Journal of Science and Technology 19 (June 2021): 82-91 *ISSN 1994-0386*

A STOCHASTIC PRODUCTION FRONTIER ANALYSIS OF TECHNICAL EFFICIENCY OF LONGLINE MARINE FISHERY IN COASTAL BANGLADESH

M.G. Rabbani[1]* and M.J. Kabir[2]

[1]Department of Economics, Hajee Mohammad Danesh Science and Technology University, Dinajpur, Bangladesh; [2]Agricultural Economics Division, Bangladesh Rice Research Institute, Gazipur-1701, Bangladesh

ABSTRACT

The paper aimed to assess the technical efficiency of longline fishing boats in Bangladesh to provide policy suggestions for formulating the regulation of marine fishery management. The cross-section data were collected from the head crew of 100 longlines fishing boats from Chattagram and Cox's Bazar in 2018. The technical efficiency and inefficiency effects of some specific variables were assessed by applying a translog stochastic production frontier model. The mean technical efficiency of small-scale marine longlines fishing gears was 85%. Besides, total cost (0.290) and the number of hooks (0.246) have a significant ($P \leq 0.000$) positive impact on efficiency in the longline fishing gears. However, the crew size (-0.116) had significant ($P \leq 0.006$) negative impact on fishing. Moreover, age of head crew (-0.300), education of head crew (-0.529) and horse-power of boat engine (-0.088) had significant ($P \leq 0.052$) positive effect on inefficiency. The technical efficacy of longline fishing gears can be enhanced through (i) replacing the old gears and boats with modern equipment and vassal and (ii) by developing the skills of crews through providing training. Thus, policy supports are needed for changing the marine fishery regulation and the infrastructure of longline fishery.

Keywords: Technical efficiency, longline, translog stochastic, Bangladesh

INTRODUCTION

Bangladesh possesses vast marine water resources; the role of marine fisheries in total fish production was only 15% (BBS 2018). The growth rate of marine fisheries (0.8%) was notably lower than culture (3.46%) and freshwater capture (1.58%) fisheries. Although Bay of Bangle is blessed with about 511 marine species, its contribution to the national fish production is not satisfactory that is about 16.28 percent of total production (Murshed *et al.* 2014 and Shamsuzzaman *et al.* 2017). A significant decrease had been shown in the production of the marine fisheries since last twenty years. But a significant

*Corresponding author: Email: drgolamrabbani65@gmail.com, Cell phone: 8801717226779

amount of foreign exchange earning comes from this marine sector (Islam & Haque, 2018 and Shamsuzzaman *et al.* 2020). In case of export of these marine resources, a positively increasing trend was captured during periods from 2000 to 2011 but there was no such trend or rapid increase in exports for marine fisheries during period 2016-2017 (Shamsuzzaman *et al.* 2020). The majority of the commercially targeted stocks are reported to be over-exploited and there were significant declines in catches during last 2-3 decades. In the Bay of Bengal, both industrial and artisanal fisheries exploit coastal and offshore marine fisheries resources without any management plan. (Hussain *et al.* 2010 and Shamsuzzaman *et al.* 2020). On the other hand, the fish stock has been decreasing because of the lack of regulation for limiting indiscriminate catch of marine resources. The availability of destructive modern fishing gears affected on fish production. The government sets utmost priority regarding the protection, conservation and biodiversity of marine and coastal resources (Hussain *et al.* 2010). A large number of industrial trawler fleet is used for catching shrimp and finfish in the coastal water bodies. The small-scale operations include small-scale near shore fry fishing with push and drag nets are dominated in the marine fisheries in Bangladesh. The overall deployment length of set bag nets, gill nets and longlines of the manual and power operated boats were in the range between 6 to 12 meters. Longline gear is highly target specific, non-destructive and can be operated with low power engines. Sails can be used for propulsion to reduce fuel consumption and environmental pollution. With some modification to their traditional fishing, skilled fishers can use this method. The operation can be semi-automated by shooting the gear manually and hauling it back with a mechanical device (George 1993). The small-scale fishing operation catches multi-species and different sizes and ages. The near-shore resources are heavily exploited. Therefore, all of these fishing gears need to be brought under the rules and regulations (FAO 2004). The small-scale sector should bring under co-management arrangements through zoning for controlling inputs and reserving resources. Besides, both the marine fisheries and aquaculture are highly exposed to climatic variability and climate change (FAO 2014). Appropriate marine resources harvesting policy substantially affected the fish stocks. As a result, the marine fisheries policy in particular the precautionary approach and the ecosystem approach need to be developed for improving the structure, function and biological diversity of the wider ecosystem (and vice versa). Finally, modern fishing gear needs to be adopted; mechanized fishing vessels should be registered and limits their catch (Hussain *et al.* 2010). It is critically very important to assess the efficiency of fishing gears for increasing their efficiency and harvesting capacity. The effects of random variation in output can be separated from inefficiency by the stochastic production frontiers (Xuan *et al.* 2011). The assessment of technical efficiency is an effective approach for improving the management of open water capture fisheries. The social benefit of the marine resources can be improved through efficient utilization of labor, capital and marine resources. However, there is a lack of researches on the assessment of technical efficiency of commercial fisheries due to inadequate data and the complexity of small-scale fisheries in the Southeast Asian region (Xuan *et al.* 2011). Onumah *et al.*

(2018) studied on the production rick and technical efficiency of fish farm in Ghana where they applied stochastic frontier production function with translog model to identify the efficiency. They estimated technical efficiency score of 0.74 on average and also identified that about 26 percent potential output was lost due to the technical inefficiency. On the contrary another study was done by Islam *et al.* (2016), where they also used stochastic frontier analysis to identify technical efficiency among the fish farmers of Malaysia. The result showed that only 37 % farms were technically efficient in fish cultivation which was very low. Moreover, none of the studies found to assess the technical efficiency of longline fishing gears in Bangladesh. The main objective of this paper is to examine the level and determinants of technical efficiency of Longline fishing boats, based on their 2018 operating cost and catch data. Due to its flexible properties, a translog stochastic production frontier is estimated. Other efficiency measures, especially allocative efficiency, are important in fishery management, but due to data constraints, this paper focuses only on technical efficiency. Therefore, the estimation of technical efficiency of the longline fishery would be highly useful to researchers and managers as well as policy people in formulating fishery management regulations in Bangladesh.

The traditional bio-economic model is unable to assess the economic viability of marine capture fisheries through accounting (i) multi-species technology base fishing firms (Kirkley and Stand 1995, Kirkley and Stand 1998 and Squires 1987), (ii) regulated versus unregulated inputs (Dupont 1991) and (iii) inefficient rented in fleet composition (Dupont 1990). The problem was resolved by the stochastic frontier production function approach because the model is the potential to account for the technical efficiency of marine fishery harvesting developed (Aigner *et al.* 1977 and Meeusen and Broeck, 1977).

METHODOLOGY

Study location and sample size

A two-stage sampling technique was applied to collect data for the study. Two coastal districts, such as, Chattagram and Cox's Bazar, were selected purposively for the study because of a large number of people involved in small-scale marine fisheries for their livelihood in the selected areas. Three types of fishing gear such as gillnet, set-bag net and longline are used for harvesting marine fish in coastal Bangladesh. Only the longlinefisherrmen were considered for the study because longline fisheing gear is frequently used in this areas as well as limitation of time and budget. A simple random sampling technique was applied for selecting the sample fishermen for the research. The total sample size was 100 crews of longline fishing boats, of which 50 from Cox's Bazar, and 50 from Chattagram. A pretested semi-structured questionnaire was used for collecting necessary data to address the objectives of the study. The data were collected from January to August 2018. All output and input variables used in the production frontier analysis were measured on a per-trip basis.

Analytical technique

The maximum potentiality of firms under a given set of inputs and technologies was estimated by the stochastic production frontier model in the study. The firm-specific technical efficiency and inefficiency effects were assessed to identify the boat and operator-specific variables that may influence technical efficiency (Rahman *et al.* 2012). Allocative efficiency assessment is needed for the proper utilization and management of scarce marine resources. However, the study assessed the technical efficiency due to the lack of adequate data for measuring the allocative efficiency.

The effects of variable inputs on marine fisheries production and the efficiency of resources used in the longline fishing net were assessed by the translog production frontier function model because the model is the potential to give better estimates than the Cobb-Douglas stochastic frontier (Singh *et al.* 2011) The translog model has less restriction on production and substitution elasticity as well as contains a flexible function. The stochastic translog frontier production function is described in equations 1 to 4 below. The maximum likelihood estimate (MLE) approach is used for estimating technical efficiency using the software program STATA (Tenaye 2020).

The fuel, lubricant, fishing hours, number of crews, number of hooks, ice and other commodities were used as variables. However, for the purpose of this study, all the inputs are aggregated into four, such as trip hours per day, crew size, number of hooks and total input cost, including meals and miscellaneous for considering as input variables of production frontier analysis.

The translog stochastic production functions as follows:

$$InY = \beta_0 + \sum_{i=1}^{4} \beta_i \, InX_i + \frac{1}{2}\sum_{i=1}^{4} \sum_{j=1}^{4} InXi.InXj + \sum_{l=i}^{3} \delta Li + V_i - U_i ---------- (1)$$

The linearised double-log form of (1) is

$$InY = ln\beta_0 + \beta_1 InX_{1i} + \beta_2 InX_{2i} + \beta_3 InX_{3i} + \beta_4 InX_{4i} + \delta_1 InL_{1i} + \delta_2 InL_{2i} + \delta_3 InL_{3i} + V_i - U_i \text{-------}(2)$$

Where, Ln= Natural logarithm, Y_i = Output (total catch kg/trip), β and δ are unknown parameter to be estimated, X_{1i}= Fishing duration (days/trip), X_{2i}= Number of crew (employed/trip), X_{3i}=Total cost (Tk/trip), X_{4i}=No. of hook, L_{1i}=Cox's Bazar, L_{2i}=Chattagram,

v_i-u_i= error term

Functional form of the technical inefficiency model

$$U = \gamma_0 \; + \sum_{i=1}^{5} \varphi Zi + V_i - U_i ------------------------ (3)$$

The empirical model of gear specific technical inefficiency is

$U_i = \gamma_0 + \varphi_1 Z_{1i} + \varphi_2 Z_{2i} + \varphi_3 Z_{3i} + \varphi_4 Z_{4i} + \varphi_5 Z_{5i} + Vi\text{-}Ui$,- - - - - - - - - - - - - -- - -- - -- - -- --------(4)

Where, γ and φ are unknown parameter to be estimated, z_{1i}= Age of head crew (year), z_{2i}= education of head crew (Years of schooling), z_{3i}= Experience of head crew (year), z_{4i}= Capacity of engine (Horse power), z_{5i}=Boat used (Age of boat), Vi-Ui = error term

It has been argued that technical efficiency is positively influenced by the human capital in particular age, education and fishing experience of crew the boat locally knows as maji. It is also postulated that the technical efficiency is positively impacted by the engine horsepower and boat's age. Moreover, the technical inefficiencies estimation of the above model (equation 2) is possible when the technical inefficiency effects Ui are stochastic and the distributional have particular properties (Coelli*et al.* 2005). Therefore, those variables were considered for modeling the technical inefficiency of longline fishing gears.

RESULTS AND DISCUSSION

Production function parameter

Table 1 presents the parameters of the translog frontier production function of longline fishing gears. The trip duration per day of longline fishing gear had an insignificant positive impact on marine fish catch as the coefficient of trip days was positive (0.055) in aggregate situation. The finding implying that marine fish catch may increases insignificantly due to the increased length of a trip keeping other factors remaining the same. It is not surprising that fish production rises with the longer fishing duration simply because of a time effect on production. The coefficient of crew size longline fishing boat was significantly negatively (P= 0.006) associated crew size (-0.116). The coefficient indicated that if other factors remaining constant, the marine fish catch might decrease by 0.116 % subject to employ crews in the longline fishing boat by 1%. It may because a higher number of crews were employed in the longline fishing boats.

Table1. Stochastic production frontier estimates of longline fishing gears in coastal Bangladesh

Variables	Coefficient	Standard Error	P>z
Constant	0.059	0.009	0.000
In trip hours per day	0.055	0.038	0.156
In crew size	-0.116	0.042	0.006
In total cost	0.290	0.027	0.000
In number of hooks	0.246	0.069	0.000
Cox's Bazar	0.198	0.008	0.000
Chattagram	0.206	0.011	0.000

Source: Survey result, (Computed by Author)

The efficiency of longline fishing boats were positively associated with total cost (0.290). It meant that marine fish caught by longline fishing boats might increase by 0.29% in the aggregate situation subject to increase total fishing cost by 1%. It is not surprising that total cost is positively associated with total fish production since the involvement of cost rises with the employment of better and more modern fishing equipment. The coefficient of hooks (0.246) of longline fishing gears was found to be statistically significant ($P \leq 0.001$). The result meant that fish production of longline fishing gears might increase by 0.25% in the aggregate situation subject to rise hooks by 1%, keeping other factors remaining constant.

Inefficiency parameters

Table 2 presents the determinants of the technical inefficiency models for longline fishing gears. The technical inefficiency of longline fishing gears was significantly ($P \leq 0.052$) negatively associated with age of head crew (-0.299), indicating that technical inefficiency decreases with the increased age of head crew. The result indicates that experience crews have higher efficiency than younger head crews. Therefore, the technical efficiency increases with the rise of the age of head crews. The technical inefficiency of longline fishing gears was ($P \leq 0.089$) negatively associated with education of head crew (-0.528), indicating that technical inefficiency decreases with the increased education of head crews in the aggregate situation (Table 2). It implies that efficiencies of higher educated head crews were higher than lower educated captains of the boats. It meant that higher educated head crew of the fishing boats are technically more efficient than lower educated drivers. It may because more technical know-how is required for operating the longline fishing gears than that of gillnet and other fishing gears. Similarly, Squires *et al.* (2002) claimed that formal education of head crews might improve cognitive skills. Therefore, economic inefficiency might be reduced by employing more educated head crews as well as by improving their knowledge about technological innovation. This result is consistent with the a priori expectation that technical efficiency increases with an increase in years of schooling as well as positively correlated with the adoption of improved technology and techniques. The technical inefficiency of longline fishing gears was significantly ($P \leq 0.627$) negatively associated with head crew's experience (-0.044), indicating that technical inefficiency decreases with the rises head crew' experience in the aggregate situation (Table 2). It implies that the efficiency of longline fishing gears might be higher for experienced captains of the boats compared to novice ones. The result indicates that crews having higher fishing experiences were technically more efficient than less experienced boat operators. It may be because of experienced boat operators have better knowledge about the area of fish harbour, technique and time of setting net, water depth, currents and tide and vulnerability about weather. The significant and negative association between fishing experience and inefficiency indicates that marine fishing experience increased the scale of efficiency. Similarly, reported that the crew's experience had positive influences on the technical efficiency of longline fishing boats. It implies that experienced crews are more efficacious in marine fishing than non-experienced ones (Sharma *et al.* 1993).

Table 2. Parameter estimates of technical inefficiency models of longline fishing boats in coastal Bangladesh

Technical inefficiency model			
	Coefficient	Standard error	P>z
Constant	-37.931	337.491	0.911
Age of head crew	-0.299	0.155	0.052
Education of head crew	-0.529	0.311	0.089
Experience of head crew	-0.044	0.091	0.627
Engine horse power	-0.088	0.0466	0.058
Age of boat	-0.017	0.444	0.698
Variance parameter			
Constant	15.964	9.088	0.079
Ln likelihood	58.611		

Source: Survey result, (Computed by author)

The technical inefficiency of longline fishing gears was significantly ($P \leq 0.058$) negatively associated with engine horsepower (-.088). The result indicates that technical inefficiency is negatively associated with engine horsepower (Table 2). It meant that technical inefficiency decreases with the increase in engine horsepower in the aggregate situation. The negative coefficient of engine horsepower in the technical inefficiency effect model implies that a higher horsepower engine has less impact on the technical inefficiency of fishing boats compared to less horse powerboats. The finding implies that the boat having less horsepower (HP) is technically less efficient compared to the boat having higher HP. It may be due to the boats having higher horsepower are generally larger in size and potential to cruise to the deep sea for fishing. It was also the case that higher horsepower boats are larger and employed more assistant crews to handle net and fish as well as they stay longer in the sea compared to less horsepower boats. All of these factors have a positive relationship with fish production or catch.

The technical inefficiency of longline fishing gears was insignificantly negatively associated with the age of the boat (-0.017). It indicates that technical inefficiency insignificantly decreases with increases boat's age in the aggregate situation (Table 2). The result implies that the technical inefficiency effect of the new boats was lower than the old boats, which implies that the new boats are comparatively more efficient than old boats.

Technical efficiency of longline fishing boats

The technical efficiencies of the longline fishing boats of coastal Bangladesh were in the range between 0.498 to 1.00. The mean efficiency level and standard deviation of fish production of longline fishing gears were 0.852 and 0.144, respectively (Table 3). The results indicate that the longline fishing gears capture about 85% of the potential (stochastic) frontier marine fish production levels under the current levels of inputs and technologies at coastal Bangladesh. The key insight of the findings is that there is potential to increase marine fish production by 15% through improving technical efficiency without additional investment for inputs. It meant that fishermen have further potential to increase fish supply using the existing resources subject to improve the technical efficiency. Technical efficiencies of longline fleets was 0.84 at Hawaii (Sharma *et al.* 1993) that supports the present investigation.

Table 3. Summary statistics of longline fishing boat

Variables	Observation	Mean	Std. Deviation	Minimum	Maximum
Efficiency	60	0.852	0.144	0.498	1

Source: Survey result, (Computed by Author)

Technical efiiciency distribution of longline fishing boats

The estimated technical efficiency for the longline fishery ranges from 0.49 to 1.0, with a mean efficiency level o.85. The frequency distribution of the estimated technical efficiencies is depicted in figure 1. The technical efficiency index of about half (48%) of the longline fishing gears was 0.9 or above. The efficiency index of 18% longline fishing gears was in the range between 0.8 to 0.9. The model indicates that 66% of the longline fishing gears of coastal Bangladesh operating with 80% and higher efficiency. The mean technical efficiency for the longline fishery in Bangladesh is almost same 0.85 for the longline fishery in Hawii (Sharma and Leung 1993). The findings meant that a large proportion of the longline fishing boats performing mostly to the efficient frontier. However, there is an ample opportunity to increase marine fish production through enhancing efficiencies of the one-third (34%) of the less efficient longline fishing gears operated in coastal Bangladesh.

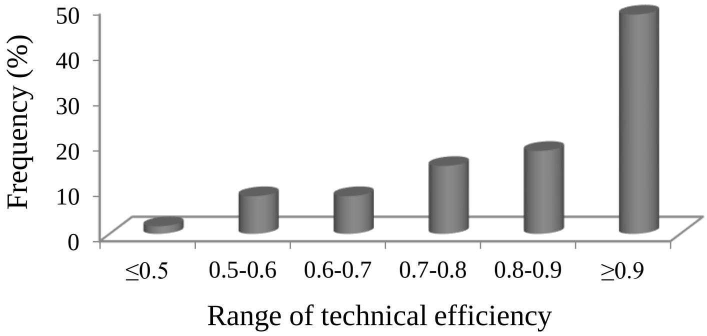

Figure 1. Frequency distribution of technical efficiencies of the longline fishing gears.

CONCLUSION

A translog stochastic frontier model shows that the technical efficiency level of longline fishing gears in coastal Bangladesh was 85%. The finding implies that there is an opportunity for increasing marine fish production by longline fishing gears by 15% through reducing the technical inefficiency without increasing the cost for inputs. The marine fish supply may increase by 15% with existing resources. The technical inefficiency model indicates that crews' age, education, experience, and horsepower of the engine had significant potential for improving technical efficiency. The key insight of the modeling outcomes is that there is potential for enhancing marine fish caught by longline fishing boats through employing educated and experienced crews and higher horsepower engines in the larger vessel. Thus, policy supports are needed for improving the efficiency through reducing indiscriminate caught and enhancing the efficiency of longline fishing gears.

REFERENCES

Aigner DJ, Lovell CAK, and Schmidt PJ. 1977. Formulation and Establishment of Stochastic Frontier Production Function Models. Journal of Econometrics. 6:21-37.

Tenaye A. 2020. Technical Efficiency of Smallholder Agriculture in Developing Countries: The Case of Ethiopia. Economies. 8(2): 34.

BBS (Bangladesh Bureau of Statistics). 2018. Statistical Yearbook, Statistics Division, Ministry of Planning, Government of the People's Republic of Bangladesh, Dhaka, Bangladesh.

BBS (Bangladesh Bureau of Statistics). 2019. Statistical Yearbook, Statistics Division, Ministryof Planning, Government of the People's Republic of Bangladesh, Dhaka, Bangladesh.

BER (Bangladesh Economic Review). 2019. Finance Division, Ministry of Finance, Government of the People's Republic of Bangladesh, Dhaka, Bangladesh.

Coelli TJ, Rao DSP, Donnell CJ and Battese GE. 2005. An introduction to efficiency and productivity analysis. Springer, USA. pp. 41-83.

DoF. 2019. Yearbook of Fisheries Statistics of Bangladesh. Fisheries Resources SurveySystem, Department of Fisheries, Ministry of Fisheries and Livestock, Bangladesh. 36: 135.

Dupont DP. 1990. Rent dissipation in restricted access fisheries. Journal of Environmental Economics and Management. 19(1): 26-44.

Dupont DP. 1991. Testing for input substitution in a regulated fishery. American Journal of Agricultural Economics. 73(1): 155-64.

FAO. 2004. Marine small-scale fisheries of Bangladesh: A general description, Bay of program, Food and Agriculture Organization (FAO), Rome, Italy. Retrieved fromhttp://www.fao.org/3/ae486e/ae486e00.pdf.

FAO. 2014. Fishery and aquaculture country profile: Bangladesh, Country profile fact sheets. In: FAO Fisheries Division, Italy, Rome. Retrieved fromhttp://www.fao.org /fishery/facp/BGD/en.

FAO. 2020. The state of world fisheries and aquaculture. Sustainability in action. Rome, Italy. Retrieved from https://doi.org/10.4060/ca9229en.

FAO. 2001-2021. Fishing gear types. Set longlines. Technology fact sheets. In: FAO Fisheries Division [online], Italy, Rome. Updated 13 September 2001.

George JP. 1993. Longline fishing(FAO Training Series). FAO, Italy, Rome. 22: 81.

Hussain MG and Hoq ME. 2010. Sustainable Management of Fisheries Resources of the Bay of Bengal Compilation of national and regional workshop reports. Support to Sustainable Management of the BOBLME Project, Bangladesh Fisheries Research Institute. Pub./Rep. 2: 122.

Islam GMN, Tai SY, and Kusairi MN. 2016. A stochastic frontier analysis of technical efficiency of fish cage culture in Peninsular Malaysia. Springer Plus. *5*(1): 1-11.

Islam MR and Haque M. 2018. The trends of export and its consequences to the GDP of Bangladesh. Journal of Social Sciences and Humanities. 1(1): 63-67.

Kirkley J, Squires D and Strand IE. 1998. Characterizing managerial skill and technicalin a fishery. Journal of Productivity Analysis. 9(2): 145-160.

Kirkley JE, Squires D and Strand IE. 1995. Assessing technical efficiency in commercial fisheries: The mid-Atlantic sea scallop fishery. American Journal of Agricultural Economics. 77(3): 686-697.

Kehar S, Madan MD, Abed GR, Pratheesh OS and Ganesh T. 2011. Technical efficiency of freshwater aquaculture and its determinants in Tripura, India. Agricultural Economics Research Review. 22: 185-195.

Meeusen W and Broeck van-den J. 1977. Efficiency estimation from cob-douglas production functions with composed error. International Economic Review. 18(2): 435-444.

Murshed-e-Jahan K, Belton B, and Viswanathan KK. 2014. Communication strategies for managing coastal fisheries conflicts in Bangladesh. Ocean and Coastal Management. 92: 65-73.

Onumah EE, Onuma, JA, and Onumah GE. 2018. Production risk and technical efficiency of fish farms in Ghana. Aquaculture. 495: 55-61.

Rahman K, Mia M and Bhuiyan M. 2012. A stochastic frontier approach to model technical efficiency of rice farmers in Bangladesh: An Empirical analysis. The Agriculturists. 10(2): 9-19.

Sharma KR and Leung P. 1993. Technical efficiency of the longline fishery in Hawaii:Application of a stochastic production frontier. Marine Resource Economics. 13: 259-274.

Shamsuzzaman MM, Islam MM, Tania NJ, Al-Mamun MA, Barman PP, and Xu X. 2017. Fisheries resources of Bangladesh: Present status and future direction. Aquaculture and Fisheries. 2(4): 145-156.

Shamsuzzaman MM, Mozumder MMH, Mitu SJ, Ahamad AF, and Bhyuian MS. 2020. The economic contribution of fish and fish trade in Bangladesh. Aquaculture and Fisheries. 5(4): 174-181.

Squires DR. Quentin-Grafton MT and Omar IH. 2002. Technical efficiency in the Malaysian gillnet artisanal fishery. Economic and Environmental Network.Http.//eeu.au.edu.au.pp. 3-12.

Squires D. 1987. Fishing effort: Its testing, specification, and internal structure in fisherieseconomics and management. Journal of Environmental Economics and Management. 14(3): 268-282.

Xuan TN, Vassdal T, Khanh NQT, Kim ANT and Thanh TPT. 2011. Technical efficiency of gillnet fishery in Da Nang, Vietnam: Application of stochastic production frontier. Fish for People. 9(1): 7.