Technical Efficiency and Small-scale Fishing Households in Tanzanian coastal Villages: An Empirical Analysis.

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Abstract

The effort to conserve fisheries resources and improve the welfare of small-scale fishing households is an important objective of Poverty Reduction Strategies (PRS) in Tanzania. The success of such strategies depends both on the variation and the level of efficiency within small-scale fishing households. This paper examines the technical efficiency of small-scale fishing households in Tanzania using data from two coastal villages (Mlingotini and Nyamanzi). A stochastic frontier (with technical inefficiency effects) model is specified and estimated. The estimated mean technical efficiency of small-scale fishing households is 52%. Results show that the efficiency of individual fishing households is positively associated with fishing experience, size of farming land, distance to the fishing ground, and potential market integration and negatively related to non-farm employment and bigger household sizes.

We find that future policies aiming at targeting conservation-development issues in fishing communities should be concerted to provide mechanisms, which improve the access of small-scale fishing households to less destructive fishing tools via provision of credits, and markets as well as the creation of new employment opportunities in other sectors.

Keys words: Fishing households, Fisheries development, Stochastic production frontier, Technical efficiency, Tanzania

JEL codes: D13, O13, Q22,

1. Introduction

In Tanzania, the role of fishing in national development, both from a poverty alleviation point of view and from a national economic perspective, poses some interesting concerns. For a long time, fishing has been regarded as one of the most important activities, which form the basis of livelihood of households living along the coast (UN, 1992; Coughanowr, et al., 1995; Moffat, et al., 1998; Lindèn and Lundin, 1996). The fisheries sector is almost entirely dominated by small scale, poor fishing households who produce 95% of total marine catch in Tanzania (Semesi, et al., 1998; TCMP, 2001). The contribution of marine fishery to the GDP varies between 2.1-5.0% for Tanzania mainland and 2.2-10.4% in Zanzibar (Jiddawi and Öhman 2002). Fish caught in Tanzania is primarily consumed on the home market, where per capital consumption has been estimated to be between 25-30 kg $person^{-1}$ (Jiddawi, 2001). The fisheries products are important exports products, creating earnings of US$ 12.0 million for Tanzanian mainland and US$ 0.6 for Zanzibar (Jiddawi, 2001)[1].

The demand for fish in Tanzania is increasing due to the increase in population living along the coast and with the expansion of tourism activities (Francis and Bryceson, 2001; TCMP, 2003). As a result, the number of households participating in fishing is increasing due to high prices driven by high demand of both fish and fish products (Bagachwa and Maliyamkono, 1994). However, recently Tanzania has witnessed a poor performance of fishery productivity, in terms of production per unit efforts. The reason being that the sector is characterized by open access where there is crowding of efforts to coastal inshore waters. This is attributed to the lack of technical skills and capital on the fishing households' side to go beyond the inshore waters. The intensity has been increasing in the inshore waters and leads to over fishing (Jiddawi, 2001). 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 incorporate socio-economic and environmental objectives in their planning decisions. In Tanzania, sustainable development in the small-scale fishery sector, associated with

[1] Fisheries products include shellfish (shrimps and lobster) and crabs.

increased income of households participating in fisheries is one of the major targets of the national plans[2]. In addition to this, the World Bank has recently launched a new grant within the Global Environment Facility (GEF) for the Tanzanian Marine and Coastal Environment Management project (WB, 2005). The project aims at promoting coastal resource management and improving quality of life and social wellbeing of coastal households.

The fisheries sector, despite being an important source of livelihood for the majority of coastal households, has been plagued by a number of problems. These include poor and inefficient fishing gears and vessels, lack of capital, poor fisheries management, limited access to better market coupled with poor handling facilities, poor infrastructure and high post-harvest losses (Semesi, et al., 1998; TCMP, 2001). Together with a lack of alternative employment opportunities and increased number of fishing households, the above mentioned problems have been the main cause of the decrease in fish catch as well as degradation of fish stock and over-exploitation. As a result, most households will continue to be trapped in poverty. The main challenge for the growth of small-scale fisheries is how to improve production performance while, at the same time, ensuring sustainable level of fisheries resources. Therefore, measurement and analysis of small-scale fishing households' performance become important.

Various initiatives have been undertaken by international organizations, governmental and non-governmental organizations in order to ensure that fishing activities bring about economic, social and nutritional benefits. The initiatives have focused on the necessity of making small-scale fishing households more efficient, while finding a way to conserve fisheries resources by combining management of limited access to fisheries resources and incentives for participants to exit the sector (Allison and Ellis, 2001). However, these initiatives did not consider the importance of small-scale fishing households behavior in their decision-making process.

Although the importance of fishing households' behavior has often been raised in policy debates on coastal resources management, little empirical evidence is available on

[2] The National Fisheries Sector Policy and Strategy Statement of 1997 and the National Environmental Policy of 1997, both stress the need to promote conservation development and sustainable management of fisheries resources. Implementation of the Fisheries Master Plan of 2002 is also geared towards supporting those initiatives so that the resource contributes more to the livelihood of the fishers.

the validity of such arguments. This implies that there is a need to understand the nature of small-scale fishing households' operations and how small-scale fishing households respond to regulations or other stimuli with respect to their preferences. This will enable policy makers to develop efficient policies targeting coastal resources conservation and households' welfare. Empirical studies suggest that productivity in fishing depends on the fishing households' preferences, technology, assets endowments (physical, financial, human and social), and available infrastructure (Gaertner et al., 1999; Salas, 2000; Salas and Gaertner 2004). Nevertheless, although the literature suggests a number of explanations to this phenomenon, there have not been any recent empirical studies in Tanzania, which can validate these hypotheses. In this sense, the empirical evidence is very important in order to identify the factors that limit the productivity of small-scale fishing households so that policies can be designed to enhance efficiency based on recent and reliable information.

Taking the above into consideration, this paper measures and analyses the performance of small-scale fishing households in Tanzanian coastal villages. The paper applies a stochastic production frontier model, which measures the relative technical efficiency in a consistent way while also shedding light on the factors associated with these efficiency differences based on a framework that has been used in other fisheries studies (see for example, Sharma and Leung, 1999; Squires, et al., 2003; Lokina, 2005). The availability of such knowledge can be a valuable aid to policy makers in designing policies to improve the overall efficiency and hence improve the welfare of fishing households. Data used in this study originates from an on-site survey collected between January – March 2004 based on a sample of 217 households, of which 124 households were fishing (for details see Sesabo and Tol, 2005).

The rest of the paper is organized as follows. Section 2 presents the theoretical framework while section 3 describes the data, variables and empirical model. Section 4 presents empirical results and discussion and section 5 offers conclusion and policy implications.

2. Methodological issues

In this paper we used a stochastic production frontier to calculate technical efficiency of each fishing household. The production frontier represents the maximum output attainable for each input level given the state of technology. Firms operate either on a frontier (they are technically efficient) or beneath the frontier (they are technically inefficient). The technical efficiency (TE) in production refers to the achievement of maximum potential output from a given amount of factor inputs, taking into account physical production relationship. Figure 1 illustrates these concepts for a simple process in which a single input produces a single output. The production frontier is OV. The firm operating at point A is technically efficient, while the firm operating at B is technically inefficient. The TE score for the technically efficient firm is 1, while for the technically inefficient is $q / q*$.

Aigner et al. (1977) and Meeusen and van den Broek (1977) were the first to propose the modeling estimation and application of stochastic production frontier**.** The production frontier analysis models are motivated by the idea that deviations from the production 'frontier' may not be entirely under the control of the production unit under the study. These models allow for technical inefficiency, but they also acknowledge the fact that random shocks outside the control of producers can affect output. They account for measurement errors and other factors, such as weather conditions, diseases, etc, on the value of output variables, together with the effects of unspecified input variables in the production function. The main virtue of stochastic frontier model is that, at least in principle these effects can be separated from the contribution of variation in technical efficiency. The stochastic frontier approach is preferred for assessing efficiency in fishing because of the inherent stochasticity involved (Kirkley et al., 1995). However, the distribution to be used for the inefficiency error has been source of contention (Griffin and Steel, 2004). Since households in developing countries typically fall below the maximum that is possible, the deviation from actual maximum output becomes the measure of inefficiency and is the focus of interest for most empirical work. Increasing the technical efficiency would result in the growth of production without increasing costs, that is, reducing poverty. At the same time, pressure on the environment would be checked. In addition, as the poor tend to be more efficient, income distribution would improve as well. Increasing technical efficiency thus supports all three pillars of sustainability.

The stochastic frontier model proposed by Aigner et al., (1977), and then extended by Huang and Liu (1994) and Battese and Coelli (1995) is a good approach to identify the significance of improving the productivity of small-scale fishing households. Consider fishing households denoted by i whose fishing output is determined by the following production function:

$$\ln(y_i) = x_i\beta + \varepsilon \quad \text{where} \quad \varepsilon_i = \text{vu}_i - \text{mu}_\text{i} \quad \text{(Stochastic Frontier Model)} \qquad (1)$$

Where; $i =$ 1, 2,......, N ; y_i measures the value of fishing output of the i^{th} household; x_i is (1 x K) vector of value of the inputs and other explanatory variables; and β is a 1 x K vector of unknown scalar parameters to be estimated. The error term νu_i is an idiosyncratic error term similar to that in traditional regression model and is assumed to be independently and identically distributed as $N(0,\sigma^2_{\text{vu}})$. The term captures random variation in output due to factors beyond control of the households, such as weather, measurement errors in dependent variables and omitted explanatory variables. The error term mu_i is a non-negative random variable, accounting for the existence of technical inefficiency in production and it is identically distributed as half-normal $\text{mu}_i \sim \left|N(0,\sigma^2\right|$. The inefficiency effect of mu_i is assumed to consist of both unobserved systematic effects, which vary across the small-scale fishing households. The subtraction of the non-negative random variable mu_i, from the random error νu_i, implies that the logarithm of the production is smaller than it would otherwise be if technical inefficiency did not exist (Battesse and Coelli 1992)

However, following Battese and Coelli (1995), the inefficiency distribution parameter can also be specified as

$$\text{mu}_i = \delta_0 + z_i\delta + \omega_i \quad \text{(Inefficiency Model)} \qquad (2)$$

Where; ω_i is distributed following $N(0,\sigma_\omega^2)$, z_i is a vector of household specific effects that determine technical inefficiency and δ is a vector of parameters to be estimated. Household specific factors that may affect technical efficiency include household size, fishing experience, and agricultural land-ownership, among others. Input variables may be included in both Equations (1) and (2) provided that technical inefficiency effects are stochastic (Battese and Coelli, 1995)

The condition that $\text{mu} \geq 0$ in Equation (1) guarantees that all observations either lie on, or are beneath the stochastic production frontier. Following Battese and Corra (1977) and Battese and Coelli (1995), the variance terms are parameterized by replacing σ_{vu}^2 and $\sigma_{\text{m}\mu}^2$ with

$$\sigma^2 = \sigma_{\text{mu}}^2 + \sigma_{\text{vu}}^2 \text{ and } \gamma = \frac{\sigma_{\text{mu}}^2}{(\sigma_{\text{vu}}^2 + \sigma_{\text{mu}}^2)}$$

The value of γ ranges from 0 to 1, with the value equal to 1 indicating that all the deviation from the frontier are due entirely to technical inefficiency (Coelli et al., 1998). The technical efficiency of the i^{th} household can be defined as:

$$TE_i = \frac{E(Y_i | \text{mu}_i, X_i)}{E(Y_i | \text{mu}_i = 0, X_i)} = e^{-\text{mu}_i} \quad (3)$$

Where; E is the expectation operator. Thus the measure of technical efficiency is based on a conditional expectation given by Equation (3), given the value of $\text{vu}_i - \text{mu}_i$ evaluated at the maximum likelihood estimates of the parameter in the model, where the expected maximum value of Y_i is conditional on $\text{mu}_i = 0$ (Battese and Coelli, 1988). The measure TE_i takes the value between zero and 1 and the overall mean technical efficiency of households is:

$$TE = \left\{ \frac{1-\phi\left[\sigma_{\mathrm{mu}} - (\mathrm{mu}/\sigma_{\mathrm{mu}})\right]}{1-\phi(\mathrm{mu}/\sigma_{\mathrm{mu}})} \right\} e^{-\mathrm{mu}+(1/2)\sigma_{\mathrm{mu}}^2} \tag{4}$$

Where; $\phi(.)$ represents the density function for the standard normal variable.

A variety of distributions (e.g. exponential, truncated-normal and gamma) are used to characterize the technical efficiency term mu_i in the existing literature that apply the stochastic production frontier.[3] While models that involve two- distributions parameters (e.g. gamma and truncated normal) can accommodate a wider range of possible distributional shape, their application appears to come at a potential cost of increased difficulty in identifying parameters (see Ritter and Simar, 1997). Different simulations exercises carried out by Greene (1990) indicated that the most straightforward model (i.e. half normal) is preferable to other models from an econometric point of view[4]. Hence, our analysis on the factors affecting small-scale fishing households efficiency is based on the half-normal model.

3. Data, variables and empirical model

3.1. Data

The data used for this empirical application is a sub-sample of a random sample survey conducted between January-March 2004 on 217 households in two districts in Tanzanian coastal regions. The households in the sample are located in Nyamanzi village (West district) and Mlingotini village (Bagamoyo district). The selection of the villages was purposeful rather than random. They were selected based on the consultations with the Institute of Marine Sciences in Zanzibar, for households that reflect the diversity of environmental condition and economic opportunities available to households in the coastal area.

The design and data collection was carried out under supervision of corresponding author by trained enumerators who had experience with the coastal villages surveyed. Information from these coastal households was gathered through

[3] See Kumbhakar and Lovell (2003) for a more comprehensive discussion of alternative distribution assumptions found in the literature.
[4] For details see Kumbhakar and Lovell, 2003-pp90-91

questionnaires and observations. Structured interviews were conducted with head of households covering information on households' demographic structure, labor allocation, land ownership, income sources, sales of outputs, access to markets, coastal resources problems and attitude towards management of coastal resources. Household income from agriculture, fishing, seaweed-farming, wage-employment and self-employment was estimated according to reported production (for consumption or sale) at prevailing market prices. Fishing, transport and other assets were valuated subjectively by respondents as equivalent to current resale value. From the original 217 households in the survey, 124 households participated in fishing, which was the most important occupation in the study area. Sesabo and Tol (2005) analyze other aspects of this dataset.

3.2. Variables and variables construction

Production frontiers in fisheries are generally depicted as a function of fishing efforts and stocks abundance (Cunninghum and Whitmarsh, 1980; Hannesson, 1983). In theory, fishing effort encapsulates all physical inputs used in harvesting (Anderson, 1986). In empirical works, it is typically represented as a function of certain easily measurable production inputs. In the present study, these are fishing boats and gears. Table1 describes selected characteristics of the sample of households participating in fishing occupation.

The output of fishing activity is presented in terms of total fishing income earned by the household (taking into account the value of fish sold and consumed in Tanzanian Shillings (Tshs)[5]), while yield is measured as total fishing income (Tshs) produced per hour (hr)[6]. Table1 indicates that the mean yield of fishing activity of the surveyed sample was 741 Tshs/hr, with a range of about 64.6-4808 Tshs/hr. 'The yield gap' between the average and the lowest fishing yield was 674.9 Tshs/hr and between the average and the highest was 3349 Tshs/hr. These results suggest that there is a considerable room for improving average fishing yield in the study area.

[5] During time of survey 1 US$ is equivalent to 1100 Tshs
[6] The species are typically harvested in different seasons and are sold in different markets. We converted the measurements of catches (for example kilograms, buckets, basket, number of fish etc.) to uniform prices across households. Therefore, the bulk of the variability in the dependent variable of the frontier model can be attributed to harvest rather than price changes. Revenue has been used as output measure in a number of TE studies (Fousekis and Klonaris, 2003; Coelli and Perelman, 2000; Neff et al., 1993)

Due to the nature of fishing in the study area, access to the means of production, e.g. ownership of nets, canoes etc., shape the pathway in which small-scale households undertake fishing. In addition, the access to production-enabling resources such as renting of fishing boats influence the productivity of fishing in most of coastal communities. In the present study, boat ownership and renting, as well as the possession of fishing gears are the main inputs used in fishing. Thus, boat ownership and ability to rent are used as one of fishing inputs (a proxy for fishing capital) due to the fact that they require large investment. The capital input is measured as summation of the value of fishing boats and the rental cost in Tanzanian Shillings. In addition to production inputs, fishing gears is used. All inputs are expressed in terms of their value in Tshs. On average the value of capital and gears were 169,219 Tshs and 48,225.90 Tshs, respectively (Table1). Boat ownership, boat renting and possession of fishing gears are important determinants of total fishing income (catch). Therefore, boat ownership and rental costs are used as proxies of fishing capacity.

Variables representing household characteristics employed in the inefficiency analysis include agricultural land size in hectares, household size, household head fishing experience (presented in years), the distance to fishing ground as presented by the average kilometers a household member travel from the shore to fishing ground, access to markets as measured in transport costs and a dummy variable of participation in group activities.

The net effect of land ownership on fishing efficiency is ambiguous, since participation in agricultural activities may restrict production and decisions regarding fishing activities, thereby increasing inefficiency. On the other hand, an increase in agricultural income might reduce the financial constraint, particularly for the resource poor small-scale fishing households and enable them to invest in fishing inputs. The simplified assumption is that household heads whether male or female, are also a primary decision maker on participation in various activities. Table1 shows that on average small-scale fishing households own 3.8 ha of farming land.

The household's size also has an ambiguous effect. The family size is associated with the availability of timely labor, in this case larger families are likely to be more efficient. On the other hand, a large household with more female and dependants increase inefficiency in fishing due to low supply of fishing labor. This is because in coastal rural areas of Tanzania, fishing is a male dominated activity. Table1 indicates that a typical household consists of 4.7 members. In addition, on average the shares of women workers and dependants within the surveyed sample are 31.12% and 33.12%, respectively.

Fishing experience of the household's head, which represents human capital, is generally postulated to have a positive impact on efficiency. This common view of the role of experience in fishing comes from the fact that it enables heads of households to have information on fishing ground, where fish go and spawn, and water currents. On average, households' members participating in fishing had 17.8 years of fishing experience (Table1). The distance to the fishing ground captures the availability of the fish stock. It is postulated that the longer the distance they travel to fish, the higher the fishing efficiency. Hence, its effect on technical efficiency is expected to be positive. The reason behind this is that most of fisheries resources near the shore are overexploited due to the use of poor and destructive fishing methods driven by an increase in population in coastal areas. Furthermore, if the productivity is low, and travel time is large, why bother? Table1 shows that on average the distance traveled by household members to fishing grounds was 6.8 km. Affiliation to fishing group activities provides mechanisms for mutual aid among members. These associations and groups are established to secure labor, skills, as well as credit. Therefore, the current study assumes that access to group activities have a negative effect on inefficiency. The data from the Table1 shows that 74% of households had a member who participates in group activities.

The net effect of off-farm employment on inefficiency is unclear, since participation in non-farm employment may restrict production in the fishing sector and thereby increase inefficiency. This may be due to the fact that in rural coastal settings, most of these activities do not require a higher level of initial capital and both fishing and off-farm employments activities are labor intensive. Hence participation in one activity reduces labor input to other activities. On the other hand, income from off-farm employment may reduce financial constraints, particularly for resource-poor households, enabling them to procure inputs such as fishing boats, thereby increasing productivity. On average, fishing households had yearly income of about 1,342,510 Tshs, from other activities such as self-employment as well as wage employment (Table1).

In this study, transport costs are used to capture the relationship between market integration and technical efficiency. Those households incurring higher costs sell their products far from the villages and they integrate into markets outside the local village. This implies that households with the capacity to integrate in different markets by covering of transport costs may be more efficient than those who cannot cover the costs. Fishing households had average transport costs of about 115,166 Tshs per year (Table1).

3.3 Empirical model

There are several functional forms that have been developed to measure the physical relationship between inputs and outputs. The most common forms are Cobb-Douglas (CD) and the transcendental logarithmic (translog) functions. The translog production function reduces to the CD if all the coefficients associated with the second-order and the interaction terms of fishing inputs are zero. In this study, the generalized likelihood ratio tests are used to help confirm the functional form and specification of the estimated models. The correct critical values of the tests statistic come from a χ^2 distribution (at the 5% level of significance) and a mixed χ^2 distribution, which is drawn from Kodde and Palm (1986). This study employs the following translog stochastic production:

$$\begin{aligned} \ln Y_i = \beta_0 + \beta_1 \ln capital + \beta_2 \ln gear + \beta_{11} (\ln capital)^2 + \beta_{22} (\ln gear)^2 \\ + \beta_{12} \ln gear \ln capital + \nu \mathrm{u}_i - \mathrm{mu}_i \end{aligned} \tag{5}$$

Where; the subscript i , indicates the *i*th household in the sample (*i*=1, 2, ….,124); ln represents the natural logarithm (i.e. logarithm to base e); $\beta_{ij} = 0$ for all $i \leq j = 1,2$ implying Cobb-Douglas production function. Symmetry has also been imposed by $\beta_{ij} = \beta_{ji}$ and inputs are capital and gear. Y Represents the output of fish (this is the aggregate value of fish caught per day weighted by the respective prices); *capital* represents the value of boat owned, shared or rented (in Tshs); *gear* represents the value of gears (in Tshs); β_s are unknown parameters to be estimated, $\nu \mathrm{u}_i$ is a random stochastic disturbance term and $\mathrm{m}\mu_i$ stands for technical inefficiency term.

In this study, the following model is used to estimate determinants of household specific technical efficiency. The model is specified as:

$$\begin{aligned} \text{mu}_i &= \delta_0 + \delta_1 \ln(hhsize) + \delta_2 \ln(\exp f) + \delta_3 \ln(land) + \delta_4 \ln(distf) + \delta_5 \ln(otherinc) \\ &+ \delta_6 \ln(tranpcst) + \delta_7 partic \end{aligned} \quad (6)$$

Where; *hhsize* represents number of household members; *expf* represents household head fishing experience (in years); *distf* represents distance to fishing ground (in kilometers); *land* represents the amount of agricultural land owned (in ha); *otherinc* accounted for the availability of income from other activities (in Tshs); *tranpcst* represents the total transport costs (in Tshs); *partic* represents the group dummy which has the value of 1 for households participating in groups, and 0 otherwise; δ_0 is the intercept and δ_i are unknown parameters to be estimated.

The technical inefficiencies equation (6) can only be estimated if the technical inefficiency effects, mu_i, are stochastic and have particular distribution properties (Coelli and Battese, 1996). Therefore, the following null hypotheses were of interest and were tested: no technical efficiency, $\gamma = \delta_1 = ... = \delta_7 = 0$; technical efficiency effects are nonstochastic, $\gamma = 0$; and the household specific factors do not influence the technical inefficiencies, $\delta_1 = ... = \delta_7 = 0$. Under $\gamma = 0$, the stochastic frontier model reduces to a traditional average response function that is without technical inefficiency. Various tests of null hypotheses for parameters in the frontier production functions as well as in the inefficiency model are performed using generalized likelihood-ratio test statistic defined by;

$$\lambda = -2\left[\ln\{L(H_0)\} - \ln\{L(H_1)\}\right] \quad (7)$$

Where; $L(H_0)$ and $L(H_1)$ represents the value of the likelihood function under the null H_0 and the alternative H_1 hypotheses, respectively. If the null hypothesis is true, the rest statistic has approximately a chi-square or a mixed chi-square distribution with the degree of freedom equal to the difference between parameters involved in the null and alternative hypotheses.

Since the coefficients of the translog stochastic frontier in Equation 5, do not have a straight forward interpretation, the elasticity of output with respect to kth inputs variable η_k , evaluated at mean values of the relevant data point can be derived as;

$$\eta_k = \frac{\partial y}{\partial x_k} * \frac{x_k}{y} = \frac{\partial \ln y}{\partial \ln x_k} = \alpha_k + \sum \beta_{kj} \ln x_j \tag{8}$$

Where; $x's$ are means of inputs variables (i.e. capital and gears). The elasticity, η_k , measures the responsiveness of output to 1% change in kth input. The measure of return to scale (RTS) is representing the percentage change in output due to a proportional change in the use of all inputs. This is estimated as the sum of output elasticities for all inputs. If this estimate is greater than, equal to or less than 1, we have increasing, constant or decreasing returns to scale, respectively.

4. Empirical Results and Discussion

The parameters of the stochastic production frontier model Equation (5), and those for the efficiency model, Equation (6), are estimated simultaneously using the maximum-likelihood estimation (MLE) program FRONTIER 4.1 (Coelli, 1996). Several generalized likelihood-ratio tests regarding the stochastic frontier coefficients, inefficiency model and variance parameters are summarized in Table 2. The stochastic production frontier model results and efficiency model are presented in Table 3 and Table 4.

4.1 Production Frontier

In order to be able to estimate the potential contribution of physical inputs to the level of fishing output, we estimate the normal production function using ordinary least squares. Our results indicate that 85% (Adj R^2=0.85) of the fishing output variation is explained by fishing capital and gears (Table 3)

Considering that the Cobb-Douglas form is nested within the translog function form, a hypothesis is performed to determine whether the Cobb-Douglas or the translog specification is an adequate representation of the frontier production function. Table 2 shows that the null hypothesis of the Cobb-Douglas frontier form can be rejected by the data at a 5% critical level, and hence, all results presented in this study refer solely to the translog.

The direct estimates of Equation (5) do not bear any economic meaning on them. The production elasticities for the estimation of translog model is evaluated by means of relevant data points defined by Equation (8) are 0.45 (σ=0.0207) and 0.32 (σ=0.0416) for capital and gears inputs, respectively[7]. All the coefficients have a positive relationship with respect to output. If capital value increases by 10%, there seems to be a possibility of increasing output by about 4%. The return to scale parameter was found to be 0.77 (σ=0.0256), implying a decreasing return to scale (expansion of all inputs by 1% increases output by 0.77%).[8] This is consistent with expectations, since minimum efficient scale in small artisan fishermen in developing countries is usually found to be rather low. This may be partly explained in terms of lack of communication and transport infrastructure, imperfect inputs and output markets as well as poor fishing tools due to poverty.

4.2 *Technical efficiency distribution and heterogeneity*

We report summary statistics of efficiency score by household characteristics (size of agricultural land, household size, experience in fishing, distance to fishing grounds, other income opportunities, market integration and affiliation to group activities) in Table 4. The results obtained suggest a significant degree of heterogeneity by small-scale fishing households and their characteristics. The average efficiency score are higher for the small-scale fishing households with large agricultural land, better access to far fishing grounds and markets, and other employment opportunities. This suggests that better access to these factors could improve efficiency.

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[7] The standard errors of elasticities were computed using the formula proposed by Kalirajan and Tse (1989, pp181)

[8] The standard error was calculated using the following formula:
$Var(\text{return to scale}) = Var(capital) + Var(gears) + 2\,\text{cov}(capital, gears)$, with the assumption that the covariance between two variables is approximately equal to zero.

Figure 2 provides frequency distributions of efficiency estimates using the efficiency estimates for all small-scale fishing households. A technical efficiency measure of 100 indicates a complete efficiency use of the inputs included in the frontier function specification. Figure 2 shows that the technical efficiency ranges from 13% to 100% with mean technical efficiency estimated to be 51.68%. This implies that on average small-scale fishing households could increase production by 48.12% by improving their technical efficiency. The results indicate that ca. half of households have technical efficiency of less or equal to 50%, ca. 1/5 have efficiency scores of 51 to 60%, ca. 1/10 have technical efficiency ranging from 61% to 70%, and only 17% have a technical efficiency above 70%. Despite the wide variation in efficiency, it is clear that about 70% of households seem to be skewed towards technical efficiency level of less than 61%. The results imply that a considerable amount of production can be obtained by improving technical efficiency of small-scale fishing households.

The null hypothesis specifies that small-scale fishing households are technically efficient. This implies that inefficiency effects are absent and the variables included in the inefficiency effect model, have no effect on the level of technical efficiency. This hypothesis can be rejected by the data (Table 2). This null hypothesis is also rejected, showing that the joint effect of these variables on efficiency is statistically significant.

The estimated value of the γ-parameter, which is associated with the variance of the technical inefficiency effects in the stochastic frontier, is 0.51 (Table 3). This result suggests that technical inefficiency effects are significant components of total variability of fishing output for the sample of households (Battese and Coelli, 1995). The null hypothesis, which specifies that the explanatory variables in the technical inefficiency model are not stochastic, is rejected by the data. Therefore, small-scale fishing households are not technically efficient, which implies that inefficiency effects are present. Thus, it can be concluded that the explanatory variables in the technical efficiency model do contribute significantly to the explanation of the technical inefficiency effects for small-scale fishing households in the study area.

The last assumption to be tested is that the inefficiency factor error term mu_i has a truncated normal distribution, obtained by truncating (at zero) the normal distribution with mean mu, and variance σ^2_{mu}. If mu is pre-assigned to be zero, then the distribution is semi-normal. From Table 2, it can be seen that the null hypothesis cannot be rejected by the data, which indicate the distribution of mu_i is semi-normal.

4.3 Determinants of technical inefficiency

Given the efficiency estimated for each fishing household, we proceed by identifying the determinants of this variable. We try to answer the question; why are some fishing households are more efficient than others? A negative sign on a parameter that is explaining inefficiencies means that the variables improve technical efficiency, while the reverse is true for a positive sign. Table 5 lists coefficients of the explanatory variables of technical inefficiency model. As expected, the coefficient of experience (*expf*) is negative, which means that fishing experience pay-off well. Household members who participate in fishing with more years of experience in fishing are found to be more efficient than their counterpart. The fishing experience variable appears to be an important human capital for increasing fishing productivity. This result is consistent with earlier studies on fishing sectors (Sharma and Leung, 1999; Squires et al., 2003; Tingley et al., 2005; Lokina, 2005).

The coefficient of land size (*land*) is found to have a significant negative influence on technical inefficiency (Table 5). This shows that households with large tracts of land appear to be more efficient as compared to households with less land. The reason, which is most likely to explain this result, is that in coastal settings, landless fishermen lack the opportunity to increase their capital resources and to improve fishing productivity. This suggests that agricultural land provides an important complement to many marine-based activities because of lack of financial institutions, which provides investment capital for fishing activity. These results are consistent with the findings of Sesabo and Tol (2005) for rural coastal households that land endowment is often associated with more fishing income, and a higher investment in fishing. In addition, Bailey and Pomeroy (1996) showed that many artisanal fishermen in Southeast Asia possess land that enables them to combine fishing with farming.

The distance (*distf)* to fishing grounds has a parameter value of δ= -0.09 (Table 5). This implies that fishermen who travel long distances to access fishing grounds tend to be more efficient than their counterparts. This is expected since a long distance to a fishing ground would imply larger access to fishing grounds with more fish stock. The result indicates that those households who manage to access far fishing grounds normally catch more fish. This result is further supported by the fact that fishermen with high-value fishing boats, travel a longer distance because their boats are advanced compared to their counterparts. However, the distance (distf) and boat value was found to be weakly correlated.

Concerning the variable, which captures the potential market integration (*tranpcost*), the coefficient indicates that households with higher transport costs tend to be more efficient **(**Table 5). The market integration involves transaction costs from markets, poor infrastructure and high markets margin (Sadoulet and de Janvry, 1995). In Tanzanian coastal areas, just like other rural areas in developing countries, transaction costs emanate from a number of sources. Small-scale fishing households are located in remote areas far away from service providers and major consumers of fishing products. The distance to market when combined with poor infrastructure, poor access to assets and information is manifested in higher exchange costs. The results indicate the presence of transaction costs, which suggest that rich fishing households are able to integrate into different markets than their poor counterparts. This enables them to secure high prices. As a result, richer fishing households are motivated to increase their productivity and hence they tend to have a higher level of efficiency. In addition, households with higher transport costs have market security due to the fact that they can sell their products in different markets (in both local and town markets). This is consistent with findings of Halafo et al. (2004**),** which showed that infrastructure and lack of access to markets are some of constraints facing artisanal fishermen in Lake Malawi.

Pertaining to the household size (*hhsize),* the estimated coefficient is significant and positively associated with technical inefficiency (Table 5). This means that households with a larger size tend to be less efficient than those with a smaller size. The result is consistent with our prior descriptive statistics results, which indicate that efficiency scores decreases with the increase in household size (see table 4). This implies that households with larger size have a higher proportion of dependents compared to their counterparts. The correlation between share of dependants in the household and size of households was found to be positive (0.5447), suggesting that as household size increases, the number of dependants increases too. Indeed, Parikha and Shah (1994) and Karki (2004) report a positive relationship between households' size and technical inefficiency in Pakistan and Nepal, respectively. Consequently, an increase in household size means a reduction of labor force as a result of increased number of dependants.

The income from other non-farm activities accruing to households (*otherinc*) has a significant positive impact on inefficiency. This result is in contrast with the descriptive statistics, which shows a negative correlation between inefficient and income from other non-farm employment opportunities. This implies that households with more income from these activities are more efficiency than their counterparts. One possible explanation could be that landless small-scale fishing households have significantly (p= 0.0418) low valued fishing capital compared to their rich counterparts and this does not give them a comparative advantage of participating in fishing. As a result, they opt to allocate most of their labor into other employment opportunities, thus reducing labor supply to fishing activities that is essential for enhancing production efficiency. As a result, the supply of labor to off-farm activities by households could possibly be restricting fishing production and thereby worsening technical efficiency.

5. Conclusions and Policy Implications

This paper has examines technical efficiency among a sample of small-scale fishing households in two villages using a translog stochastic frontier model. Also, information is provided on the extent of technical inefficiency in small-scale fishing households. The results obtained from this paper have shown that the average technical efficiency level is about 52%. This implies that the fishing productivity level is substantially smaller than what the fishing households could have achieved had they used productive factors more efficiently. Comparing the average efficiency levels of small-scale fishing households, we find a high level of heterogeneity. There are households with an efficiency of about 99.9%, while others have an efficiency of around 13%. This reveals that household characteristics play a crucial role in reducing efficiency.

The inefficiency model allows us to identify some determinants of inefficiency of small-scale fishing household efficiency. The findings indicate that the fishing experience, agricultural land ownership, distance to fishing ground, and the ability to cover transport costs are significant variables for improving technical efficiency. However, affiliation to groups in terms of sharing and renting fishing assets does not appear to alter the extent to which fishing households are able to produce maximum output with a given mix of inputs. This suggests that efficiency-enhancing policies need not discriminate among households on the basis of whether they participate in communal activities or not. In addition, the results show that the number of household members and the choice to participate into non-farm employment is associated with low fishing technical efficiency.

These findings have important policy implications in promoting efficiency among small-scale fishing households in the two villages studied and in Tanzania in general. The positive effect of distance to fishing grounds, in particular indicate that reduced travel costs would augment the productivity of small-scale fishing households since they will be able to access unexplored fishing grounds. This finding supports the views of Anderson (1986) and Friedman (1998) in that small-scale fishing households in developing countries have been unable to fully exploit the available fish resources. In addition to this, it was observed that the tendency of households to fish in the same ground and the use of poor fishing tools lead to the problem of over-fishing, which in turn decreases fishing productivity (see Sesabo and Tol, 2005). These results indicate that investments in fishing boats are essential in order to improve fishing efficiency and enable small-scale fishing households to access long distance, less exploited areas, which will have abundant fish resources. However, this should be selected carefully to ensure that the additional costs are recovered through increased catch and fish quality. In addition, there is a need to promote those programs that are geared towards improving credit facilities. This would offer capacity to small-scale fishing households to invest in more advanced fishing boats. As a result, households would be able to explore far away fishing grounds, thus reducing the problem of onshore over-fishing.

These findings show that the relationship between transport costs and technical efficiency is positive. The data suggests those small-scale fishing households that are able to cover high transport costs, do better in efficiency terms, than those households whom do not incur high transport costs. This means that households with higher costs have more potential to integrate in different markets while those without capacity to integrate in different markets do miss the opportunities for efficiency gains. From a poor household perspective, the result indicates that the lack of market access creates disincentives in catching more fish. Indeed, poor infrastructure has been identified as one of the major impediments to small-scale fishing households in coastal villages (Sesabo and Tol, 2005). This result points to a need of improving market access (such as investing in infrastructure) to households so as to enhance efficiency in fishing in particular for poor small-scale fishing households.

Overall, this study indicates that substantial productivity gains can be obtained by continuously improving small-scale fishing households production efficiency. Hence it is important to strengthen the capacity of small-scale fishing households, so as to improve their welfare. This can be done through their empowerment to acquire improved fishing tools and vessels. This will enable them to be efficient in their operation. Credit facilities to small-scale fishing households in most developing countries are not easily available because creditors categorize fishing as a high-risk investment. To overcome this presumption, most of small-scale fishing households form groups in order to pull resources together. Even though affiliation to group activities did not have a direct effect on efficiency, there is a need among international, governmental and non-governmental organizations to recognize the importance of formation of viable fishing groups so as to channel their support to these kinds of groups. Most of these groups are new, small and unregistered and their performance is yet to be assessed in order to improve them.

In general, this study suggests that there are several factors that could be affected by public instruments. These factors are related to input quality, specifically the acquisition of improved gears and vessels and provision of market access. Accordingly, government policies should be geared towards increasing and improving access of small-scale fishing households to capital. This would allow them to increase investment in modern fishing tools. This will not only help in reducing pressure on inshore fishing ground but also improving their efficiency. In line with this view, there is a need to promote investment in infrastructure so that fishing households can gain access to markets with their products. This will enable them to reduce their post-harvest losses. These kinds of policies may be very important in order to improve the livelihood of small-scale fishing households along the coastal regions in Tanzania.

Despite the limitation of our cross-sectional data, which makes it impossible to estimate multi-seasonal and time varying efficiency, this study sheds light on the sources of inefficiency faced by small-scale fishing households in Tanzanian coastal areas. To get a clearer picture of sources of fishing inefficiency, one important extension for analyzing the role of fishing household characteristics in fishing efficiency would be the use of seasonal and panel data. The data on fishing household behavior in Tanzania is limited, just like in other developing countries. In order to build up panel data concerning the behavior of fishing households, there is a need for government and non-government organizations, and research institutions to invest in information gathering. This is necessary so as to gain a wider knowledge of small fishing household characteristics, which is crucial in the design of policies that deals with poverty reduction.

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Table 1 Selected characteristics of the sample households participating in fishing

Variable description	Variable	Mean	Standard deviation
total fish output (Tshs.)**	*totfish*	452853	631690
Yield (total output/hour)	*tfy*	741	834
Capital value (in Tshs)**	*capital*	169219	231742
Gears value (Tshs)	*gears*	48226	62210
Household size (persons)	*hhsize*	4.7	2.2
Experience in fishing (years)	*expf*	17.8	12.9
Land owned (ha)	*land*	3.8	2.9
Distance to fishing ground (km)	*distf*	6.8	3.2
Non farm income (Tshs)**	*othy*	1342510	1506014
Transport costs (Tshs)**	*tranpcost*	115165.9	112383
Participation*	*partic*	74.2%	-

* The participation variable is specified as one for households members participating in group activities and zero otherwise
** 1 US$ =1100 Tshs in 2003

Table 2 Hypotheses tests

Null Hypothesis	Test statistics[a]	critical value[b]	Decision
$H_0 : \beta_{ij} = 0$ for all $i \le j = 1,2,3$ (Cobb-Douglas Frontier)	12.76	7.81	Reject H_0
$H_0 : \gamma = \delta_1 = ... = \delta_7 = 0$ [c] Fishing households are technically efficient (no inefficient effects)	585.2	17.75	Reject H_0
$H_0 : \delta_1 = ... = \delta_7 = 0$ (Coefficients of the explanatory variables in inefficiency model are simultaneous equal to zero)	582.6	16.81	Reject H_0
$H_0 : u = 0$	2.1	3.84	Accept H_0

a : $\lambda = -2\left[\ln\{L(H_0)\} - \ln\{L(H_1)\}\right]$ has a χ^2 distribution

b: Critical value is at 5% level

c: λ follows a mixed χ^2 distribution. The critical value are in Kodde and Palm (1986)

Table 3 Parameter Estimates of the Stochastic Production Frontier

Variable	Production Function		Stochastic Production Frontier	
	Coefficient	t-statistics	Coefficient	t-statistics
(Constant)	4.5483	1.61*	-3.5598	-11.6***
ln(*capital*)	-1.5742	-2.84***	0.4297	6.1***
ln(*gear*)	0.891	1.78*	0.4046	6.7***
ln(*capital*)*ln(*capital*)	0.1423	3.61***	0.0068	1.4
ln(*gear*)*ln(*gear*)	0.0291	0.74	-0.0013	-0.32
ln(*capital*)*ln(*gear*)	-0.1078	-1.7*	-0.0059	-0.92
Variance Parameters				
sigma-squared ($\sigma^2= \sigma^2+ \sigma_v^2$)			0.0016	8.06***
Gamma [$\gamma=(\sigma^2/(\sigma^2+ \sigma_v^2)$]			0.51	8.45***
Log likelihood			234.9	
Mean efficiency			0.52	
Observations			124	
Adjusted R^2	0.85			

Coefficients followed by (*), (**) and (***) indicate significance at 10, 5 and 1% level, respectively

Table 4 Summary of Technical efficiency by households characteristics

Households characteristics		Technical Efficiency		
		Mean	Standard Deviation	observations
Agricultural Land Ownership in hacters	0	27.15	0.0786	20
	0.1 to 2.5 hacters	44.69	0.1439	23
	2.6 to 5.5	50.86	0.1122	44
	above 5.5	70.27	0.1822	37
Household Size	less than 3 members	55.23	0.2334	17
	3 to 5 members	51.66	0.2063	68
	above 5 members	50.17	0.1742	39
Experience in Fishing	less than 5 years	21.9	0.0412	10
	5 to 10 years	37.38	0.0423	31
	above 10 years	63.22	0.1594	77
Distance to Fishing ground	less that 5 km	33.66	0.0798	51
	5 to 10 km	59.42	0.1041	63
	above 10 km	94.8	0.0524	10
Other non-farm income	less than 300001 Tshs	23.28	0.0412	14
	300001 - 600000 Tshs	36.62	0.0462	32
	600001 - 900000 Tshs	46.23	0.0201	17
	above 900000 Tshs	67.62	0.1504	61
Group Affiliation	Participants	55.79	0.1959	92
	non- participants	39.87	0.1617	32
Total transport costs	less than 100000 Tshs	41.82	0.1365	78
	100001 to 150000 Tshs	59.41	0.144	17
	above150000 Tshs	73.68	0.1769	29

Table 5 Estimated Technical Inefficiency Function

Variable	coefficient	t-statistics
(Constant)	4.4557	18.43***
ln(*hhsize*)	0.3516	9.97***
ln(*expf*)	-0.1346	5.79***
ln(*land*)	-0.0078	5.19***
ln(*distf*)	-0.0978	1.97**
ln(*otherinc*)	0.0063	5.28***
ln(*transpcost*)	-0.3358	9.84***
Partic	-0.0041	0.38

Coefficients followed by (*), (**) and (***) indicate significance at 10, 5 and 1% level, respectively

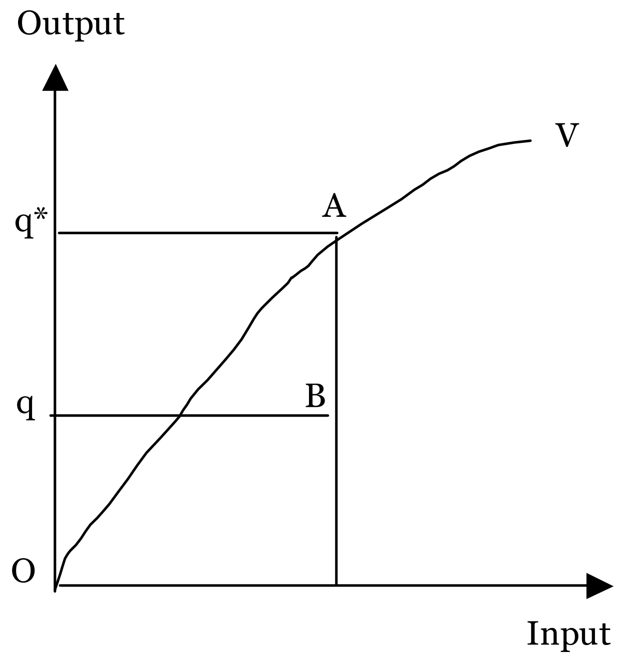

Figure 1 Technical efficiency and inefficiency

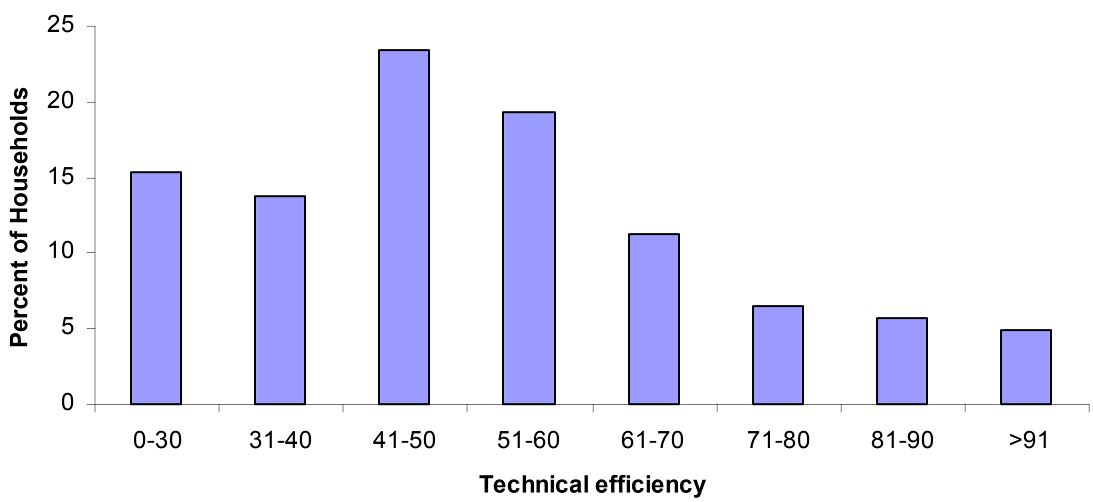

Figure 2 Technical Efficiency Scores for small-scale fishing households

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