, Dey, Rabbani, Sudhakaran & Thapa (2009) examined the level of technical efficiency (TE) and its determinants of small-scale fish production in the West Tripura district of the state of Tripura, India. The study was based on the cross-

sectional primary data collected from 101 fish farmers through a multi-stage random sampling method. The study employed stochastic production frontier approach, and followed both one-stage and two-stage procedures to analyze the determinants of technical efficiency. To test the distribution of error term both normal half-normal and normal truncated normal were compared and finally the study support normal half normal was more appropriate than the other. The study revealed the Cobb-Douglas form of stochastic frontier production function was more dependable than that of trans-log form under the farming conditions in the West Tripura district of Tripura state. One-stage procedure with technical inefficiency model bestows reliable estimates of coefficients of stochastic frontier production function than that of two-stage procedure. The input seed quality was found as an important determinant of TE. The study recommended that the state government needs to play a role to ascertain the supply of quality fish fingerlings at adequate time and quantity to the farmers in the study area.

Dawang, *et al.* (2012) conducted a study to measure Economic Efficiency of Captured Fisheries in Pandam Lake fisheries of Plateau State, Nigeria The study also measured the net farm income, technical efficiency (TE), allocative efficiency (AE), and economic efficiency (EE) of the said region. The study was based on primary data collected from all licensed fishers, in addition to a daily fishing activities record of fishers carried out through a catch assessment survey conducted between November 2010 and March 2011. Output was measured in kg of individual fishers and input includes fishing gears, number of fishing gears owned by the individual fisher, time taken for passive gears to remain active in water. The corresponding cost frontier model was used to measure allocative efficiencies of the fishers that includes cost of gillnet, malia trap, cost of hook line, gura trap, cost of repairs and depreciation on

equipment. The stochastic frontier production function simultaneously estimated the technical inefficiency and its non-input determinants. The analysis indicated that the coefficients of age of fishers and educational status were negative, with extension contact and educational status showing statistically significant. This indicates that increasing these two variables would increase technical efficiency. Family size was positive, indicating that this factor could lead to increase in technical inefficiency of farmers in the study area. The stochastic frontier cost function also simultaneously estimated the allocative inefficiency showed that coefficients of age of fishers and family size were negative, with age of fisher being significant, i.e., suggesting that as the fishers become very old, their cost minimising efficiency decreases. The study found decreasing returns to scale and that fishing exploitation was in stage II of the production surface. This showed that efforts could be improved to expand the present scope of production and harvesting to actualise the full potential of fishers that could result to the attainment of more output. The estimated values of the parameters of stochastic cost frontier model of the fishers implied that about 78 percent variation of total cost incurred by fishers were as a result the differences in the fishers' allocative efficiency. The study suggested that transformation for effective and sustainable fisheries exploitation would need the involvement of educated fishers, extension education, and constraining of fishing gear at the fishery.

Onumah and Acquah (2010) conducted the stochastic production frontier approach to analyse the technical efficiency and its determinants of fish farms in Ghana using a cross-section data of 150 farms. The study considered the explicit effects of family and hired labour on production by setting the log-value of the zero-observation of these two sources of labour to zero with dummy variables. The study found that expected elasticities of mean output with respect to all input variables are positive and

significant. Findings also showed that family and hired labour used for fish farming in Ghana may be equally productive. Fish farms in Ghana are revealed to be characterised by technology with increasing return to scale. The combined effects of operational and farm specific factors were found to influence efficiency. The study found that inclusion of interaction between some exogenous variables used in the inefficiency model was significant in explaining the variation in efficiency. Results also showed that small pond operators were more efficient than farms with large ponds. Mean technical efficiency was estimated to be 78 percent.

Ogunniyi, Ajao and Sanusi (2012) examined the technical efficiency in artisanal fisheries in Lagos State of Nigeria. The study employed a two stage random sampling procedure for the selection of 120 respondents. The result of the stochastic frontier production function showed that hired labour, cost of repair and capital items were critical factors that influences productivity of artisanal fishermen with the coefficient of hired labour being highly elastic. This implied that employing more labour would significantly increase the catch in the study area. The mean efficiency value was 0.92 showed that there was a marginal potential of about 8 percent to increase the catch, hence the income of the fishermen. The factors that influence productivity of fishermen include year of education, mode of operation and frequency of fishing. These factors also have important implication on the technical efficiency of fishermen in the study area.

A similar study was conducted by Ogunbameru (2012) who measured fish catch efficiency of fishing households in Ogun-waterside of Ogun State, Nigeria. The study was based on primary data collected by using multistage sampling procedure is adopted in selecting the sample size. The stochastic production frontier model of Cobb-Douglas functional form was employed to estimate the catch efficiency. The

Frontier Version 2.0 software developed by Coelli (1992) was used to estimate the parameters. The two dummy variables were used to capture the effects of technology and extension on the placement of the catch function. The estimated model indicated that fishing experience, capital asset, outboard engine, education and extension contact were significant factors influencing fish catch by the households. The fishing households were found to operate below the stochastic frontier. The technical efficiency was found to vary between 29.8 and 84.3 percent. The mean technical efficiency was obtained at 78.5 percent. There existed a scope of increasing fish catch by 5.8 percent provided all the fishing households adopt the fishing method of the most efficient firm in the sample. Based on the results the study suggested that there should be sufficient capital or credit (fund) facilities given to the fishing households in order to improve the catch efficiency and overall standards of living. In this context, credit was viewed as more than just another resource such as labour, equipment and other inputs.

Viswanathan *et al*., (2000) examined the technical efficiency and fishing skill in Kedah, Malaysia Trawl Fishery. Multistage sampling method was applied to obtain the 126 respondents. Fishers were stratified based on gear type and the list of fishing vessels in the area was collected from the fisher co-operative unit office for 1994, the period of the study. The 126 trawl vessels in the sample were selected randomly from a population of 488 trawl vessels. Both inputs and output were measured in physical terms. The study recognized the role of skipper skill related to finding and catching fish, knowing or sensing when to leave a spot for another, managing and supervising crew, responding to breakdowns in equipment and machinery, response to changing tides and weather, seasonal variations in resource abundance, and numerous other factors. The study considered that skipper skill may positively influence on fish catch

efficiency. Technical efficiency varies by ethnicity of the skipper. The dummy variable for Chinese and others skippers is negative and statistically significant in the technical inefficiency function. The number of Malay skippers declines with increases in efficiency whereas the number of Chinese and other ethnic group skippers rises with increases in efficiency. This study provided one of the few pieces of empirical evidence on the magnitude of variation in skipper skill, interpreted as technical efficiency, and the factors that could affect it. The study recommended that a skipper training program for the least efficient skippers may be called for to meet the objectives of equity and fairness as expressed in the New Economic Policy and its successor, the New Development Plan. Such training programs would also be consistent with the one of the initial aims of the license limitation program, which was to promote equity among all ethnic groups in Malaysian society.

Singh (2008) conducted a study on farm specific economic efficiency of fish production in South Tripura district. The farm specific economic efficiency under different categories of fish farms was examined by estimating technical and allocative efficiency. The stochastic frontier function model of Cobb-Douglas functional form was employed to estimate the farm level TE and AE of the farmers in the study area. The study was based on the primary cross section data. The category of fish farm was based on pond size. In the study for measuring economic efficiency the total input cost, which was the dependent variable for the estimation of stochastic cost frontier include average expenditure on seed, feed, fertilizer, and average wage rate per man-day. The result showed that all independent variables in the stochastic frontier production function was considered to be significant which indicated that there was a scope for increasing production of fish by increasing the level of these inputs. The estimated elasticities of production of inputs exhibited decreasing returns to scale. In

category I random error effect was found to be dominant over inefficiency effect. The category I fish farms (≤ 0.32 acre of pond area) were found to be relatively more technical as well as allocatively efficient, thus economically more efficient, than category II farms (>0.32 acre of pond area). The study revealed that fish farms of Tripura are yet to achieve their best. The results of the study further shown that any expansion in the use of any resources by the fish farmers would bring more than proportionate increase in their output, given the increasing returns to scale obtained in production.

Zibaei (2012) used the meta-frontier production function to examine provincial differences in fishing technologies of southern coastal provinces of Iran. The study was based on primary data obtained from a random sample of 520 fishery vessels, the results of this study were estimated using DEA. The results of the estimating meta-frontier showed that mean technical efficiency for selected provinces varies between 0.408 and 0.542, while ranging between 0.650 and 0.728 when assessed according to the regional frontier. The highest mean technical efficiency based on metafrontier was found for Sistan-va-Baluchestan, while Bushehr has the lowest mean technical efficiency. The results also indicated that the main explanations, behind the fact that Sistan-va-Baluchestan had the highest technical efficiency in comparison to other provinces, could be found in access to more suitable vessels and especially, access to the deeper waters of the Oman Sea and Indian Ocean to fish the big pelagic species.

Osawe, Adegeye and Omonona (2008) studied the technical efficiency of fish farmers in Ibadan metropolis of Oyo State, Nigeria. The study highlighted the real importance of aquaculture in this region over agricultural production. Technical efficiency of fish production was measured by using the stochastic frontier production analysis. The data collection in this study was primary in nature using a set of structured

questionnaire from 82 fish farmers. Both inputs and output were measured in physical terms that included pond size as a proxy for farm size, quantity of labour used, total feed and stocking rate (pices). The mean technical efficiency of the fish farmers was found to be 0.90. The distribution of results also showed that fish farmers in Ibadan metropolis were more efficient in the use of inputs though not all the inputs. The inefficiency variables like tertiary education, experience of the fish farmers, pond types and cooperative membership were found to positively influence the technical efficiency. Some farmers could gain more by reducing the inputs (e.g. labour use) for the same level of output. The study showed that inputs in fish production need to be efficiently used by all farmers so as to produce optimal level of output. The study further recommended that there should be intervention by the government as well as international agencies for up-gradation of both agriculture and fish production in the region.

A significant study was conducted by Onoja and Achike (2011) to analyse the efficiency of resource-use among rural fish farmers in Rivers State, Nigeria. The objective of the study was to measure the technical efficiency of small-scale rural fish farms and the factors influencing farm level inefficiency among farmers and production elasticities. The study employed the Trans-log form of Stochastic Frontier Production Function along with inefficiency effects. The results showed that mean level of efficiency of rural fish farmers was 71 percent. The inefficiency factors such as farm size, education, experience of fish farmers and household size had a positive influence on technical efficiency while age of the farmers, credit access and pond feeding system negatively influence the same. The study suggested that there should be adequate level of fish culture, from their small-scale levels to commercial levels by providing farm credit access and availability so that fish farmers may be more

efficient thus reaping the benefits of economies of ultimately leading to higher profits and farm incomes.

Jamnia, Mazloumzadeh and Keikha (2015) measured the technical efficiency of fishery in the Chabahar region, Southern Iran. They used the production frontier model for two different groups of Iranian fishery (inshore and offshore) by specifying a Cobb–Douglas production function. The production frontier included a model for vessel-specific inefficiencies to obtain technical efficiencies of a sample of 300 fishing vessels including 166 inshore operating vessels and 134 offshore operating vessels in the study area. Explanatory variables of technical inefficiency were estimated simultaneously, and output elasticities and returns to scale were also explored. Results provided key information on the relative efficiencies, output elasticities, returns to scale, and the economic performance of each fishing vessel. The mean technical efficiency levels for inshore and offshore operating vessels were estimated to be 66 and 56 percent respectively. Turning to the inefficiency effect model, for inshore operating vessels the inefficiency effects that include age of captain, formal education of captain, GPS and participation of captain in training programs were found to have positive and significant effect on technical efficiency. Especially the captain training program was found to have an influential effect on improving of efficiency for inshore operating vessels. The coefficient for fishing experience of the captain was positive although insignificant. In case of offshore operating vessels the coefficients for fishing experience of captain, formal education of captain, GPS and captain training programs were significant and have a positive effect on technical efficiency. In case of both types of operating vessels in the fishery sector of the studied region the participation of the captain in training programs was found to have a major influence on both technical efficiency as well as the amount of

fish harvested. The output elasticity estimates for both groups indicate increasing returns to scale. The study indicated the presence of increasing returns to scale in Iranian fishery.

Ele and Nkang (2014) measured technical efficiency and the factors that affect crayfish catch in the Lower Cross River Basin, Nigeria. They measured technical efficiency and its determinants in two seasons (rainy seasons and dry season). The study was based on the primary data that involved purposive sampling of accessible fishing villages. Three separate technical efficiency models assuming Cob-Douglas production frontier were used. Aggregate data collected were separated into seasons and the models were estimated across seasons. The results showed that that labour, credit, mesh size and motorization were all significant variables for aggregate data. For dry season all the variables except credit were significant. And for the rainy season all except the mesh size was not significant. Contact with extension and fishing experience were the only determinants that were consistently significant in both seasons and they had the apriori expected signs. The mean level of technical efficiency was 79 percent for aggregate data but for dry and rainy seasons it was 49.7 percent and 62.8 percent respectively. The determinants of technical efficiency were age, fishing experience and educational levels. The study recommended that special credit arrangement should be provided to the crayfish fishermen especially in the rainy season. Mesh size should be monitored and necessary control should be enforced especially during the dry season.

Lim, Lalif and Hussein (2012) investigated whether technology and other non input determinants affect fishing efficiency on local Trawl vessels operating in Penang, Malaysia. Technical efficiency was measured using two approaches namely, stochastic frontier analysis and data envelopment analysis. Data was collected from

the field survey covering 68 trawl vessels operating in Penang. To determine the level of technical efficiency input variables include landings per trip, number of crews, length of trip, diesel consumption per trip, vessel size and engine power. The determinants of technical inefficiency include family background of the fishermen, age of the fishermen, year of experience of captain, education level of fishermen together with age of vessel were analysed using SFA and Tobit regression. The results showed that in both SFA and DEA approaches the mean technical efficiencies estimated were high. However the mean technical efficiency was found to be higher in SFA than in DEA approach. The trans-log production frontier specification was more appropriate functional form compared to Cobb-Douglas form. The determinants of inefficiency effects models for both SFA and Tobit regression consistently indicated that possession of echo sounder and experience of fishermen had a significant and positive influence on technical efficiency. The study recommended that fishermen should install echo sounder to increase their landings as echo sounder was the only significant determinants of inefficiency. The study also opined that since the results of two approaches did not differ much, neither DEA nor SFA could be declared to be better or superior.

In a previous study Lim, Latif and Hussein (2011) measured technical efficiency of Penang Trawl Fishery, Malaysia. In this study technical efficiency was measured by applying Data Enveloped Approach (DEA). The study applied randomly selected sample of 69 Penang trawl vessels as a units. Output was measured in terms of landings per trip of each vessel, and inputs measured in term of number of workers, fishing effort, diesel consumption per trip, vessel capacity, and engine horsepower of each vessel. The determinants of inefficiency were measured by Tobit regression model that include, family background dummy, years of education of captain,

experience of captain, age of vessel and possession of echo sounder dummy. This study showed that Penang trawl fishery still has the potential to increase the productivity and to fully utilize the inputs. The average technical efficiency for the vessels was estimated at 56.6 percent with the majority of trawl vessels having efficiency in the range of 40 to 49.9 percent. Captain and also echo sounders had positive influence on technical efficiency. Knowledge and experience accumulating from generation to generation within a fisherman family were likely to be important assets to the captain. Furthermore, higher age of vessel would have a negative influence on fishing efficiency.

Akanni and Akinwymi (2008) measured efficiency of private entrepreneurs in the Nigerian capture fisheries. Nigerian fishermen operate under two simple technologies (i) manual propulsion technology (MPT) and (ii) outboard engine technology (OET) which could be single or double engines. The maximum likelihood estimates (MLE) of stochastic catch frontier was found separately for the entrepreneur fishermen practicing manual propulsion fisheries (MPT) and for those practicing the outboard engine propulsion fisheries. The inefficiency determinants such as credit facilities, fishing experience, size of aquatic bodies were used in both methods. The data was collected from primary sources. A random sample of 150 entrepreneurs comprising of 90 private operators of MPT and 60 of OET was collected and analyzed. Information were obtained on the types of fishing technology, fish catch rate, available credit facilities, input costs and use of labour. The results indicated that the MPT operators both labour and bait were positive and highly significant. For OET operators labour, fuel, credit and ice blocks were positively contributing to the quantity of fish catch. The mean technical efficiency was estimated at 0.63 and 0.83 for MPT and OET operators respectively. In this study probit model was used to identify the

determinants of investment in and the use of motorized (modern) fishing technology among entrepreneur fishermen. The significant variables were the level of education, fishing distance, fish catch level, available credit facilities, number of contact hours with extension agents and gender. These were the success factors associated with investment in and the use of motorized engines by the entrepreneur fishermen. The study found education as a success factor towards an improved efficiency level of the fishermen. The study recommended that enlightenment campaigns and better education for the entrepreneur fishermen would further help them to attain higher efficiency levels in their fish capture operations. It also highlighted the importance of Government, corporate bodies, and extension agents. The study showed that the motorized engines were costly and unaffordable by individual entrepreneur fishermen. It was therefore suggested that these fishermen should come together in the form of cooperative societies in their states so that they may be better organized to receive assistance from various sources. If these recommendations were followed effectively and sincerely, then it would help to improve the efficiency levels of the entrepreneur fishermen in the Nigerian capture fishery. These recommendations would have a positive impact on their welfare as well.

Esmaeili (2006) examined the technical efficiency of the fishing industry, and identified factors that could be causing inefficiency of Iranian fishery in the Persian Gulf. A stochastic production function among fishery vessels was estimated. The data for the study were derived from a field study of the fishery in Hormozgan Province. A sample of 142 fishing vessels was selected using stratified random sampling, and the vessels were classified into two groups of wooden (89) and fibreglass (53) construction. Information about the vessels and socio-economic data on the fishers was collected through face-to-face interviews with skippers. Both trans-log and Cobb-

Douglas frontier production models were estimated using maximum likelihood estimation, but based on statistical criteria, the Cobb-Douglas form was preferred. The results indicate that technical efficiency in the fishery was relatively low, and that wooden vessels of medium size were more efficient than small fiberglass vessels. Both skippers' socio-economic drivers and vessel instrumentation have a significant impact on efficiency. Ownership of two-way radio and ownership of GPS are important considerations that influence fishing efficiency and the skipper's level of education and experience are qualities that also affect it. Owner-operated vessels and younger skippers were more efficient than others. Understanding these constraints may contribute to increasing the efficiency of the Iranian fishery in the Persian Gulf.

Najmudeen and Sathiadhas (2007) estimated the output elasticities associated with selected inputs and to find out the potential of optimum utilization of inputs for enhanced production of trawl fishery along the Kerala coast, southwest of India. In order to optimize the input utilization, the techno-economic efficiency of fishing operations was commonly assessed by employing various production function models. In view of the contribution of mechanized trawlers to the total marine fish production of India, an attempt was made to assess the input-output relationship in trawler operations at three major landing centres along the Kerala coast using the model Cobb-Douglas production function. The data were collected from 50 mechanised trawlers from three landing centres along with the Kerala coast for a period of five years from 1998 to 2003. The inputs such as vessel capacity units, operating costs, labour, quantity of fuel used and repairing and maintenance charges per year unit were used in the model.

The result showed that input variables such as number of fishing days per unit, fuel consumption and the quantity of fuel used in a year were significant in all three

landing centres. The study however did not use the stochastic production frontier model for measuring economic efficiency nor did it show the factors other than input effects on economic efficiency in the study. The relationship between various inputs and outputs of trawler operations were used by Cobb-Douglas production function model.

Martinez-Cordero and Leung (2005) extended the analysis reported in Martínez-Cordero and Leung (2004) for a group of semi-intensive shrimp farms in Mexico. Modifications to the traditional Total Factor Productivity (TFP) and Technical Efficiency (TE) indicators were carried out in order to incorporate in the evaluation the environmental effects of aqua cultural activities. In a framework of sustainable operations and development, these indicators (called environmentally-adjusted Total Factor Productivity EATFP and environmentally-adjusted Technical Efficiency (EATE) allow for a better assessment of aqua cultural activities, where enterprises were evaluated not only for obtaining the target product but also for how successfully farms were in generating the minimum amount of undesirable outputs (wastes or pollutants). In this study unbalanced panel of 11 farms were analyzed using an input distance function, and the environmental effects evaluated were total Nitrogen (N) and Phosphorous (P) discharges in farm´s effluents, calculated using mass balances for N and P reported for semi-intensive shrimp farms in Mexico. The results show that in all years EATE and EATFP were lower than the traditional TE and TFP scores. In the first period of evaluation (1994, 1996-1998) the TE and TFP trend was opposite to yields. As expected, years following disease outbreaks result in a drop in all the economic indicators, but the fall was bigger in 2001 compared to 1996. In the second period (2001-2003) and despite drastic reductions in annual yields, productivity and efficiency did not fall in the same proportion, meaning that both private and

governmental efforts to assure that shrimp farming operations were carried out more efficiently, with higher productivity, were producing results, even though the fact that production continues being impacted by viral diseases.

Onumah and Acquah (2010) used a single stage 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. The study was based on primary data through field survey method. The result showed that expected elasticities of mean output with respect to all input variables considered were positive and significant. The aqua culture farms operating in the said region were characterized by technology with increasing return to scale. The estimated gender dummy coefficient was significantly negative, indicating that farm decision makers who were males operate more efficiently than their female counterparts. The coefficient of age was estimated to be positive and significant in the inefficiency model which shows that older farmers are technically less efficient than the younger ones. The combined effects of operational and farm specific factors were found to influence efficiency. The study further revealed that inclusion of interaction between some exogenous factors and input variables in the inefficiency model were significant in explaining the variation in efficiency. Comparison of mean technical efficiency according to regions did not show any significant variation. The findings indicated that there was possible for the farms in this sample to improve their performance by using the best practice technology. Allocation of resources to improve the level of formal aqua culture and extension services would play an important role in this respect. Formation of aqua culture association should be encouraged to enhance coordination between young and old

farmers. It would also be important to advice large farm on how to take advantage of economies of scale to improve efficiency.

The study by Almeida, Lorenzen and Mcgrath (2003) revealed that regional differentiation in fleet characteristics and economic efficiency, as well as the total elasticity of scale in the commercial fishing fleets of the Brazilian Amazon. Data were collected through 893 interviews with boat operators in four major ports on the River Amazon. Boats operating from the largest cities (Bele´m and Manaus) were mostly operated by hired skippers and non-permanent crews, while boats from smaller cities (Santare ´m and Tefe´) were mostly owner-operated and use permanent crews. In the lower Amazon, a large proportion of fishermen (89 percent in Santare´m and 53 percent in Bele´m) were based in rural areas, while in the upper Amazon commercial fishermen are predominantly urban-based. A Cobb–Douglas production function was estimated to determine output elasticities for the different inputs, and test for regional differentiation in stock levels. A production function analysis identified boat length, gear type used (i.e, gill net or purse seine), number of fishermen employed, quantities of fuel and ice used, and education level of the skipper as significant factors determining the catch. The analysis provided no evidence of regional differences in stock levels. The use of purse seines was associated with significantly higher catches, all other factors being equal. Purse seines were banned in the lower Amazon (Santarem and Belem), and this resulted in overall lower levels of technical efficiency in this region. No significant total scale effect on efficiency was detected. These results were discussed with respect to the institutional sustainability of current fisheries co-management initiatives.

Greenville, Hartmann, and Macaulay (2006) studied the technical efficiency of fishers who operate in the NSW Ocean Prawn Trawl Fishery. A stochastic frontier analysis

was used to investigate the influence that input controls have had on the technical efficiency of fishers. Data on 61 vessels' catch, effort, and boat characteristics, and catch and effort for the remaining fishers in the fishery from 1997–98 to 2002–03 were obtained from Technical Efficiency in Input Controlled Fisheries. From this model, the vessel-specific technical inefficiency effects will be identified. In conjunction with the analysis, production elasticities, marginal productivities of inputs, and the returns to scale experienced in the fishery were analysed. Further, changes in factor productivity calculated to examine whether any inefficiencies have been offset through changes in productivity. The relationship between technical efficiency and controlled and uncontrolled inputs were examined. In addition, changes in total factor productivity were analysed to examine whether fishers have been able to partly offset managerial controls through gains in factor productivity. Using the stochastic frontier, economies of scale were examined to obtain implications for future policy decisions. The calculated returns to scale for both the trans-log and Cobb-Douglas formulations of the model were found to be greater than one. From this result, the fishery exhibits increasing returns to scale. Unfortunately, the calculated elasticities for days and capital inputs from the trans-log model are only significant at 11 percent and 10 percent. The study showed input controls have had a negative effect on the technical efficiency of fishers; however, controls do not appear to have had a lasting effect on productivity.

Demena (2011) attempted to find out the factors that are responsible for determinants of fish catch levels in Eritrean artisanal fishery. This study mainly used cross-sectional data from Fishery Development Project baseline household survey collected using the two-stage stratified cluster sampling in Eritrean artisanal fishery. Furthermore, qualitative data from both primary and secondary data sources was used.

These data sources have been triangulated with a combination of various analytical tools - descriptive statistics, bivariate analysis, multivariate regression, and the probit model. The results reveal that the type of boat, fishing experience, crew size, access to ice, and household size were positively and significantly related to catch levels. Fisher's age was negatively and significantly related to fish catch. This indicates that younger fishers are more likely to be productive. Crew size was also found to be the most important factor that affects catch. In contrast, access to credit facilities, non-fishing income and fisher's age significantly linked to reduced catch levels. In addition to the situational exploration of the characteristics of artisanal fisheries, the estimation of standardized regression coefficient showed the type of fishing boat was the most important variable in the fishery production function. This implied that enhancing fish production required the adoption and use of inboard motorized fisheries against the less resourceful and relatively traditional outboard engine boats among artisanal fisher folks. Consequently, a probit model employed to pin down the likelihood relation between adoption and use of inboard motorized fishing technology and fisher's characteristics, household resource endowment, and technology characteristics. Access to credit facilities, cooperative membership and operational costs were found to influence the artisanal fishers towards the adoption and use of better fishing technology.

Felthoven (2001) estimated of harvesting capacity and utilization in the catcher-processor sector of the Bering Sea and Aleutian Islands Pollock fishery, and analyzed many of the changes brought about by the American Fisheries Act (AFA) in 1998. The study used two proposed methods for measuring fishing capacity – one is stochastic production frontier (SPF) approach and the other is data envelopment analysis (DEA) in multi-input, multi-output applications to the catcher-processor

fleet. The purpose of using these two models was to compare the efficiency of fishing capacity from SPF with those generated using DEA techniques. The resulting capacity estimates from the models were then compared and used to characterize the degree of excess capacity in this sector of the pollock fishery and illustrated that substantial differences in capacity estimates might arise when the stochastic aspects inherent in harvesting technologies are ignored. Since DEA and SPF models allow one to analyze technical efficiency in production, the frameworks were also used to compare pre- and post-AFA technical efficiency among individual vessels and the Pollock catcher-processor fleet as a whole. Results from both the DEA and SPF models indicated that the mean TE scores for AFA-eligible vessels exceeded those of the AFA-ineligible vessels. The study clearly justified the use of two models in capacity estimates.

Eggert (2000) examined the level and determinants of technical efficiency for a sample of Swedish demersal trawlers, which mainly target Norway lobsters but also shrimps and demersal fish. The data on per-trip gross revenues, fishing effort, gear choice, month of fishing and vessel attributes were analyzed using a trans-log stochastic production frontier, including a model for vessel-specific technical inefficiencies. Output elasticities and returns to scale were also examined. The technical inefficiency effects were found to be highly significant in explaining the levels and variation in vessel revenues. The mean efficiency for the sample vessels was estimated to be 64 percent. The inefficiency model indicated that fishers were more efficient the more hours they fish, that older vessels were less efficient, that vessels from a city were more efficient than vessels from more rural areas, while the size of vessel did not influence efficiency according to the results. The first hypothesis, that inefficiency effects are not stochastic and that technical inefficiency effects were absent, was rejected. Hence, the traditional average production function

(OLS) was not an adequate representation of the data. The rejection of the second null hypotheses implied that the technical inefficiency effects do not have a traditional half-normal distribution with zero mean. The returns to scale was estimated at 0.76. The hours coefficient was negative, which indicated that the fishers were more efficient the more hours they fish. The estimate of GRT was not significantly different from zero, i.e., the larger vessels would not contribute more efficient. The age coefficient was positive, which implied lower efficiency with increasing age. The overall mean technical efficiency (TE) was estimated to 0.64. Despite the importance of allocative efficiency, due to data constraints, this study dealt only with technical efficiency.

Walden and Kirkley (2000) measured productive efficiency and fishing capacity. This study presented several programs for modeling production efficiency and fishing capacity. The programs were written in the General Algebraic Modeling System (GAMS) language, a mathematical programming language used in a variety of linear, nonlinear, and mixedinteger programming models, general equilibrium models, and network models. Each program in this work book used data envelopment analysis (DEA) to calculate measures of productive efficiency and fishing capacity. The sections describe several linear programming models to estimate input and output technical efficiency and capacity output based on the approach used by Färe *et al.* (1994). Each model is accompanied by an example and description of a GAMS program. One advantage GAMS has over other available DEA programs is that it allows direct estimation of the variable input utilization rate. The value of lambda is the ratio of the optimal use of each input to its actual usage. Various DEA models were presented which estimate input-oriented technical efficiency, output-oriented technical efficiency (with and without explicit slack variables), capacity, and capacity

utilization. Each model was accompanied by a GAMS program. A key objective was to demonstrate the flexibility of GAMS in modeling DEA problems. This was particularly important in fisheries where production problems generally differ from the standard model.

A related study was conducted to determine factors affecting the technical efficiency of the inshore fisheries in Kuala Terengganu, Malaysia, by Aisyah, Arumugam, Hussein and Latiff (2012). The study was based on primary data collected from the fishermen during peak and non peak season. Data envelopment analysis (DEA) and Tobit analysis were employed to determine the technical efficiency level and factors influencing technical efficiency among the fishermen. Results showed that, most fishing units exhibit a low degree of technical efficiency, which implied that either fishing inputs were used inefficiently or insufficient inputs were used in fishing activities. Technical efficiency during peak and non peak season was clearly explored. The mean technical efficiency for the sample was estimated to be 55 percent for the peak season and 40 percent for the non peak season. Management variables (planning, staffing and controlling) and demographic variables (size of horsepower, size of family and formal education) exert positive effects on technical efficiency of inshore fisheries in Kuala Terengganu. These findings suggested that there was much room for improvement in efficiency among a large segment of the inshore fishermen. With appropriate training and using more advanced technologies, fishermen' level of technical efficiency could be raised.

Lokina (2008) measured technical efficiency and skipper skill using Tanzanian fishery data for the two artisanal fisheries targeting either Nile perch or dagaa in Lake Victoria. The purpose of this study was to analyze the relative level of efficiency and to explore potential proxies for skipper skill. The effects of skipper skill were

included in technical inefficiency and assessed it through simultaneous estimation of a stochastic production (both neutral and non-neutral), frontier functions, and an inefficiency function. The results suggested that the Tanzanian artisanal fishers of Lake Victoria were relatively technically efficient and that skipper skill played a role in the efficiency of the boat. For the Nile perch fishery, efficiency increased when the skipper had more experience. The two factors of skippers owning their vessels and revenues being shared after cost deduction imply increased efficiency. For the dagaa fishery, efficiency increased with the skippers' education. In both fisheries, efficiency increased if the owner shared 50-50 with the crew. A particularly interesting finding for both fisheries was that the local management (beach management units, or BMUs) led to improved efficiency. Development of the BMUs could potentially contribute to necessary limitations of capacity, which would make sustainable efficiency improvements for the Tanzanian fishers of Lake Victoria possible.

Weningera and Waters (2003) controlled access management in the northern Gulf of Mexico commercial reef fish fishery, including vessel entry restrictions, a total allowable catch (TAC) policy that is enforced with periodic fishery closures, and per-trip catch limits for qualifying vessels, has failed to achieve key management objectives. The study provided an ex-ante estimate of potential economic benefits under tradable harvest permits, one of the management alternatives being considered by industry and the Gulf of Mexico Fishery Management Council. Under tradable permits, or property rights-based management, fishing mortality was controlled by allocating exclusive, tradable rights to harvest specified quantities of fish during each harvest season. The directional distance function (DDF) provides a complete functional representation of the feasible set. The DDF gives the maximal translation of activity in the reference direction that keeps the translated activity in the feasible

set. The data also exhibit considerable variation in total catch quantities. The maximum total catch per-trip for all species is 11 times larger than the per trip average, and the maximum total catch per season was 4.4 times larger than the seasonal average. Large variation in the number of trips per season further illustrated large variation in the scale of operation. A Wilcoxon–Mann–Whitney nonparametric test of the null hypothesis of common performance for classes 1 and 2 vessels (harvesting strictly positive) was rejected at 1 percent level of significant. This result is consistent with expectations once one recognizes that class 1 vessels harvested on average 30,000 pounds of red snapper under distorting regulations whereas, class 2 vessels harvested on average roughly 1000 pounds of red snapper under distorting regulations.

Kareem, Dipeolu, Aromolaran, Akegbejo-Samson (2008) conducted a study on fishing activity in Ogun State, Nigeria. The study investigated the costs and returns of the respondents and the stochastic frontiers production analysis was applied to estimate the technical, allocative efficiency and economic efficiency among the fish farmers using concrete and earthen pond systems in the State. The results of economic efficiency revealed an average of 76 percent in concrete pond system while in earthen pond system it was as high as 84 percent. The results of the analysis of the mean technical efficiency for both systems revealed that in concrete pond system it was 88 percent while earthen pond system it was 89 percent. Similarly, the allocative efficiency results revealed that in concrete pond system the figure was 79 percent while earthen pond system it was 85 percent. Stochastic production frontier estimates revealed that pond area, quantity of lime used, and number of labour used were significant factors that positively contributed to the technical efficiency of concrete pond system while pond, quantity of feed and labour were the significant factors in

earthen pond system. The results therefore concluded that only years of experience was the significant factor in concrete pond system in the inefficiency sources model. On the basis of the findings, the study suggested that government of Nigeria should provide a conducive environment for the establishment of both concrete and earthen pond system;, encourage more citizenry, mostly youth to set up both pond systems in a bid to alleviate poverty and un-employment in the State and the country at large.

Truong (2009) investigated the level and determinants of technical efficiency for a sample of gilnnet fishing vessels operating in Da Nang in 2009 by using a stochastic production frontier, which involved the simultaneous estimation of a trans-log stochastic frontier model and a model for vessel-specific technical inefficiencies. Furthermore, the other important determinants of this fleet were also examined such as the output elasticities, marginal productivities of inputs, and returns to scale. The empirical results suggested that the effects of technical inefficiencies were found to be considerably significant in explaining the differences in individual vessel efficiencies. The mean technical efficiency for the sample vessels was estimated to be a relatively low, 0.76, implied that this fleet had potential to improve the productivity at least in the short-run, given the availabilities of their technology and resource conditions. The analysis also demonstrated that engine power, vessel size, net-contributors, and owner-operated vessels had a positive impact on vessel efficiency, although the effects of vessel-size and owner-operator effects were insignificant. Whereas, vessel age had a strong negative effect on technical efficiency, it may seem strange when this analysis suggests that the experience and education level of fishermen also has a negative side, even though the effect of fishermen's education level was found to be insignificant.

Hiariey, Mulyono and Baskoro (2011) conducted a study to examine annual changes of fishing capacity of small-pelagic fishery at the Fisheries Management Area of Banda Sea, Moluccas, Indonesia. The study was based on panel data collected by covering 22 time points starting from 1985 until 2006, and were considerably reviewed and computed. The fishing gears and fishing effort were then treated as variable inputs, while catch as a variable output. Fishing efficiency was measured in this study by using data envelopment analysis (DEA) approach. The increase in efficiency was found in period 1989 to 1992 because proportion of increasing production was larger than that of fishing unit, but proportion of fishing trip got smaller. 6 out of 22 decision making unit (DMU) had efficiency score of 1 and this score was used as a base value in determining relative efficiency. The findings included annually estimated technical efficiency and its scale, the optimal allocation of fishing inputs, status of fishing capacity, and strategy of input utilization.

Kompas,Che and Grafton (2004) estimated technical efficiency effect of input controls in a fishery the northern prawn fishery of Australia. The study was used unbalanced panel data to estimate the stochastic production frontiers for the northern prawn fishery from two different data sets 1990–1996 and 1994–2000. A trans-log specification production function was initially estimated, but a pre-test with the null hypothesis of the Cobb-Douglas as the correct functional form could not be rejected for two models under two different data sets. The study showed that technical efficiency depends negatively on an unregulated input, gear headrope length, but positively on a measure of vessel size and engine power that was used to control fishing effort. The mean technical efficiency of both data sets were 0.725 and 0.774 respectively for the periods 1990-1996 and 1994-2000. The study was important because it showed that the substitution to unregulated inputs (gear headrope length)

from regulated inputs had contributed to a decline in overall technical efficiency. It suggested that the use of input controls, especially limits on engine and hull size, had been contrary to the stated objective of the fishery regulator to maximise economic efficiency. The main conclusion of this study was that fishery managers need to pay particular attention to the inputs that were controlled, and to the possibilities of input substitution and their effects on technical efficiency when regulating a fishery.

Olayiwola (2013) analyzed the factors influencing technical efficiency of fish production in ijebu-ode Local Government Area of Ogun state. Random sampling technique was used in selecting the 150 farmers from the Ijebu-ode Local Government Area. The technical efficiency was measured by stochastic production frontier based on Cobb-Douglass production function. In this study, inputs like hired labour and family labour were considered in the production frontier model. The results also revealed that coefficients of pond size, fingerlings and family labour were positive while feed and hired labours were negative and statistically significant in fish production. The inefficiency inputs like capital, year of schooling and farming experience all have positively influence on technical efficiency. The return to scale was 0.61 indicating a positive decreasing return to scale and production was in stage II. The policy implication was that there was still more opportunities to raise the present level of technical efficiency of the fish production in the study area. The study made recommendation to encourage young people to practice fish farming. Finally, suggestion was made to carry out further research on fish farming as related to food security and food sufficiency.

Hoyo, Espino, and Toribio (2004) measured determination of technical efficiency of fisheries a case on the Gulf of Ca´diz, Spain. Four different types of models used in this study one that is deterministic frontier analysis for cross-section data estimated by

COLS. Second model comprises stochastic frontier analysis for cross-section data. Third model was fixed-effects model for panel data estimated by Least Square Dummy Variable. And the final model was stochastic frontier analysis for panel data estimated by Maximum likelihood method, assuming a half-normal distribution for the inefficiency error term. Different models result in different estimates of parameter values and of technical efficiency. For cross-section data, model one provided much lower estimates of inefficiencies than model two, but vessels were sorted in the same way in relation to inefficiencies. These differences were caused by the consideration of stochastic influences in the capture function in model 2. Model 2 is nearly the same as model 1 except for the intercept, as expected because of the mutual consistency of the two estimators. Two conclusions were drawn firstly, the higher the useful life of vessels is, the smaller the technical efficiency is; and secondly, the present total allowable catch regime based only on vessels larger than 12 m was unsuitable for this fishery.

Fousekis, P. and Klonaris, (2003) conducted a study to measure technical efficiency and its interactions with vessel and skipper-specific characteristics for the fleet of trammel netters in Greece. Primary data was collected from 532 trips of 39 trammel netters during the period May 2000 to April 2001. Technical efficiency was estimated using trip data from a sample of vessels applying stochastic frontier model along with the inefficiency effects model. The result showed that the coefficient associated with labor was positive and statistically significant while coefficient associated with gear was negative implying that an increase in the use of this input results into wiping out differences in TE. The results further indicated that larger vessels tend to be less technically efficient than the smaller ones. The scale elasticity at the sample mean was found at 1.26 implying that trammel netters in Greece operate under increasing

returns to scale. The inefficiency effects such as education, family background were found to have a positively influence on TE. It appeared that skippers with primary education tend to be less technically efficient than those with higher education levels. The positive effect of the family background dummy indicates that the stock of knowledge and experience accumulating from generation to generation within a fishermen family was likely to be an important asset for skippers. The parameters associated with age were statistically significant. Their signs imply the existence of 'life-cycle effects'. In particular, TE increases with a skipper age but at a decreasing rate.

Sharma and Leung (1999) measured technical efficiency and its determinants for a sample of domestic longline fishing vessel operating in Hawaii in 1993. Trans-log stochastic production frontier was estimated for firm-specific technical inefficiency effects in order to identify the relevant vessel and operator-specific variables, experience of the fishermen, education dummy vessel size, vessel age that could influence technical efficiency. Data was collected from two sources, a cross sectional survey was conducted to collect information including vessel characteristics, fishing targets and operating costs. The second source was the 1993 sales and revenue data from the Hawaii Department of Aquatic resources commercial catch reports. All output and input variables used in the study were measured on a per-trip basis. Output elasticities, marginal productivities of inputs and returns to scale were also investigated. The result showed that the mean technical efficiency level was recorded as 84 percent. Vessels that target swordfish, and those varying target by season, set, or trip, tend to be less efficient than those vessels targeting tuna and those mixing targets in all trips. Experience of the fishermen was found to be positive and highly significant on technical efficiency. Other inefficient effects such as vessel size and

fishermen's education level were positive but insignificant influence on vessel efficiency. The result also showed that returns to scale (the sum of output elasticities for all inputs) was 1.87 thus implying that Hawaii based longline fishery was operating under increasing returns to scale. The study suggested that further analysis should be done on the seasonal effects on efficiency by collecting trip-level production data to estimate the separate production frontier for each target group with large sample size. It further suggested that future studies should also focus on measuring allocative and economic efficiency.

Pascoe and Coglan (2002) examined the variations in the technical efficiency of demersal trawlers operating in the English Channel through the estimation of a stochastic frontier production function. The data collection was recorded from log book where detail inputs and quantity of output for the UK demersal boats operating in the English Channel, were available over a four-year period (1992 to 1995). For comparative purposes, both a normal and frontier production functions were estimated. The most important measurable factor affecting efficiency was the age of the vessel. However, unmeasurable factors accounted for about 65 percent of the variation in efficiency, and as much as 9 percent of the total variation in catches between boats. It was postulated that most of this variation was due to differences in skipper and crew skill. The study suggested that improved search technology may give some skippers an advantage over those using less efficient technologies. Improved sonar equipment could increase the ability of skippers to find fish, and hence the advantage of some of the traditionally better skippers who had better knowledge of the fishing grounds might be reduced.

The studies reviewed above provide the general guidelines or direction of further research. Although there may be several approaches to a new study on technical

efficiency and its non-input socioeconomic determining factors for the selected sample of Sone Beel fishermen in Karimganj district of Assam, only a few selected aspects out of the broad approaches observed in the above literature reviews may be practically implemented. A lot of points crop up from the research articles reviewed above. For example, some studies were dedicated towards efficiency of fish production and open access of fishing in both inland and marine fishery. On the other hand many studies compared measurement of technical efficiency of fish catch by using stochastic frontier approach along with the inefficiency effects model and data envelopment analysis simultaneously. It is also reviewed that in many studies Cobb-Douglas production frontier specification was preferred to trans-log stochastic production frontier as an econometrically more appropriate functional form to capture the technological relationship between inputs and output. Finally the problem of efficiency measurement in planned fisheries (man-made tanks/ponds/reservoirs) owned by individuals or co-operatives poses a different problem where a set of firms or entrepreneurs produce a homogeneous or heterogeneous product. Here each fish producer may be viewed as an individual firm. However the present study is on catch efficiency in open access fishing (as monsoon or peak season is considered only) in a large wetland (beel area) or catchment area that spreads immensely during June to September every year.

Largely based on the above literature the present study selects a specific approach to measurement of technical efficiency and the factors outside inputs that influence it. For instance fisherman here is viewed as the catcher who either singly or with the help of a team harvests fish in a very large water-body where property rights are not defined. Thus either the catcher or the catch team becomes the unit of efficiency measurement and production frontier analysis and estimation. Thus for teams the

measurement and analysis has to be at the team level. But for individual catchers who are not part of a team, the measurement and analysis has to be at the individual level.

Moreover several studies point out the role of certain vital non-input determinants of technical efficiency. These factors are outside the direct or endogenous inputs in the production function. The above studies suggest that factors which are hypothised to explain technical efficiency variations across fishing teams are age, experience, education, non fishing income of the fishermen. These factors are also incorporated in the present study as non-input determinants of technical efficiency. Finally although the studies reported above are all significant and renowned contributions to literature in their own merits, a few gaps in research on fish catch efficiency across countries and regions are identified below. These gaps provide opportunities for further or newer studies in this area of applied micro-econometrics. These gaps are enlisted in the following sub-section.

2.3 The Research Gap

It is observed that though there are many studies worldwide on fish catch efficiency, but similar studies in India are very rare. This is perhaps due to non-availability of reliable data on inputs and outputs in Indian fishing scenario. However in case of India two such studies on technical efficiency measurement are just touched upon, like for instance the one by Singh et al., (2009) and another due to Najmudeen and Sathiadhas (2007)**.** But the influence of non-input factors may have been modeled in a more effective manner in order to explain efficiency differentials across catchers.

Four points crop up from this review. First, stochastic production frontier models and their estimation in Indian fisheries are rare. Second, influences of standards of living, overall quality of life and other selected socio-economic variables on the level of

technical efficiency of fish catch are rarely studied by researchers. Third, apart from one in case of Tripura, no micro-econometric studies on fishing efficiency have been conducted in the North-East, and in particular no such studies have been conducted in Assam. Forth, the studies that are available in literature, e.g., Kalirajan (1981), Pitt and Lee (1981), Heshmati and Kumbhakar (1997), Hassanpour et al., (2011), Singh et al., (2009), Aisyah, et al., (2011), Lim, Lalif and Hussein (2012) and others, use a two step approach to measure farm level technical efficiency and influence of non input factors on farm level technical efficiency.

This literature gap in this area justifies the necessity and importance of the present research undertaking. The present study avoids the two stage method and adopts the Kumbhakar, Ghosh and McGuckin (1991) and its improvement, namely the Battese and Coelli (1995) one stage maximum likelihood method, for simultaneously measuring farm level technical efficiency and impact of inefficiency effect variables (basically the exogenous or environmental factors and some other non-input factors). In this context, the proposed study seeks to bridge the above research gap by making a systematic study of the problems faced by a typical Sone Beel fisherman in Karimganj district of Assam. Accordingly, based on the experience of the existing literatures, the study focuses on the key reasons behind socio-economic backwardness of fishing households and thus provides invaluable policy suggestions of the sole objective of promoting the standards of living and thus the overall quality of life of this age old fishing community of Southern Assam. Finally, there is no study till today has been undertaken on efficiency measurement in Sone Beel region.

A study on technical efficiency of fish catch in Sone Beel region is important for many reasons. One, measuring technical efficiency of the fishermen and identifying the non input factors impacting on it will provide indications for the formulation of

economic policies likely to improve fishermen efficiency and fish stock in general. Two, at the micro-level, improved efficiency helps to increase the levels of income through increased profit and hence reduce poverty. Three, given the high costs of fish production and the low productivity, knowledge on technical efficiency levels will provide guidelines to government on how to improve output by fishermen. To sum up, the present study is both important as well as pioneering in nature as there are no studies reported till date on the efficiency measurement and its socio-economic correlates among traditional fishermen fishing in the Sone Beel in Southern Assam.