Journal of Ocean and Coastal Economics

Volume 8 | Issue 1 Article 2

Are Small-scale Fishers in Oman Technically Efficient? The Case of Al-Batinah Coastal Fisheries

Jaynab Begum Yousuf
Sultan Qaboos University

Shekar Bose

Msafiri Daudi Mbaga
Sultan Qaboos University

Recommended Citation

Yousuf, Jaynab Begum; Bose, Shekar; and Mbaga, Msafiri Daudi () "Are Small-scale Fishers in Oman Technically Efficient? The Case of Al-Batinah Coastal Fisheries," *Journal of Ocean and Coastal Economics*: Vol. 8: Iss. 1, Article 2.
DOI: https://doi.org/10.15351/2373-8456.1125

1. INTRODUCTION

It is well-recognized that small-scale fisheries (SSF) in developing countries play a crucial role in food security and poverty alleviation, employment generation especially in the rural and coastal communities, and, therefore, contribute to the well-being of many millions people globally (FAO 2018,Tietze 2016, Teh and Sumaila 2013, FAO and WFC 2008, Béné et al. 2007). While there is no universally best way to define SSF as they differ across countries (Smith and Basurto 2019, FAO and WFC 2008, Salas et al. 2007), the characteristics (in relative terms) that are commonly used to describe SSF include the following: low level of technological sophistication, use of less capital in production, labor-intensive production, presence of unskilled labor and part-time fishers, a large number of small-size boats targeting a mix of species, poor economic returns, complicated production process influenced by culture and traditions of small-scale fishing communities, among others (Tietze 2016, Damasio et al. 2016, Salas, et al. 2007, McGoodwin 2001).

However, the sector has been confronted by a number of challenges such as overfishing, overcapacity, lack of compliance and weak enforcement, and economic inefficiency in both harvest and post-harvest operations, inefficiency in various stages of supply chain, a lack of coherent, reliable and accessible information both globally (Pomeroy 2012, de Graaf et al. 2011, Salas et al. 2007) and locally (Bose et al. 2019a, Al-Siyabi and Bose 2018, Bose et al. 2017, Al Balushi et al. 2016, Qatan et al. 2016, Al-Jabri et al. 2015, Al-Subhi et al. 2013).

Given this background, the conservation of coastal fisheries resources, biological and economic sustainability of small-scale fishing operations and the maintenance of socio-economic benefits from the resource for those who depend on it are crucial both in global and local contexts as failure to safeguard small-scale fisheries will seriously affect the livelihood of small-scale fishers. International agencies have been emphasizing on the improvement of the economic efficiency and the socio-economic viability of SSFs (FAO and WFC 2008, Tietze 2016). The desire for long-term sustainability in SSFs necessitates the assessment of economic efficiency which is one of the principal components of sustainability. Furthermore, the results from such assessments provide direction to decide on the future course of actions and insist on appropriate policy development to correct inefficient use of economic resources involving SSF in many developing countries globally. Technical efficiency (TE) - as a component of economic efficiency - is inherently linked to economic profitability of a fishing boat as it measures the ability of a producer to produce the maximum level of output for a given set of inputs and the state of production technology (Farrell 1957).

Considering the background information, the main objectives of this paper are two-fold. Firstly, to measure technical efficiency of small-scale harvesting operations involving five key demersal species (i.e., Catfish, Emperor, Grouper, Seabream and Snapper) of Al Batinah coastal fisheries in the Sultanate of Oman (See Figure 1).[1] These selected species are popular in both domestic (Yousuf et al. 2019a; Al Balushi et al. 2016) and export (Al Naabi and Bose 2020) markets and represent about 55% of the total demersal fish landings (in 2016) in the governorate. Secondly, to determine the significance of firm-specific factors affecting the efficiency of fishers' harvesting operations. These two objectives will be empirically evaluated through the application of a single-stage Stochastic Production Frontier (SPF) approach proposed by Battese and Coelli (1995) Given the stochastic nature of fisheries, this parametric approach appears to be the most appropriate tool for technical efficiency analysis in fisheries.

The present study has both local and global relevance. To the best the of authors' knowledge, there is a genuine dearth of empirical studies in the country on the assessment of technical efficiency (TE) in SSF using a parametric approach that could provide some scientific evidence on the extent of TE (or the lack of it). While technical efficiency analysis using a parametric approach has been routinely conducted in various commercial fisheries context (Kirkley et al. 1995, Campbell and Hand 1998, Sharma and Leung 1998, Pascoe and Tingley 2007, to name a few), the use of such approach involving SSF in developing countries is limited. Digal et al. (2017), Squires et al. (2003) and Zen et al. (2002) are some examples of such studies. More importantly, very little is known about the applicability of such econometric technique in efficiency analysis of SSF in developing countries. Furthermore, a review of literature on technical efficiency analysis involving SSF revealed that a number of studies used data envelopment analysis (DEA) approach due to its ability to deal with multiple inputs and outputs simultaneously. Examples of such country-specific studies include Al-Siyabi and Bose (2018) in Oman, Digal et al. (2017) in Philippines, Teame (2017) in India, Wiyono and Hufiadi (2014) in Indonesia. Empirical results (generated from the use of either parametric or non-parametric methods) of this technical efficiency literature involving SSF indicate the presence of technical inefficiency in harvesting operations, over-utilization of inputs and a lack of close harmony between the economic theory and practice (Al-Siyabi and Bose 2018; Digal et al. 2017, Rabbani et al. 2017; Zen et al. 2002).

To this end, the present paper not only fills the existing knowledge gap in SSF research concerning developing countries but also complements the existing global literature by adding country-specific information.

[1] Al-Batinah governorate is divided into two parts North and South and they are two of the eight (i.e., Musandam, North Al-Batinah, South Al-Batinah, Muscat, North Ash Sharqiyah, South Ash Sharqiyah, Al-Wasta and Dhofar) coastal governorates of Oman (See Figure 1). Al-Batinah north governorate has six coastal wilayahs (province) and they are: Sohar, Al-Suwaiq, Al-Khabura, Saham, Liwa and Shinas. Al Batinah South has two coastal wilayahs: Barka, and Musana'a (MOT 2016). Al Batinah governorate has a 275 km long coastline (Al-Oufi et al. 2000).

DOI: 10.15351/2373-8456.1125

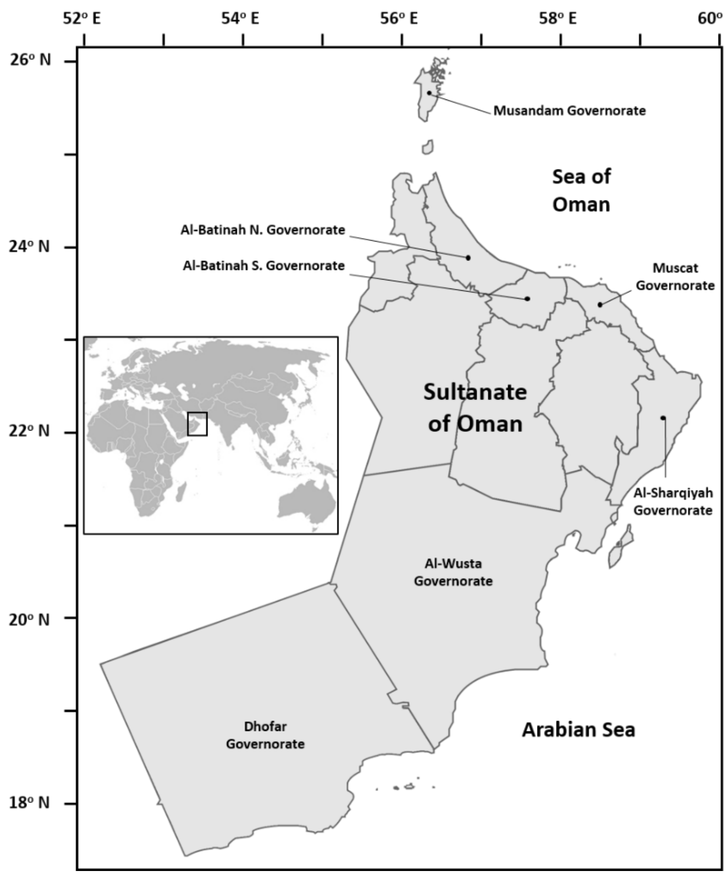

Figure 1. Map of Sultanate of Oman showing all the Governorates.

1.1. Brief Overview of Oman's Coastal Fisheries Sector

In 2019, approximately 96% of the total marine landings (approximately 555 thousand tons) was from SSF with approximate gross value and foreign exchange earnings of US$ 750 million and US$ 270 million respectively. More than fifty thousand small-scale fishers were directly involved in SSF of Oman (MAF 2020). The SSF sector is characterized as being multi-species in nature and the regulatory methods that have traditionally been used are mesh size and gear restrictions, closed seasons and areas and size limits. The small-scale fishing fleet in Oman is dominated by fiberglass boats and boats are more or less homogeneous in terms of length (Al-Siyabi and Bose 2018) with average boat length ranged 21-27 ft. (Bose et al. 2020). Consequently, small-scale fishing boats are generally limited to operate in inshore waters and carrying out daily fishing trips. Crew size is constrained by boat size and vary from 1 to 3 (Al-Siyabi and Bose 2018). Majority of boats are owner operated. Intense competition among fishers is observed by Al Oufi et al. (2000) and Belwal et al. (2012).

Since the inception of Oman Vision 2020 various Five-Year development plans were formulated for the fisheries sector to support the economic diversification policy agenda mainly aimed at raising the fisheries contribution to national income and food security (MNE 2007a; MNE 2007b). The ‘Vision 2040’ prepared by the World Bank for the fisheries and aquaculture sector is intended to create a profitable and ecologically sustainable fisheries sector in Oman (World Bank 2015). Recently, the fisheries sector was selected as one of the five promising sectors in the 9th Five-Year Plan (SCP 2017).

Various notable changes took place in the fisheries sector to promote sustainability. Examples include the ban of demersal trawl-fishing in 2009 (Al-Masroori and Bose 2016), the establishment of Central Wholesale Fish Market in 2014 at Barka, Al Batinah Governorate with specific aim at improving efficiency in fish distribution, to promote fierce competition among buyers and achieving fair price for fishers (Bose et al. 2019b; Al-Jabri et al. 2015) and the recent implementation of coastal fishery (Al-Masroori and Bose 2016). In relation to SSF in Oman, further information on the empirical assessment of the dynamics of physical capital and net investment, economic performance of specific fishing gear and other socio-economic aspects can be found in case-study format by Bose et al. (2020), Al-Qartoobi et al. (2018) and (Belwal et al. 2015), respectively.

2. METHODOLOGY

2.1 Data and Variables

The data used in this study were obtained from the Statistics department at the Ministry of Agriculture and Fisheries (MAF), Oman, using two types of survey data. First, the boat-level data on landings (kg) and gross value (Omani Rial, OMR) of five demersal species (i.e., Catfish, Emperor, Grouper, Seabream and Snapper), gear types, duration of fishing trips (hours) and crew members for the period 2000-2016 were collected from the routinely conducted survey by the Ministry of Agriculture and Fisheries (MAF), Oman. Second, the data on engine power (hp), boat age and fishers age and level of education were collected from an *ad hoc* survey conducted by the MAF in 2012. The boat ID was used to combine the vessel specific data from the two data sources.

While the high frequency boat-level data were desirable to carry out the intended empirical analysis they posed challenge as there were many zero-catch records. To minimize the number of zero-catch observations for the selected species (Catfish, Emperor, Grouper, Seabream and Snapper) the boat-level data were aggregated to give a yearly boat-level data series consisted of 740 observations for the period 2010-2016. Using landings and gross value, the price information with respect to the five species were also derived. Finally, the data set consisted of aggregate revenue per hour, number of fishing hours, number of crews, horsepower, boat age, owner's age and level of education along with dummy variables to capture yearly and spatial variation. Information regarding the boat and owner's age were adjusted accordingly to match the period of analysis. The panel data set was unbalanced due to the unequal number of boat-level observations across years. However, unbalanced panel data is not unique to the case at hand being found in other studies of technical efficiency (Guttormsen and Roll 2011). It was also found that the sampled vessels do not operate in every time period of the data that hinder the application of panel data model. Therefore, following Coelli et al. (2005) the data were pooled with the assumption that all boats have access to the same technology in every period and there are zero covariance between any error terms. In efficiency analysis this type of data pooling exercise was also conducted by Coelli et al. (2005) and García del Hoyo et al. (2004).

2.2 Output and Input Variables for Production Frontier

When the fishery is characterized by joint-production the output measure under SPF presents certain challenges since the approach considers only single output as mentioned earlier. If using quantity as an output measure some form of aggregation is required in the multi-species fisheries case. To avoid this problem of aggregation, some studies have used the value of total catch. For instance, Sharma and Leung (1998) used value of catch per trip instead of quantity as the output variable in case of the mixed Hawaiian long-line fishery. Hence, the selection of aggregate revenue per fishing hour as the dependent variable.

With regard to the input variables, engine horsepower (hp), crew size, and number of fishing hours were used. The present study followed the conventional theory of a production function and included labor, capital, and other inputs into the production function and characterized them as either fixed or variable inputs. For instance, engine horsepower (hp) was considered as a proxy for capital characteristic and crew size was considered fixed by vessel specific requirement (i.e., boat size) (Kirkley et al. 2002). Furthermore, 'number of fishing hours' was specified as variable input in the production process.

With regard to the inefficiency model (as the dependent variable measures the shortfall of output from the frontier for each productive unit), independent variables representing firm specific characteristics such as boat age, skipper age, owner education, and homeport (measured by area dummy variables) were used. Various proxies were used in the fisheries literature to capture the inter-annual variation in stock such as catch-per-unit of effort (CPUE) (Sharma and Leung 1998), dummy variables (Campbell and Nicholl 1995; Coglan et al. 1998; Bose 2001). The present study used yearly dummies in the inefficiency model as Sharma and Leung (1998) argued that CPUE is not a suitable input variable to consider in production analysis due to its possible inter-relationship with other inputs. The area dummy variables for wilayat 'Khabourah' and for the year 2016 were excluded from the inefficiency model to avoid the problem of perfect multicollinearity (i.e., the dummy variable trap). The description and the summary statistics of the variables used in the analysis are presented in Table 1.

2.3 Empirical Model

Following Aigner, Lovell and Schmidt (1977) and Battese and Corra (1977), a general functional form of the SPF involving cross-section data can be given as follows:

$$Y_i = f(X_i;\ \beta)\exp(V_i - U_i); \qquad i=1,2,3\ldots\ldots,N \qquad (1)$$

where *i* represents the ith firm; Y is the output, X is a vector of input quantities; β is a vector of unknown parameters; $V_i \sim N(0, \sigma_v^2)$ represents the random error (statistical noise) and U_i accounts for technical inefficiency and is non-negative and assumed to be iid. $N(0, \sigma_u^2)$. Further details on model specifications, technicalities, empirical applications and advantages and disadvantages of frontier techniques can be found in Battese (1992), Coelli (1995), and Murillo-Zamorano (2004), to name a few.

As there was no a priori reason for choosing one distributional form over the other, some statistical tests were performed to decide on the statistical hypothesis with regard to correct specification of the production frontier function, distribution of the technical inefficiency term, and the overall significance of the variables in the inefficiency model. A generalized likelihood ratio test as defined below was used to decide between the null hypothesis (H_0) of Cobb-Douglas functional form against the alternative (H_1) of translog functional form as follows.

$$LR = -2[ln\{L(H_0)\} - ln\{L(H_1)\}] \sim \chi^2\ (with\ df = No.of\ restrictions\ imposed) \qquad (2)$$

Where, $L(H_0)$ and $L(H_1)$ denote the values of likelihood function under the null (H_0) and alternative (H_1) hypotheses respectively. The critical values for this test statistic are provided in Kodde and Palm (1986, Table 1).

Similar empirical test is also performed to decide on the appropriate distribution of the inefficiency error term (that is half-normal versus truncated normal) and to test the null hypothesis of technical inefficiency effects are absent (that is, all parameters in the inefficiency model are jointly zero). In addition, the null hypothesis of non-stochastic technical inefficiency effects (i.e. γ=0) and joint-test on a sub-set of inefficiency factors were also performed. The results of these hypotheses tests are provided in Table 2.

Based on the test results, the following Cobb-Douglas functional form of equation (1) is used where the dependent and the independent variables (excluding binary and coding variables) are expressed in the logarithmic form. It should be noted that in a *log-log* form of the Cobb-Douglas specification the coefficient represents partial elasticity of output.

$$lny_i = \beta_0 + \beta_1 lnx_{1i} + \beta_2 lnx_{2i} + \beta_3 lnx_{3i} + v_i - u_i \qquad (3)$$

where *i* is the ith boat. The dependent variable y_i represents the 'aggregate revenue per fishing hour' and the independent variables are $x_{1i}(crew), x_{2i}(fishing\ hours), and\ x_{3i}(hp)$ of the ith boat. $\beta_0, \beta_1, \beta_2$ and β_3 are the parameters to be estimated. The $v_i\ and\ u_i$ are random variables as described above.

https://cbe.miis.edu/joce/vol8/iss1/2
DOI: 10.15351/2373-8456.1125

The next step is to define the technical inefficiency as a function of potential firm-specific factors as follows: $u_i = f(Z_i;\ \delta)$, where Z_i is a vector of firm-specific and exogenous variables and δ denotes vector of unknown parameters to be estimated. The following inefficiency model is used to capture the technical inefficiency factors.

$$u_i = \delta_0 + \delta_1 z_{1i} + \delta_2 z_{21} + \delta_3 z_{3i} + \delta_4 z_{41} + \delta_5 z_{5i} + \delta_6 z_{6i} + \delta_7 z_{7i} + \delta_8 z_{8i} + \delta_9 z_{9i} + \delta_{10} z_{10i} + \delta_{11} z_{11i} + \delta_{12} z_{12i} + \delta_{13} z_{13i} + w_i \quad (4)$$

where δ_0 is the constant, variables z_{1i}, z_{2i}, and z_{3i} represents boat age, owner age, and owner education respectively. Variables z_{4i}, z_{5i}, z_{6i} and z_{7i} represent area dummies for Shinas, Sohar, Liwa, and Saham respectively. Variables z_{8i}, z_{9i}, z_{10i}, z_{11i}, z_{12i} and z_{13i} represent annual dummies. The coefficients δ_1 to δ_{13} are the parameters to be estimated and w_i is the error term.

Following Battese and Coelli (1995), the parameters of the production frontier (3) are estimated jointly in a single-step along with the parameters of the inefficiency model (4) using the maximum likelihood techniques. The single-step process developed by Battese and Coelli (1995) avoids the problem associated with the two-stage process regarding the distribution of the inefficiency effects by jointly estimating the production frontier function and inefficiency model (Campbell and Hand 1998). The software program STATA (version 15) was used to estimate the parameters and efficiency scores.

3. EMPIRICAL RESULTS AND DISCUSSION

The description and the summary statistics of the variables used in the analysis are provided in Table 1.

Table 1. Description and Summary Statistics of variables used in SPF and Inefficiency. Models: 2010-2016 and Sample size(N)=740

Variable Description	Summary Statistics			
	Mean	**SD**	**Minimum**	**Maximum**
Stochastic Frontier Model				
Dependent Variable				
Average revenue per fishing hour (OMR)*	52.628	115.192	0.193	1319.485
Independent Variables				
No. of Crew (x_1)	2.414	0.807	1.000	7.000
No. of fishing hours (x_2)	12.011	12.553	1.000	111.000**
Horsepower (x_3) (in kW)	61.952	31.667	20.000	250.000
Factors in Inefficiency Model				
Independent Variables				
Boat age (z_1) in years	13.878	8.146	1.000	30.000
Owner's age (z_2) in years	38.264	14.042	14.000	70.000
	2.000	0.928	1.000	4.000
Education (z_3)***			0.000	1.000
Area Dummy (z_4 to z_7)			0.000	1.000

Yearly Dummy (z_8 to z_{13})				

*1 Omani Rial (OMR) ≈ 2.59 USD). * * Number of fishing hours comprises of the aggregate hours in a year. *** The different education levels were coded from 1 to 4. 1 denotes fishers who have a high school degree, 2 denotes fishers who can read and write, 3 denotes fishers who can only read and 4 denotes fishers with a higher education degree

The statistical test results for functional specification form of the production frontier are presented in Table 2. Based on the results, the null hypothesis (H_0) could not be rejected at the 5% (two-tailed) level and, therefore, supports the Cobb-Douglas functional specification.

Table 2. Test for Cobb-Douglas Versus Translog Production Function.

Independent Variables	**Log-Likelihood Value**		**LR Test Calculated χ^2**	**df**	**Tabulated χ^2 (two-tailed)**	**H_0 accept or reject?**
	Cobb-Douglas	***Translog***				
ln(hrs) ln(hp)	-1197.458	- 1193.375	8.166	3	9.348	Accept
ln(hrs) ln(crew) ln(hp)	-1196.381	- 1192.141	8.48	6	14.449	Accept

The results of the generalized LR tests concerning the distribution of the efficiency term, presence of inefficiency (γ=0) and joint significance of the inefficiency factors with regard to the production frontier model are presented in Table 3. Following Tingley et al. (2005) all the delta (δ) variables were grouped into 3 categories and then the joint likelihood test was carried out. The first group consists of the inefficiency variables that represent boat age, age of the fisher and their level of education. The second group consists of the area dummy variables and the third group consists of the yearly dummy variables.

It can be noted from the results presented in Table 3 that half normal distribution for the inefficiency model was rejected against the truncated normal distribution. In addition, the null hypothesis (H_0:γ=0) in relation to the presence of inefficiency was rejected at the 5% level. Finally, the null hypothesis with regard to the joint significance of the inefficiency factors was rejected in all cases. This lends support to the inclusion of those inefficiency factors into the model.

https://cbe.miis.edu/joce/vol8/iss1/2
DOI: 10.15351/2373-8456.1125

Table 3. Results of the Generalized Likelihood Ratio Test.

Null Hypothesis	$ln\{L(H_0)\}$	$ln\{L(H_1)\}$	**LR Test: Calculated χ^2**	**Critical Value (α =0.05)**	**df**	**H_0: accept or reject?**
Cobb-Douglas production function	-1196.381	-1192.141	8.48	14.449	6	Accept
Half-normal distribution	-1196.381	-1183.539	25.684	5.023	1	Reject
γ=0	-1228.306	-1196.381	63.85	5.138	2	Reject
$\delta_1 = \delta_2 = \delta_3 = 0$	-1196.32	-1194.971	20.39	8.542	3	Reject
$\delta_4 = \delta_5 = \delta_6 = \delta_7 = 0$	-1204.912	-1194.971	19.882	10.384	4	Reject
$\delta_8 = \delta_9 = \delta_{10} = \delta_{11} = \delta_{12} = \delta_{13} = 0$	-1206.576	-1194.971	23.21	12.103	5	Reject

Table 4 presents the estimated results for the frontier and the inefficiency model with truncated normal distribution.

Table 4. Parameters Estimated for the Frontier and Inefficiency Model.

Distribution: Truncated Normal			
Variable	**Coefficient**	**Standard Error**	**p-value**
Constant	4.737	86.576	0.956
ln(hrs)	-0.653	0.06	0.001

ln(crew)	-0.228	0.129	0.076
ln(hp)	0.188	0.119	0.115
Inefficiency Model			
ln(boat age)	-0.029	0.059	0.618
ln(fisher age)	-0.063	0.139	0.647
Education	0.024	0.054	0.645
Shinas (area dummy)	-0.449	0.165	0.007
Sohar (area dummy)	0.322	0.193	0.096
Liwa (area dummy)	-0.162	0.256	0.527
Saham (area dummy)	-0.35	0.197	0.076
Year 1 (yearly dummy)	-1.532	0.301	0.001
Year 2 (yearly dummy)	-0.592	0.341	0.082
Year 3 (yearly dummy)	-1.283	0.302	0.001
Year 4 (yearly dummy)	-1.283	0.304	0.001
Year 5 (yearly dummy)	-1.498	0.318	0.001
Year 6 (yearly dummy)	-1.231	0.324	0.001
Constant	2.77	86.577	0.974
$\gamma = (\sigma_u^2 \div \sigma^2)$	0.007	2.58	
$\sigma^2 = (\sigma_v^2 + \sigma_u^2)$	1.445	0.075	
Mean TE	0.417		
Log likelihood	-1186.270		

https://cbe.miis.edu/joce/vol8/iss1/2
DOI: 10.15351/2373-8456.1125

It is noted that the estimated mean technical efficiency score was found to be 0.417 indicating that the representative boats are on average operating in a technically inefficient manner. From the parameter estimates of frontier model it is observed that the variable *fishing hours* was statistically significant at 1% level with unexpected sign. In a case-study of SSF in Oman, Al-Siyabi (2018) observed that the overutilization rate of fishing time ranged 56.7% to 61.4% during the period 2010-2012. The negative coefficient of fishing time may suggest that a portion of revenue is dissipating. In the present context, the overutilization of *fishing hours* could be attributed to the following factors, among others. First, fishers may be spending more time in searching for target species due to differences in resource availability among locations (Yousuf and Bose 2019a). Second, abundance of target species as biological overfishing of key species was also observed by others in Al-Batinah coastal fisheries (Yousuf and Bose, 2019b). Third, overestimation of fishing hours as the recorded time in the survey data represents the trip duration not the true fishing time. Fourth, fishers' lack of knowledge about productive fishing grounds or the small boat-size hinders fishers' movement and ability to reach productive grounds. In a case study by Abernethy et al. (2007) involving Anguillian artisanal fisheries it was observed that lack of knowledge prevented small-scale fishers from choosing fishing grounds with the greatest economic benefits. Last but not least, data measurement error as data gathering from interviews relies on fisher's accuracy. In addition, in field survey it is likely for observational and data measurement errors to creep into the recording process that may arise from data collector's recording accuracy and approximation.

While the variables *crew* and *hp* were not statistically significant, the variable crew carried a negative sign. This theoretically inconsistent result with regard to crew is not uncommon in fisheries (Al-Jabri et al. 2015; Viswanathan et al. 2002) and agricultural farming (Reddy and Sen 2004). In the present case, this negative elasticity for crew could be due to the use of family members or relatives as crew (Al-Jabri et al. 2015) and/or due to input congestion caused by the boat size.

It is also noted that the estimated value of 'γ' which represents the proportion of total variance in the combined error $(v_i - u_i)$ attributable to inefficiency is 0.007. While the variables *boat age*, *owner's age* and *education* were statistically insignificant they carried theoretically unexpected signs. With regard to 'area dummy' one area dummy (i.e. Shinas) was statistically significant at the 5% level. It is also observed that, 5 out of 6 yearly dummies were found to be statistically significant at the 5% level. Therefore, it can be suggested that the boat-level inefficiency was influenced by the location of the vessels and inter-annual fluctuation of fish stocks proxied by yearly dummy variables. With reference to inefficiency model, it should be noted that a negative sign of the estimated coefficients indicates that an increase in independent variable results in a decrease in technical inefficiency (or increase in TE) *other things being equal*.

Figure 2 presents the frequency distribution of the boat-level TE scores. The results indicate a considerable degree of technical inefficiency at the boat-level resulting in the low mean TE score over the study period.

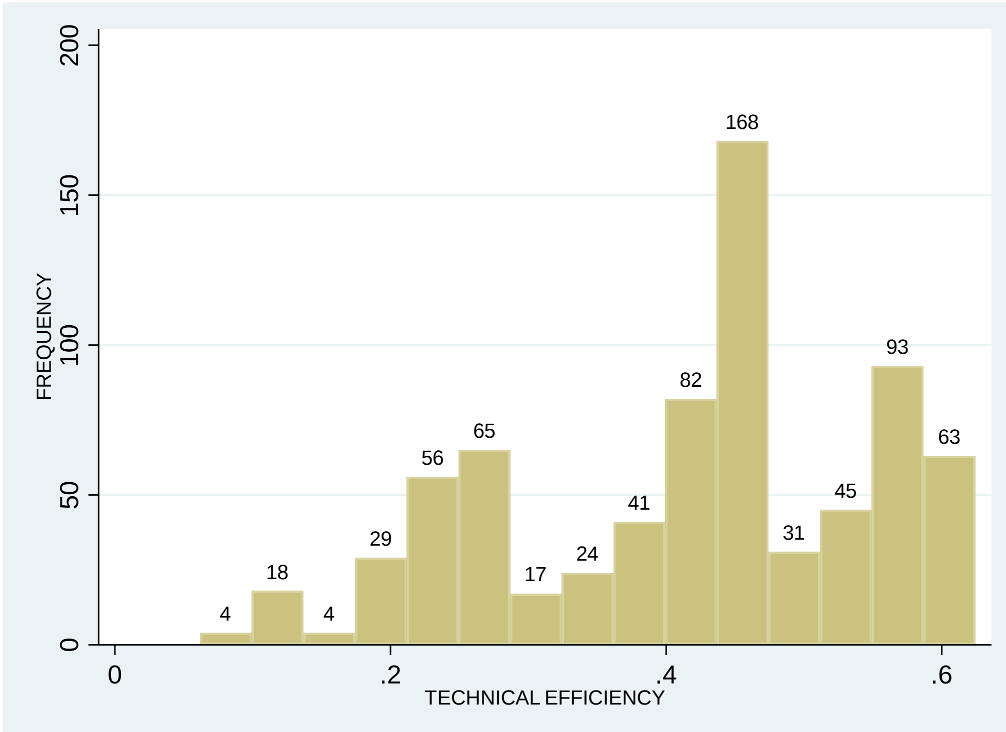

Figure 2. Frequency Distribution of Individual TE Scores.

4. OVERALL DISCUSSION

This paper applied sophisticated efficiency analysis technique to a small-scale fishery case in Oman, normally applied to industrial fisheries. A number of observations can be made from the results of the present case study. While one can argue that the basic characteristics of production function was misrepresented by the use of average revenue per hour as dependent variable, the inherent properties of production relations should prevail as small-scale fishers in Oman are price takers (Al-Siyabi and Bose 2018). With the exception of the capital input (hp), the frontier model results revealed that the input-output relationships with regard to fishing time and crew variables were not consistent with the expectations of the economic theory of production (i.e. increase in the level of inputs should bring positive change in the level of output). In the SSF context, these unusual production relations could be attributed to the following factors, among others. First, the complicated production processes of small-scale mixed fisheries (Salas, et al. 2004) influenced by cultural and traditions of small-scale fishing communities (McGoodwin 2001). In Oman, fishers are not allowed to cross the geographical boundary due to traditional rules (called Senate Al-Bahar) that constrains fishers' movement and ability to extract resources. In Anguillian artisanal fisheries case, Abernethy et al. (2007) found that not all fishers are profit maximizers and variations in social, economic and physical characteristics of fishers hindered fishers' movements and ability to extract resources. Second, overestimation of fishing time as stated earlier and the lack of coherent and good quality data observed in SSF. Third, input variables (i.e., fishing hours, crew and hp) used in the frontier model are components of a composite input - fishing effort. Therefore, complementary relationships among all inputs are required to improve catch (or revenue). In this regard, the negative effects of fishing time on the production process may be influenced by negative contribution of crew which in turn influenced by the small boat-size and unskilled family labours. Fourth, while this case study complements a comparatively limited global literature on economic performance of SSF in developing countries a particular lesson can be learned from this study in relation to the application of the sophisticated empirical approach like SPF to efficiency analysis in SSF. In line with the above discussion, one needs to recognize the factors such as, data inadequacy and quality resulting from limited financial and human resources, extent of industrialization, capital constraints (small boat size), un-skilled family labour, culture and traditions of small-scale fishing communities, among others are influencing the assessment of economic efficiency in SSF and, therefore, decide on the suitability of the econometric techniques with great caution. However, it is difficult to formulate a clear universal statement about the applicability of SPF as such applicability, to a great degree, would be subject to particular circumstances as described above. A careful consideration of the data set utilized and of the intrinsic characteristics of the small-scale fishery under consideration will guide practitioners in deciding on the appropriate implementation of the production frontier technique in efficiency analysis.

It should be noted that the extent to which the model estimates and the TE measures (average and boat-level) presented in the paper are sensitive to data adequacy and the choice of techniques remain uncertain. Also, the analysis of the sources of inefficiency as explained by the inefficiency model are not directly attributable to the production frontier. Notwithstanding, the results presented in the paper has important implications for development strategy in the sector. For instance, if the objective is to increase technical efficiency in harvesting operations and maintain the current employment status then the management authority should design appropriate technical skills development initiatives for fishers (Bose et al. 2013). This approach was also recommended by Belwal et al. (2015) in case of Al-Batinah fishers to enhance their technical skills and to change their attitudes and behavior. Furthermore, given the dearth of employment opportunities for fishers, the technical skills development initiative should encompass the notion of *occupational pluralism* to empower fishers for alternative work opportunities in related industry such as aquaculture and fishing tourism (Busaidi et al. 2019). The exploration for alternative sources of income for fishers is crucial to minimize the potential variability in fishers' income resulting from the inter-annual and spatial variability in stock abundance as the results indicated. Other approach could be to improve the so-called 'X-efficiency' (Leibenstein 1966) a major element of which is 'motivational efficiency' or 'incentive efficiency'. Under this measure, best performance fisher can be motivated by awarding for best performance in a public gathering which is likely to have positive spill-over effect on other peer fishers and help improve overall TE in fisheries. Another possible measure could be to give best performance fisher to gain international exposure by providing them with the opportunity to visit small-scale fisheries operation in other developing countries. This will promote awareness among fishers and may improve their realization of their own responsibility towards fisheries sustainability.

5. CONCLUSION

The existing literature on the application of technical efficiency analysis techniques to small-scale fisheries is vague on where the fine line is below which the technique may be inappropriate. The present paper has investigated this limit and revealed that fishers' harvesting practices are not in line with the conventional microeconomic principles of production. The cultural characteristics and traditions of small-scale fishing communities, traditional laws, use of un-skilled family labour, capital (i.e., small-size boats) and market constraints under which small-scale fishers operate, and locational differences in resource abundance seem to have an impact on the representative fishers' 'best practice' and hence, affected the shape and location of the efficient production frontier and hampered the effective use of the production frontier technique. The reasons listed to explain the negative coefficients of input variables (fishing time and crew) and the estimated TE score of less than unity for all representative boats (figure 2) seem to give credence to this line of argument. The paper has also revealed that the limitations of data and measurement errors prevalent in SSF significantly limit the application of the frontier technique. While more work is needed to get a better understanding of the production process in SSF, the results of this paper are consistent with the findings reported in other local and global studies. Based on the results, the present case study does advocate some policy directions that can be considered in Oman fisheries case. In this context, the present paper illustrates the potential contribution by providing empirical evidence and advocating that the strengths and limitations of the production frontier technique should be kept in mid in applying it to small-scale fishery situations.

DOI: 10.15351/2373-8456.1125

6. REFERENCES

Abernethy, Kirsten E., Edward H. Allison, Philip P. Molloy, and Isabelle M. Côté. "Why do fishers fish where they fish? Using the ideal free distribution to understand the behaviour of artisanal reef fishers." *Canadian Journal of Fisheries and Aquatic Sciences* 64, no. 11 (2007): 1595-1604.

Aigner, Dennis, CA Knox Lovell, and Peter Schmidt. "Formulation and estimation of stochastic frontier production function models." *Journal of Econometrics* 6, no. 1 (1977): 21-37.

Al-Balushi, Abdullah Hilal, Shekar Bose, and Anesh Govender. "Stakeholders' views on management arrangements: A case of kingfish fishery in the Sultanate of Oman." *Natural Resources* 7, no. 05 (2016): 251.

Al-Qartoubi, Ibrahim Abdullah, Hussein, Al-Masroori, and Shekar Bose. "Modelling compliance in small-scale fisheries: a case study from the Sultanate of Oman." *Asian Fisheries Science* 33, no. 2 (2020): 28-144.

Al-Jabri, Omar, Ray Collins, Ximing Sun, Shekar Bose, and Rakesh Belwal. "Measuring relationship marketing effect in small-scale fishing in Oman and enhancing efficiency and economic gains for traditional fishermen." *Marine Fisheries Review* 77, no. 4 (2015): 20-29.

Al-Masroori, H. S., and S. Bose. "Anchoring to determine negotiated catch limits: a case study of an industrial fishery in Oman." *African Journal of Marine Science* 38, no. 1 (2016): 101- 109.

Al-Oufi, Hamed, Andrew Palfreman, and Ewen McLean. "Observations upon the Al-Batinah artisinal fishery, the Sultanate of Oman." *Marine Policy* 24, no. 5 (2000): 423-429.

Al-Qartoubi, Ibrahim A., Shekar Bose, Hussein Samh Al-Masroori, and Anesh Govender. "Circle hook versus J-hook: A case study of the Sultanate of Oman." *Journal of Agricultural and Marine Sciences [JAMS]* 23 (2018): 29-39.

Al-Siyabi, M.S. 2018. "An Empirical Assessment of Technical Efficiency and Capacity in a Regional Fishery of Oman." PhD Thesis, Sultan Qaboos University, Oman.

Al-Siyabi, Mohammed, and Shekar Bose. "Capacity utilization in small-Scale fisheries: A case of the Sultanate of Oman." *Sri Lanka Journal of Aquatic Sciences* 23, no. 2 (2018): 163-172.

Al-Subhi, Khalid Khalifa Nasser, Shekar Bose, and Hussein Samh Al-Masroori. "Fishers' compliance motivations: A case study of the Sultanate of Oman." *Marine Policy* 37 (2013): 141-148.

Battese, George Edward. "Frontier production functions and technical efficiency: a survey of empirical applications in agricultural economics." *Agricultural economics* 7, no. 3-4 (1992): 185-208.

Battese, George Edward, and Tim J. Coelli. "A model for technical inefficiency effects in a stochastic frontier production function for panel data." *Empirical Economics* 20, no. 2 (1995): 325-332.

Battese, George E., and Greg S. Corra. "Estimation of a production frontier model: with application to the pastoral zone of Eastern Australia." *Australian Journal of Agricultural Economics* 21, no. 3 (1977): 169-179.

Belwal, Rakesh, Shweta Belwal, and Omar Al Jabri. "The fisheries of Oman: A situation analysis." *Marine Policy* 61 (2015): 237-248.

Belwal, Shweta, Rakesh Belwal, and Fadhil Al-Shizawi. "Fishermen on the Batinah Coast in Oman: a study from the subsistence marketplace perspective." In *E-Marketing: Concepts, Methodologies, Tools, and Applications*, pp. 618-635. IGI Global, 2012.

Béné, Christophe, Graeme Macfadyen, and Edward Hugh Allison. *Increasing the contribution of small-scale fisheries to poverty alleviation and food security*. No. 481. Food & Agriculture Organisation, Italy, Rome, 2007.

Bose, Shekar. "The Australian South-east Fishery: An analysis of quota species supply and demand." (2001).

Bose, Shekar, Farha Al-Kindy, Abdullah Al-Balushi, and Mohammed Maadood Rajab. "Accounting the unaccounted: Case of women's participation in shellfish harvesting in the Sultanate of Oman." *Gender, Technology and Development* 17, no. 1 (2013): 31-53.

Bose, S., Al Balushi, A. H., Al-Haddabi, A., & Al-Bulushi, R. (2019a). Is Co-management Feasible in Achieving Fisheries Sustainability? A Case of Oman's Lobster Fishery. *Journal of Agricultural and Marine Sciences [JAMS]*, *24*, 2-18.

Bose, S., Al-Naabi, A. M. R., Boughanmi, H., and Yousuf, J. B. (2019b). Domestic ban versus border rejections: A case of Oman's fish exports to the EU. *SAGE Open*, *9* (1), 1-12.

Bose, S., Al-Masroori, H. S., and Al-Habsi, A. M. H. A. (2017). Traditional fisheries enforcement program: A case of three coastal villages in the eastern part of Oman. *Marine Policy*, *78*, 61-67.

Bose, S., Al-Masroori, H. S., & Al-Hasani, S. D. S. (2020). Dynamics of Physical Capital in Artisanal Fisheries and Policy Implications. *Journal of Agricultural and Marine Sciences*, *25*(2), 46-57.

Busaidi, M. A., Bose, S., Claereboudt, M., & Tiwari, M. (2019). Sea turtles tourism in Oman: Current status and future prospects. *Tourism and hospitality research*, *19*(3), 321-336.

Campbell, Harry Fleming, and A. J. Hand. "Joint ventures and technology transfer: the Solomon Islands pole-and-line fishery." *Journal of Development Economics* 57, no. 2 (1998): 421-442.

DOI: 10.15351/2373-8456.1125

Campbell, Harry F., and R. B. Nicholl. "Allocating yellowfin tuna between the multispecies purse seine and longline fleets." *Marine Resource Economics* 10, no. 1 (1995): 35- 58.

Coelli, Timothy J., Dodla Sai Prasada Rao, Christopher J. O'Donnell, and George Edward

Battese. *An introduction to efficiency and productivity analysis*. springer science & business media, 2005.

Coglan, Louisa, Sean Pascoe, and R. I. D. Harris. "Measuring efficiency in demersal trawlers using a frontier production function approach." In *Proceedings of the Xth Annual Conference of the European Association of Fisheries Economists, The Hague, Netherlands, 1-4 April 1998*, pp. 236-257. 1998.

de Graaf, Gertjan J., Richard JR Grainger, Lena Westlund, Rolf Willmann, David Mills, Kieran Kelleher, and Kwame Koranteng. "The status of routine fishery data collection in Southeast Asia, central America, the South Pacific, and West Africa, with special reference to small- scale fisheries." *ICES Journal of Marine Science* 68, no. 8 (2011): 1743-1750.

de Melo Alves Damasio, Ludmila, Priscila Fabiana Macedo Lopes, Maria Grazia Pennino, Adriana Rosa Carvalho, and Ussif Rashid Sumaila. "Size matters: fishing less and yielding more in smaller-scale fisheries." *ICES Journal of Marine Science* 73, no. 6 (2016): 1494-1502.

Digal, L. N., Ramil, H. S. I., Placencia, S. G. P., & Balgos, C. Q. (2017). Technical efficiency of municipal fisherfolk in Maasim, Saranggani Province, Philippines: a stochastic frontier and data envelopment approach. *Asian Fisheries Science*, *30*(3), 169-184.

Farrell, Michael James. "The measurement of productive efficiency." *Journal of the Royal Statistical Society: Series A (General)* 120, no. 3 (1957): 253-281.

FAO, Food. "The state of world fisheries and aquaculture." *Opportunities and challenges. Food and Agriculture Organization of the United Nations* (2012).

Food and Agriculture Organization of the United Nations; World Fish Center. 2008. *Small-scale Capture Fisheries : A Global Overview with Emphasis on Developing Countries.* World Bank, Washington, DC. © World Bank. https://openknowledge.worldbank.org/handle/10986/16752 License: CC BY 3.0 IGO.

Garcia del Hoyo, Juan Jose, David Castilla Espino, and Ramón Jiménez Toribio. "Determination of technical efficiency of fisheries by stochastic frontier models: a case on the Gulf of Cadiz (Spain)." *ICES Journal of Marine Science* 61, no. 3 (2004): 416-421.

Guttormsen, Atle G., and Kristin H. Roll. "Technical efficiency in a heterogeneous fishery: the case of Norwegian groundfish fisheries." *Marine Resource Economics* 26, no. 4 (2011): 293-307.

Kirkley, James, Catherine J. Morrison Paul, and Dale Squires. "Capacity and capacity utilization in common-pool resource industries." *Environmental and Resource Economics* 22, no. 1- 2 (2002): 71-97.

Kirkley, James E., Dale Squires, and Ivar E. Strand. "Assessing technical efficiency in commercial fisheries: The mid-Atlantic sea scallop fishery." *American Journal of Agricultural Economics* 77, no. 3 (1995): 686-697.

Kodde, David A., and Franz C. Palm. "Wald criteria for jointly testing equality and inequality restrictions." *Econometrica: Journal of the Econometric Society* (1986): 1243-1248.

Leibenstein, Harvey. "Allocative efficiency vs." X-efficiency"." *The American Economic Review* (1966): 392-415.

MAF (Ministry of Agriculture and Fisheries) 2020. Fisheries statistics year book of 2019, Oman.

McGoodwin, James R. *Understanding the cultures of fishing communities: a key to fisheries management and food security*. No. 401. Food & Agriculture Org., 2001.

MNE (Ministry of National Economy) (2007a). *Long-Term Development Strategy (1996- 2020): Vision for Oman's Economy (Oman 2020)*; Ministry of National Economy, National Center for Statistics and Information, 2007.

MNE (Ministry of National Economy) (2007b). Seventh Five-Year Development Plan 2006–2010. Muscat, Sultanate of Oman: National Center for Statistics and Information, 2007.

Murillo-Zamorano, Luis R. "Economic efficiency and frontier techniques." *Journal of Economic surveys* 18, no. 1 (2004): 33-77.

Naabi, Amina Al, and Shekar Bose. "Do Regulatory Measures Necessarily Affect Oman's Seafood Export-Supply?." *SAGE Open* 10, no. 3 (2020): 2158244020950658.

Pascoe, Sean, and Diana Tingley. "Capacity and technical efficiency estimation in fisheries: Parametric and non-parametric techniques." In *Handbook of Operations Research In Natural Resources*, pp. 273-294. Springer, Boston, MA, (2007).

Pomeroy, Robert S. "Managing overcapacity in small-scale fisheries in Southeast Asia." *Marine Policy* 36, no. 2 (2012): 520-527.

Rabbani, M. G., Khan, M. A., Islam, M. S., & Lucky, R. Y. (2017). Technical efficiency of the setbag net fishery in Bangladesh: An application of a stochastic production frontier model. *The Agriculturists*, *15*(2), 59-65.Reddy, A. R., and C. Sen. "Technical inefficiency in rice production and its relationship with farm- specific socio-economic characteristics." *Indian Journal of Agricultural Economics* 59, no. 902-2016-68050 (2004).

Salas, Silvia, Ratana Chuenpagdee, Juan Carlos Seijo, and Anthony Charles. "Challenges in the assessment and management of small-scale fisheries in Latin America and the Caribbean." *Fisheries research* 87, no. 1 (2007): 5-16.

SCP (2017) Vision 2020. Supreme council for planning, Sultanate of Oman. available at: http://www.scp.gov. om/en/Page.aspx?I=14.Sharma, Khem R., and Pingsun Leung. "Technical efficiency of the longline fishery in Hawaii: an application of a stochastic production frontier." *Marine Resource Economics* 13, no. 4 (1998): 259-274.

Smith H and Basurto X (2019) Defining Small-Scale Fisheries and Examining the Role of Science in Shaping Perceptions of Who and What Counts: A Systematic Review. Front. Mar. Sci. 6:236. doi: 10.3389/fmars.2019.00236

Squires, D., Grafton, R. Q., Alam, M. F., & Omar, I. H. (2003). Technical efficiency in the Malaysian gill net artisanal fishery. *Environment and Development Economics*, 481-504.

Teh, Lydia CL, and Ussif Rashid Sumaila. "Contribution of marine fisheries to worldwide employment." *Fish and Fisheries* 14, no. 1 (2013): 77-88.

Teame, G.T. (2017). Efficiency and Capacity Utilization of India's Marine Fisheries. Management and Organizational Studies 4 (3):14-24.

Tietze, Uwe. "Technical and socio-economic characteristics of small-scale coastal fishing communities, and opportunities for poverty alleviation and empowerment." *FAO Fisheries and Aquaculture Circular* C1111 (2016): I.

Tingley, Diana, Sean Pascoe, and Louisa Coglan. "Factors affecting technical efficiency in fisheries: stochastic production frontier versus data envelopment analysis approaches." *Fisheries Research* 73, no. 3 (2005): 363-376.

Yousuf, J. B., Bose, S., Kotagama, H., and Boughanmi, H. (2019a). Preferences and intentions of seafood consumers in Oman: An empirical analysis. *Journal of International Food & Agribusiness Marketing*, *31*(2), 175-203.

Yousuf, J. B., and Bose, S. (2019b). Long run versus short run estimates of sustainable yield: A case of small-scale demersal fisheries in Oman. *Journal of Sustainability Science and Management*, *14*(5), 55-75.

Viswanathan, K. Kuperan, Ishak Haji Omar, Yongil Jeon, James Kirkley, Dale Squires, and Indah Susilowati. "Fishing skill in developing country fisheries: the Kedah, Malaysia trawl fishery." *Marine Resource Economics* 16, no. 4 (2001): 293-314.

Wiyono, E.S. and Hufiadi. (2014). Measuring the technical efficiency of purse seine in tropical small-scale fisheries in Indonesia. Asian Fisheries Science 27: 297–308.

World Bank (2015). Sustainable Management of the Fisheries Sector in Oman: A Vision for Shared Prosperity. Report Submitted to Ministry of Agriculture and Fisheries, Oman.

Zen, L. W., Abdullah, N. M. R., & Yew, T. S. (2002). Technical efficiency of the driftnet and payang seine (Lampara) fisheries in West Sumatra, Indonesia. *Asian Fisheries Science*, *15*(2), 97-106.