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# Input and Quality Controls:
# A Stochastic Frontier Analysis of Bangladesh's Industrial Trawl Fishery

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## Abstract

This paper examines the effectiveness of different management tools, particularly input and quality controls on Bangladesh's industrial trawl fishery. Results show that the efficiency of industrial trawl fishery comes from multiple owner managed vessels, export oriented vessels and registered vessels that are mainly engaged in double rigger trawling. Results also indicate that freezer vessels with small storage capacity, using small gear are relatively less efficient. This study shows that there is no depletion or reduction in marine fish stock over the period and shrimp vessels are technically more efficient than fish vessels.

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# 1 Introduction

The fishery market is one of the world's fastest growing international commodity markets. For developing countries, fishery products export generates more revenue than the combined earnings from other agricultural exports such as coffee, bananas, rice and tea. But fisheries production and yield are constrained by various factors. Without research on these constraints, any decision could generate inefficiency. Various control measures (like, input control and output control) have been considered in fisheries management to maintain the target species at or above levels necessary to ensure their continued productivity.

This paper examines the effectiveness of different management tools, particularly input and quality controls on Bangladesh's industrial trawl fishery during the period 2001-05. Stochastic Frontier Analysis is used to measure the efficiency of 103 industrial vessels. Different input and quality control measures introduced since 1983 for managing Bangladesh's industrial fishing sector have been taken without any research based evidence. Hence the objective of this research is to measure the effectiveness of input control and quality control measures. Much research has been done on efficiency and fishery, although the number of studies measuring technical efficiency in industrial trawl fishery is limited. No research has been done on measuring the efficiency of industrial trawl fishery of Bangladesh. This is the first study to contribute to the literature in terms of the efficiency of industrial trawl fishery of Bangladesh.

This paper is divided into seven sections. Section 2 gives background information and different control measures of industrial trawl fisheries in Bangladesh. Section 3 describes a theoretical framework followed by data sources and variables in Section 4. The econometric specification is described in Section 5. Section 6 presents results and discussion. Section 7 offers conclusion and recommendation.

# 2 Background

The potential of the marine fisheries sector in Bangladesh is considered to be enormous in view that the country having a 714 km coastal line and an Exclusive Economic Zone (EEZ) of 164,000 square kms. The marine water extends beyond the continental shelf, measuring 200 nautical miles from the base line (10 fathoms) including rivers and estuaries (DoF 2006). Marine capture fisheries are sub divided into artisanal and industrial fisheries. Artisanal fishery is a small scale onshore fishery and fishing occurs up to 40 meters depth with mechanized and non mechanized boats. Industrial fishery is a large scale offshore fishery and fishing occurs beyond 40 meters depth within the EEZ of Bangladesh with industrial vessels.

The industrial fisheries sector earns foreign exchange through export of marine fish and fish products including penaeid shrimp, frozen, dried and salted fish and shark fins. Production from the marine shrimp accounts for around 6.25 per cent of the total exportable production of Bangladesh (DoF 2006). The sector indirectly enjoys incentives given by the export sectors in general which include duty free import of capital machinery and raw materials, fiscal incentives for export, income tax rebates, duty drawback facilities, speedy customs clearance and subsidized credit as a part of the trade liberalization and export orientation policy of Bangladesh.

The only direct incentive given in this sector is a value added tax refund from fuel at the rate taka 1.9 per litre (i.e. less than US$ 0.04) s subsequent to export (MFD 2009).

Development of the industrial trawl fishery was established in 1974 by the Bangladesh Fisheries Development Corporation with 10 fin fish vessels donated by the USSR. These vessels were then joined by privately owned vessels, expanding further with the introduction of wooden Thai vessels under a joint venture scheme. The shrimp vessel fleets were developed in 1978 in a joint venture with Japanese and Kuwaiti vessels and subsequently more vessels were procured by local entrepreneurs. The number of joint venture fishing vessels continued to increase until 1985 (Muir 2003). At present 116 registered vessels and 30 unregistered vessels are engaged in fishing. Unregistered vessels are engaged in fishing with a special court order and these vessels are unregulated (MoFL 2009). The industrial fishing fleet is based in the port of Chittagong.

Industrial fisheries are divided into two broad categories, shrimp and fish which have been exploited to different levels. Shrimp vessels are double-rigged vessels and trawls occur beyond 40 meters depth within the EEZ of Bangladesh to catch shrimp and fish (depending on the license requirements). On the other hand, fish vessels are stern vessels and trawls occur in four different fishing areas beyond 40 meters depth within the EEZ of Bangladesh to catch fin fish and shrimp (by catch). Fish trawls occur in four different fishing areas.

The industrial fishery of Bangladesh is managed by both input controls and quality controls under the Marine Fisheries Ordinance 1983, the Marine Fisheries Rules 1983 and the Fish and Fish Products (Inspection and Quality Control) Ordinance 1983. The Marine Fisheries Ordinance 1983 regulates the management, conservation and development of marine fisheries. Input control measures in the industrial fishery sector in Bangladesh were introduced in 1983 and modified several times between 1983 and 2004 to protect fish stock both shrimp and fin fish (by catch) and to reduce sea water pollution. On the other hand, the Fish and Fish Products (Inspection and Quality Control) Ordinance 1983 regulates the issuance of licenses for export oriented fishing vessels. Quality control measures were also introduced in 1983 to ensure food safety requirements for exportable fish products and to increase the quality of catch and export volume. Following sections describe different input control measures and quality control measures under these ordinances and rules.

## 2.1 Input controls

Input control measures in the industrial fishery sector in Bangladesh were introduced in 1983 with few technical measures by restricting the area of harvest beyond 40 meters depth within the EEZ of Bangladesh and by restricting 45mm and 60 mm mesh size for shrimp trawl and fish trawl net, respectively. At the same time, capacity based licensing was introduced as a fishing effort control measure.

In 1994, as an expansion of input controls, vessel usage controls[2] and fishing capacity controls[3] were introduced. In 2000, marine reserves were declared to restrict the amount and area of

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[2] Thirty days sailing permission for freezer vessels and fifteen days sailing permission for non-freezer vessels; restriction was imposed on fishing during shrimp spawning time.
[3] Decisions were made that no license will be issued for any new shrimp vessels in the existing shrimp fleet.

harvest. The second stage fishing capacity control was also made in 2000 by making the decision that no license will be issued for any new vessel in the existing fishing fleet so that the existing number would remain constant. Based on a few reports that noted that pelagic and demarsel fishes are unexploited, the third stage modification of fishing capacity control was made in 2003 and new fishing vessels in the fishing fleet are encouraged by fishing capacity control. These modifications result a sudden increase in registered fish vessels (MoFL 2009).

Fishing usage control and effort control were also introduced in 2003 with fishing capacity control. Fishing usage controls has been introduced to replace all shrimp vessels by fish vessels that is all double rigger trawl gear with 45mm mesh size nets will be converted into stern trawl gear with 60mm mesh size nets at cod end at the end of shrimp vessels life. Minimum fishing days 150days per year was introduced as an effort control measure to identify inefficient vessels. A limited output (catch) control measure was introduced in 1985 to restrict 'by catch'. In 1993 'by catch' restriction was modified and restriction on 'no discard' were imposed in 2004 (MoFL, 2009).

These input control measures and modifications between 1983 and 2004 were made mainly for shrimp vessels based on two arguments. First, vessel operators overfished stocks. Second, to make a profit on shrimps, vessel operators threw away most fin fish to save their freezer capacity for shrimp and resulted in a wastage of fish resources and increased pollution of sea water due to decomposition of dead fin fish.

Much controversy exists for the first argument. A number of surveys have been conducted in the marine waters of the Bangladesh continental shelf to asses marine stock, but controversy remains about the extent of fish resources within the EEZ. These surveys were conducted between 1979 and 1986 and the survey area was 10-100 meters depth[4] within the EEZ of Bangladesh to asses the pelagic and demersal stock. Signals of overfishing and stock exhaustion are perceptible and being reported from artisanal capture fisheries (FAO 2006) rather the industrial trawl fisheries. No surveys have been done separately yet for artisanal and industrial fisheries.

On the other hand, there are no currently published analyzed data which suggests that shrimp trawling in the Bay of Bengal has had a significant detrimental effect on the demersal finfish fishery. There exists the unproved possibility that the shrimp industry is adversely affecting stocks of finfish which could be harvested by other fishermen (FAO 2001). Alam et al. (2001) also expressed their concern to determine whether marine fisheries are over-exploited.

The second argument was addressed in 2004 through an amendment of the Marine Fisheries Rules 1983 stating that no fishing vessels shall throw away any of its catch of fish or any aquatic resource, except marine turtle, in the sea.

## 2.2 Quality Control

Quality control measures were also introduced in 1983 to ensure food safety requirements for exportable fish products and to increase the quality of catch and export volume. Fish exports have played an important role in the export sector performance of Bangladesh in recent times.

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[4] includes both artisanal and industrial fisheries.

Bangladesh earns 4.76 percent foreign exchange from fisheries and aquaculture exports (FAO 2006). Although the share of export earnings from the fisheries sector has declined from 7.57 per cent in 1993 to 4.9 per cent in 2007, the quantity of fish exported has more than doubled between 1993 (26,607 tones) and 2007 (73,704 tones) (DOF 2007).The total value of fisheries exports has increased from USD178.91 million in 1992 to USD 515.3 million in 2007 (BB 2007). Production from marine shrimp accounts for around 6.25 per cent of the total exportable production of Bangladesh (DoF 2006).  So quality assurance is an important factor for Bangladesh's fish products to compete in the international market.

## 3 Theoretical framework

The stochastic production frontier is used in this study to measure the efficiency. Efficiency measures were introduced by Farrell (1957) who suggested that efficiency could be measured from both parametric and non-parametric functions. However, after two decades, stochastic production frontiers were developed by Aigner, Lovell and Schmidt (1977) and Meeusen and van den Broeck (1977). Their specification allows for a non-negative random component in the error term to generate a measure of technical inefficiency, or the ratio of actual to expected maximum output, given inputs and the existing technology. The idea can be applied to cross section data (Kalirajan and Shand 1994) and panel data (Battese and Coelli 1995 and Coelli et al. 2005). Following Battese and Coelli (1995) and Coelli et al. (2005), indexing vessels by $i=1,2,3,………………..,n$ the stochastic output frontier is given by:

$$Y_{it} = f(X_{it}, \beta)e^{v_{it}-u_{it}} \tag{1}$$

For time $t= 1,2,…………..,T$; $Y_{it}$ output, $X_{it}$ a $(1 \times k)$ vector of inputs and $\beta$ a $(k \times 1)$ vector of parameters to be estimated. As usual, the error term $v_{it}$ is assumed to be independently and identically distributed as $N(0,\sigma_v^2)$ and captures random variation in output due to factors beyond the control of vessels. The error term $u_{it}$ captures vessel-specific technical inefficiency in production, specified by:

$$u_{it} = z_{it}\delta + w_{it} \tag{2}$$

For $z_{it}$ a $(1 \times m)$ vector of explanatory variables, $\delta$ a $(m \times 1)$ vector of unknown coefficients and $w_{it}$ a random variable. $u_{it}$ is obtained by a non-negative truncation of $N(z_{it}\delta, \sigma_u^2)$.

The condition $u_{it} \geq 0$ in equation 1 guarantees that all observations lie on or beneath the stochastic production frontier. A trend can also be included in equations 1 and 2 to capture time-variant effects. Battese and Corra (1977) parameterize variance terms by replacing $\sigma_v^2$ and $\sigma_u^2$ with $\sigma^2 = \sigma_v^2 + \sigma_u^2$ and $\gamma = \dfrac{\sigma_u^2}{\sigma_v^2 + \sigma_u^2}$.  A value of $\gamma$ close to zero denotes that deviation from the frontier is due entirely to noise while a value of $\gamma$ close to one would indicate that all deviations are due to inefficiency. So $\gamma = 0$ implies there are no deviations in output due to inefficiency and

$\gamma = 1$ implies that no deviations in output result in stochastic random effects with variance. In other words, deviations in output are due to technical inefficiency effects.

The technical efficiency of the *i*-th vessel in the *t*-th period for the basic case can be defined as:

$$TE = \frac{E(Y_{it}|u_{it}, X_{it})}{E(Y_{it}|u_{it} = 0, X_{it})} = e^{-u_{it}} = e^{-z_{it}\delta - w_{it}} \tag{3}$$

and must have a value between zero and one. The measure of technical efficiency is based on the conditional expectation given by equation 3, given the values of $v_{it} - u_{it}$ evaluated at the maximum likelihood estimates of the parameters in the model, where the expected maximum value of $Y_{it}$ is conditional on $u_{it} = 0$.

Efficiency can be calculated for each individual vessel per year by:

$$E\left[e^{u_i}|v_i + u_i\right] = \frac{1 - \phi\left(\frac{\alpha_a + \gamma(v_i + u_i)}{\sigma_a}\right)}{1 - \phi\left(\frac{\gamma(v_i + u_i)}{\sigma_a}\right)} e^{\gamma(v_i + u_i) + \frac{\sigma_a^2}{2}} \tag{4}$$

for $\sigma_a = \sqrt{\gamma(1 - \gamma)\sigma^2}$ and $\phi(.)$ the density function of a standard normal variable (Kompas et al. 2004).

## 4 Data and variables

In this study the unbalanced panel data set consists of 103 vessels over the period 2001-05. The total number of observations is 418 with 97 missing observations. Fishing log book data, license renewal data and other office based records and primary data for the period 2001-05 are used. Fishing log book data (shrimp catch, fish catch and fishing days), license renewal data (engine power and gear type) and office based records (registration, export orientation, freezing capacity, storage capacity, gear length, quality certificate cost, laboratory certificate cost and crew) are collected from Marine Fisheries Department (MFD) under Department of Fisheries (DoF) of Bangladesh. Primary data (shrimp price, average fish price, fuel, hygiene and quality control cost) for the period 2001-05 are also collected from DoF. For primary data the DoF distributed the survey to the 146 industrial fishing vessels. After 43 fishing vessels are excluded from this research because during the study period some vessels did not voyage or were doing replacement/ repair and maintenance work or did not disclose the information, 103 industrial fishing vessels remain in the study.

The aggregate value of total catch is used for the output variable in the production function. Both shrimp and fish vessels catch shrimp and fish. The amount of shrimp and fish catch (kilogram per year) is converted into value (US dollar per year) using shrimp and fish price. The shrimp price is measured in taka and converted into US dollars using the annual exchange rate. The

average total value of catch per vessel for 2001-05 is USD 300,680.1 per year with the average of 148.299 fishing days per year.

Fuel is measured in liter per year and varies from 3,000 to 1,270,500 liters with an average of 270,008.5 liter per year. The size of crew varies between 22 and 46 with an average of 34.11005 and the standard deviation is 6.336098. Vessel specific total crew data used in this study as quality/category specific crew size is not available.

The Material input variable is a sum of expenditure on hygiene and quality control, quality and laboratory certificates and the average cost per trawler is USD 9385.78. All expenditure are drawn in taka and converted into US dollar using annual exchange rate.

Gear length is measured in meters and varies from 20 to 42 meters with a standard deviation of 6.0555 meters and average of 27.44019 meters. Engine power is measured in break horse power (bhp) and varies between 360 and 1,250bhp with an average of 640.3404 bhp and the standard deviation is 200.1249. Storage capacity is measured in kilogram per day and varies 25 and 290.31 kilogram with an average of 81.21883 kilogram and the standard deviation is 40.5633. The summary statistics of the variables for 103 trawlers are shown in Table1:

Table 1 **Summary Statistics for key variables (Unbalanced panel data: 419 observations for 103 registered vessel, 2001-05)**

| Variable | Description | Mean | Std. Dev. | Min | Max |
| --- | --- | --- | --- | --- | --- |
| Total catch | $US/year | 300680.1 | 188938.7 | 515.9071 | 1068910 |
| Fuel | Liter/year | 270309.9 | 135769.8 | 3000 | 1270500 |
| Crew | Number of total crew | 34.11005 | 6.336098 | 22 | 46 |
| Fishing days | Days/year | 148.299 | 47.61475 | 2 | 246 |
| Material inputs | $US/year | 9385.78 | 4290.262 | 155.4485 | 22536.54 |
| Gear length | Meter | 27.44019 | 6.0555 | 20 | 42 |
| Engine power | Break horse power | 640.3404 | 200.1249 | 360 | 1250 |
| Storage capacity | kg/day | 81.21883 | 40.5633 | 25 | 290.31 |

**Source:** Marine Fisheries Department (MFD) 2009. Chittagong, Bangladesh.

Time trend is used to capture the stock effect over time. Binary variables for the year 2002, 2004 and 2005 are used to measure weather variations. Export orientation is used to capture whether the vessel is export oriented (one) or not (zero). The consumer of marine shrimp is Japan and UK. A small amount of marine white fish exported to Thailand and other Asian countries through land based processing plants (DoF 2009). Since the main export product of marine fisheries is shrimp. This binary variable considers only shrimp export.

Binary variable management indicates whether the vessel is single owner (one) managed or company/multiple owner (zero) managed. Gear type indicates whether the vessel is double rigger (one) or other (zero) gear. Shrimp vessels use double rigger equipment with nets having 45 mm mesh size at cod end. On the other hand, fish vessels use stern trawl equipment with nets having 60 mm mesh size at cod end. Vessel type indicates whether the vessel is freezer (one) or non-freezer (zero). Freezer vessels can fish from 20 to 25 days per trip with 30 days sailing permission. On the other hand, non-freezer vessels can fish 10 to 12 days per trip with 15 days

sailing permission (MFD 2009 and MoFL 2009). Registration indicates whether the vessel is registered (one) or not (zero).

## 5 Econometric specifications

The specification of the log-linear Cobb-Douglas production function[5] is:

$$\ln Q_{it} = \beta_0 + \beta_1 \ln F_{it} + \beta_2 \ln C_{it} + \beta_3 \ln Fd_{it} + \beta_4 \ln Mi_{it} + \beta_5 t + \beta_6 Y_{02} + \beta_7 Y_{04} + \beta_8 Y_{05} + v_{it} - u_{it} \qquad (5)$$

Where, $Q_{it}$ is the value of total catch, $F_{it}$ is the amount of fuel used and a proxy of capital, $C_{it}$ is the total number of crew, $Fd_{it}$ is the number of fishing days, $Mi_{it}$ is the expenditure for hygiene and quality control, quality and laboratory certificate and $t$ is time trend of stock. The value of $Y_{02}$, $Y_{04}$ and $Y_{05}$ are weather dummies for 2002, 2004 and 2005.

Vessel specific factors are used in the technical inefficiency model:

$$\ln u_{it} = \delta_0 + \delta_1 \ln G_{it} + \delta_2 Gt + \delta_3 \ln Ep_{it} + \delta_4 R + \delta_5 \ln Sc_{it} + \delta_6 Vt + \delta_7 Ex + \delta_8 M + w_{it} \qquad (6)$$

Where, $G_{it}$ is the length of gear, $Ep_{it}$ is the engine power and $Sc_{it}$ is the storage capacity. $Gt$, $Vt$, $R$, $Ex$ and $M$ are dummy variables for gear type, vessel type, registration, export orientation and management of the vessel respectively. Gear length, gear type, engine power and registration are used as input control measures. On the other hand, storage capacity, vessel type, export orientation and management are used as quality control measures.

Generalized likelihood ratio tests are used to confirm the functional form and specification, with the relevant test statistics given by:

$$LR = -2\{\ln[L(H_0)] - \ln[L(H_1)]\} \qquad (7)$$

Where $L(H_0)$ and $L(H_1)$ are the values of the likelihood function under the null and alternative hypotheses. The correct critical values for the test statistics are drawn from Kodde and Palm (1986) and four different hypotheses are tested to confirm the functional form and the specification, which are summarized in Table 2.

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[5] As a pre test the null hypothesis of a Cobb-Douglas form of the production function was tested against general translog specification by setting the relevant parameters for squared and interaction terms in the translog form equal to zero ($H_0 : \beta_9 = .... = \beta_{18} = 0$). The resulting test statistic was 2.38 compared to a critical value of 17.67, which is described in Table 4. The test rejects the translog production function and Cobb-Douglas functional form was thus selected.

Table 2 **Hypothesis test for model specification**

| Hypothesis | LR test | Critical value | Decision |
|---|---|---|---|
| 1. $H_0 : \gamma = 0$ (OLS) | 99.19 | $\chi^2_{.05(1)} = 2.71$ | $H_0$ Rejected |
| 2. $H_0 : \beta_9 = .... = \beta_{18} = 0$ (Cobb Douglas) | 2.38 | $\chi^2_{.05(10)} = 17.67$ | Cannot reject $H_0$ |
| 3. $H_0 : \gamma = \delta_0 = .... = \delta_8 = 0$ (no technical inefficiency) | 97.66 | $\chi^2_{.05(10)} = 16.27$ | $H_0$ Rejected |
| 4. $H_0 : \delta_1 = .... = \delta_8 = 0$ (input control and quality control variables do not effect on inefficiency) | 67.38 | $\chi^2_{.05(8)} = 14.85$ | $H_0$ Rejected |

**Source:** Author's calculation.

At a 5 per cent level of significance the generalized likelihood ratio tests show the inefficiency effects are stochastic and the stochastic production frontier is appropriate ($H_0 : \gamma = 0$ is rejected). The tests also show the Cobb-Douglas functional form of the production function is suitable (cannot reject $H_0 : \beta_9 = .... = \beta_{18} = 0$ ) and confirms the presence of technical inefficiency ($H_0 : \gamma = \delta_0 = .... = \delta_8 = 0$ is rejected). The test also confirms that the vessel specific input control and quality control variables affect the technical inefficiency ($H_0 : \delta_1 = .... = \delta_8 = 0$ is rejected). Thus the Cobb-Douglas production function and the technical inefficiency effect model are confirmed.

## 6 Results

Maximum likelihood estimates are obtained using Frontier 4.1 (Coelli 1996). All input variables in the stochastic production frontier except crew are significant. The capital variable fuel (0.20) and the effort variable fishing days (1.03) show a significant positive effect on the production of industrial trawl fisheries. On the other hand, the negative effect of the size of crew (-0.08) on production is insignificant. The material input shows a significant negative (-0.08) effect on production. This shows that both public sectors' legal and institutional measures and private sector investments for development of the hygiene and quality control measures increase the cost of production technology and hence significantly reduce overall production in the short run. But in the long run may not reduce production as the higher quality product will increase the product price and may induce the vessel owners to produce more.

Time trend shows the overall reduction in marine fisheries stock (-.002) over the period of analysis is insignificant. The marine fish stock was significantly reduced in the year 2002 as the weather dummy shows there was a significant negative effect on the marine fisheries stock due to the variation in weather in the year 2002 (-0.11). On the other hand, the weather effect on the marine fisheries stock in the year 2004 and 2005 were positive and the year 2004 is significant. The weather effect in the year 2005 on production is insignificant and the year 2003 dropped due to colinearity. The value of gamma is 0.60 and also significant. Gamma shows that the deviation

in output is due to inefficiency effects ($u_{it}$), although random effect ($v_{it}$) is still clearly matters. Results are reported in Table 3:

Table 3 **Parameter estimates of the stochastic production frontier and technical inefficiency model**

| | OLS | | | MLE | | |
| --- | --- | --- | --- | --- | --- | --- |
| | coefficient | standard-error | t-ratio | coefficient | standard-error | t-ratio |
| **Stochastic Production Frontier** | | | | | | |
| Constant | 4.78 | 0.67 | 7.04 | 6.01 | 0.65 | 9.28 |
| Fuel | 0.29 | 0.09 | 3.23 | 0.20 | 0.08 | 2.52 |
| Crew | -0.06 | 0.16 | -0.40 | -0.08 | 0.13 | -0.61 |
| Fishing days | 0.90 | 0.10 | 8.65 | 1.03 | 0.09 | 11.81 |
| Material inputs | -0.02 | 0.04 | -0.40 | -0.08 | 0.04 | -1.76 |
| Time trend | -0.01 | 0.04 | -0.30 | -0.002 | 0.04 | -0.05 |
| Year2002 | -0.12 | 0.07 | -1.71 | -0.11 | 0.07 | -1.52 |
| Year2004 | 0.23 | 0.12 | 2.18 | 0.16 | 0.10 | 1.64 |
| Year2005 | 0.05 | | 0.35 | 0.004 | 0.13 | 0.03 |
| **Technical Inefficiency Effects Model** | | | | | | |
| Constant | | | | 22.71 | 3.26 | 6.96 |
| Gear length | | | | -6.34 | 0.60 | -10.62 |
| Gear type | | | | -1.95 | 0.22 | -8.85 |
| Engine power | | | | 0.14 | 0.33 | 0.42 |
| Registration | | | | -0.65 | 0.23 | -2.77 |
| Storage capacity | | | | -0.66 | 0.18 | -3.77 |
| Vessel type | | | | 0.33 | 0.23 | 1.39 |
| Export orientation | | | | -0.31 | 0.24 | -1.27 |
| Private management | | | | 0.91 | 0.17 | 5.40 |
| Sigma square | 0.25 | | | 0.38 | 0.04 | 10.68 |
| Gamma | | | | 0.60 | 0.06 | 9.23 |
| LLF | -300.64 | | | -251.04 | | |
| Mean efficiency (%) | | | | 82.25 | | |

**Source:** Author's calculation.

The predicted average efficiency score of the industrial trawl fishery varies from 0.27 to 0.96 between 2001 and 2005 with a mean technical efficiency of 82.25. The mean efficiency of industrial trawl fishery over time is shown in Figure 1:

Figure 1 **Mean efficiency over time, 2001-05**
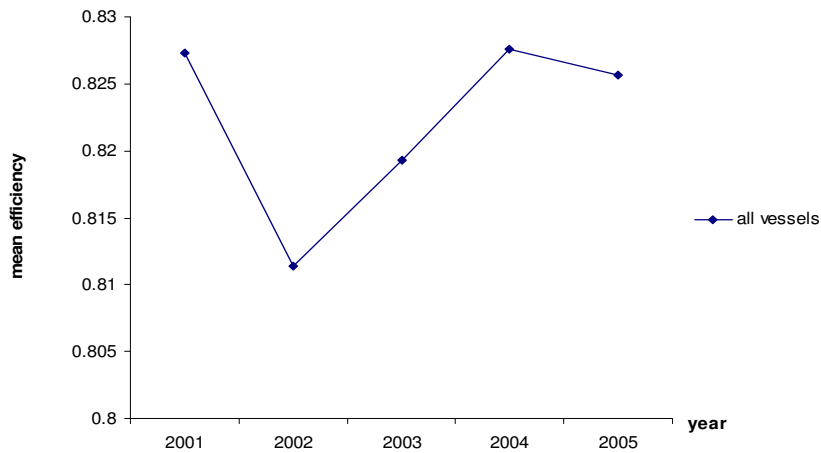


**Source:** Author's calculation.

The mean technical efficiency (82.25) indicates that there is scope to increase output without increasing any inputs. The actual average output and frontier output in Figure 2 also supports this argument as the actual output is lower than the frontier output:

Figure 2 **Average actual output and frontier output over time, 2001-05**
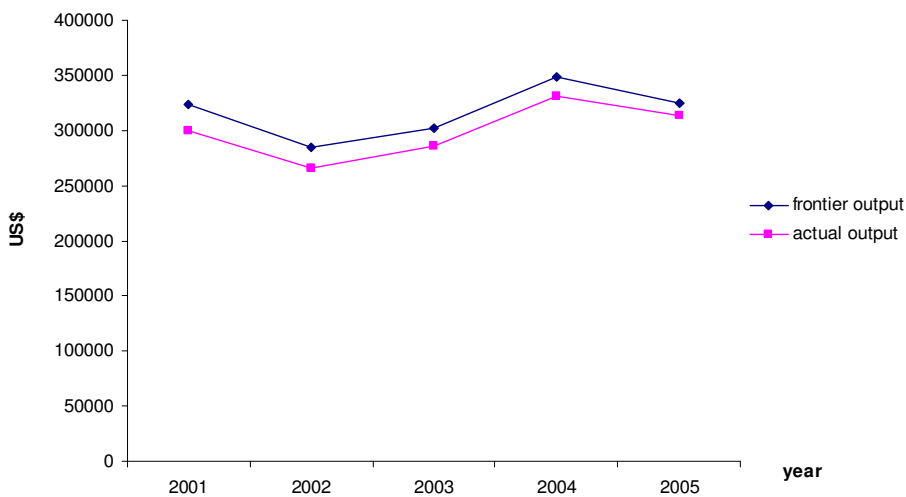


**Source:** Author's calculation.

All input control variables in the technical inefficiency model except engine power are significantly reducing inefficiency and hence increase production. The only input control variable, engine power (0.14), increases inefficiency which is insignificant. This result is may be due to the use of very old engines. Gear type (-1.95) and registration (-0.65) variables are both negative and significant. These two variables show that efficiency of industrial trawl fishery comes from registered vessels and double rigger trawl (shrimp) vessels. The mean efficiency of

shrimp and fish vessels in Figure 3 (a) also shows that the mean efficiency of shrimp vessels is much higher than fish vessels. On the other hand, the mean efficiency of registered and unregistered vessels in Figure 3(b) shows there was a sharp decline in unregistered vessels efficiency and the mean efficiency of unregistered vessels were much lower than registered vessels:

Figure 3 **Mean efficiency of vessels, 2001-05**

**(a) Fish and shrimp vessels**     **(b) Registered and unregistered vessels**
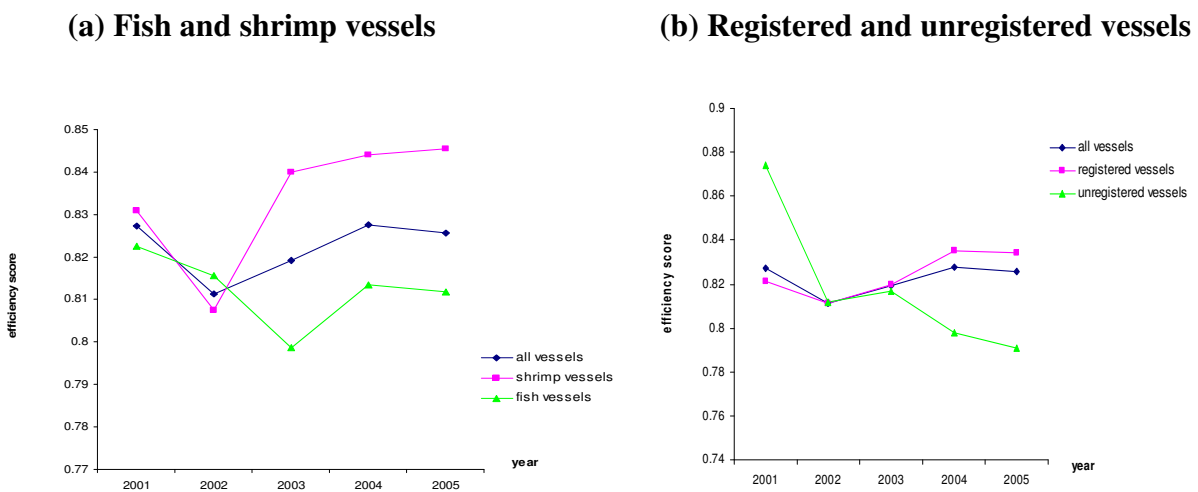


**Source:** Author's calculation.

Two quality control variables, vessel type (0.33) and private management (0.91) are positive and significant, which shows freezer vessels and single owner managed vessels significantly increase inefficiency and hence reduce production. The variable, private management confirms multiple/company ownership also import for increasing efficiency rather than single/individual ownership as the expenditure on managing hygiene and quality control measures is always high and for single owners the expenditure is unmanageable. Variables, vessel type (0.33) and storage capacity (-0.66), show freezer vessels with less storage capacity are relatively less efficient. Larger storage capacity induces vessel operators to fish more and can reduce the cost of production by fishing longer than non-freezer vessels. Storage capacity and freezing capacity is important to preserve a high volume of catch and to increase export volume. Variables, vessel type (0.33) and gear length (-6.34), show freezer vessels with small gear are also less efficient. Smaller gear reduces the opportunity to catch more fish and increases the cost of production. Variable export orientation (-0.31) is negative and significant and shows that efficiency of industrial trawl fishery comes from export oriented vessels and confirms export orientation is important in increasing the efficiency of export oriented fishing vessels.

## 7 Conclusions

The fish and fishery market is one of the world's fastest growing international commodity markets. But fisheries production and yield are constrained by several factors. To manage all constrains research based effective management control measures are appropriate. Without evidence research, any decision would generate inefficiency.

This paper examines the effectiveness of different management controls, particularly input control and quality control on Bangladesh's industrial trawl fishery during the period 2001-05, using Stochastic Frontier Analysis. Result shows that the efficiency of industrial trawl fishery comes from multiple owner managed vessels, export oriented vessels and from registered vessels that are mainly engaged in double rigger trawling. On the other hand, inefficiency comes from single owner managed vessels and unregistered vessels that are engaged in stern trawling. The result also indicates that freezer vessels with small storage capacity and small gear are relatively less efficient. This study shows that there is no depletion or reduction in marine fish stock over the period and shrimp vessels are technically more efficient than fish vessels.

The study suggests inefficiency can be reduced by regulating unregistered vessels, by introducing a sub regulation under sailing permission for freezer vessels with less storage capacity and freezer vessels that are using small gear and by replacing very old engines with new ones. Multiple ownership should be encouraged to ensure the quality of catch and to increase the export volume. At the same time specific measures for export promotion should be introduced for industrial trawl fishing. Weather variations also need to be recorded. Research based policy is also important for effective outcomes and managing the industrial fishing sector.

## References

Aigner, D. J. Lovell, C. A. K. and Schmidt, P. 1977. "Formation and estimation of stochastic frontier  production function models." *Journal of Econometrics*, 6: 21-37.

Alam, M. F. and Thomson, K. J. 2001. "Current constraints and future possibilities for Bangladesh fisheries." *Food Policy*, 26: 297-313.

Bangladesh Bank  (BB) 2007. http://www.bangladesh-bank.org/econdta/exprtrec.html date: 14/11/2007.

Battese, G. E. and Coelli, T. J. 1995. "A model of technical inefficiency effects in a stochastic frontier production function for panel data." *Empirical Economics*, 20: 325-332.

Battese, G.E. and Corra, G. S 1977. "Estimation of a production frontier model: with application to the pastoral zone of Eastern Australia."*Australian Journal of Agricultural Economics*, 21: 169-179.

Coelli, T. 1996. "A guide to Frontier version 4.1: A computer program for stochastic frontier production and cost function estimation." CEPA Working Paper,  University of New England, Armidale.

Coelli, T. J. Rao, D. S. P. O'Donnell, C. J. and Battese, G. E. 2005. *An Introduction to Efficiency and Productivity Analysis,* Springer, USA.

Department of Fisheries (DoF) 2006. "Shrimp Sub-Strategy." FRSS, Department of Fisheries. Dhaka, Bangladesh.

DoF 2006. *Annual Report 2005-06.* Department of Fisheries. Dhaka, Bangladesh.

DoF 2007. *Fisheries Statistical Yearbook of Bangladesh 2006-07*. FRSS, Department of Fisheries. Dhaka, Bangladesh.

DoF 2009.  EU pre mission survey. Unpublished official records. DoF, Bangladesh.

Farrell, M. J. 1957. "The measurement of productive efficiency." *Journal of the Royal Statistical Society*, series A, CXX: 253-290.

Food and Agriculture Organization (FAO) 2001. "The impact of shrimp trawling fisheries in living marine resource of Bangladesh." *Tropical Shrimp Fisheries and Their Impact of Living Resources*. FAO Fisheries Circular 974, Rome.

FAO 2006. "Country Review: Bangladesh". *Review of the State of World Marine  Capture Fisheries Management: Indian Ocean*. Edited by Cassandra de Young.  FAO Fisheries Technical Paper 488. FAO, Rome.

Kalirajan, K. P. and Shand, R. T. 1994. *Economics in Disequilibrium: An Approach from the Frontier.* MacMillan, New Delhi.

Kodde, D. A. and Palm, F. C. 1986. "Wald criteria for jointly testing equality and inequality restrictions."
    *Econometrica*, 54: 1243-1248.

Kompas, T. Che, T. N. and Grafton, R. Q. 2004. "Technical efficiency effects on input controls: evidence from Australia's banana prawn fishery." *Applied Economics, 36 (15)*:  1631-1642.

Marine Fisheries Department (MFD) 2009. Unpublished official records. DoF, Bangladesh.

Meeusen, W. and Broeck, J. V. D. 1977. "Efficiency estimation from Cobb-Douglas productions with composed error." *International Economic Review*, 18: 435-444.

Ministry of Fisheries and Live stock (MoFL) 2009. Unpublished official records. MoFL, Bangladesh.

Muir, J.  2003. "Economic Performance." *Fisheries Sector Review and Future Development*. Dhaka, Bangladesh.