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Efficiency Variation of Manufacturing Firms: A Case Study of Seafood Processing Firms in Bangladesh

Md. Shakil Ahmed
Research and Evaluation Division, BRAC
75 Mohakhali, Dhaka-1212, Bangladesh
Tel: +88-01911-038801 E-mail: shakil.econ@gmail.com

M. Daud Ahmed (Correspondence Author)
Faculty of Business, Manukau Institute of Technology
Private Bag 94006, Manukau 2241, Auckland, New Zealand
Tel: +64-021-0224-1824 E-mail: Daud.Ahmed@manukau.ac.nz

Abstract: Manufacturing firms in developing countries experience difficulties to deploy total capacity and realize the full potential. This research uses four years' primary data collected from the seafood industry in Bangladesh and analyzes that using stochastic frontier approach and presents an estimation model of the technical efficiency of the seafood processing firms in Bangladesh. It reveals that the industry runs on an average of 80% technical efficiency and has the potentials to increase productivity efficiency. The research also finds that the firms' age and size are the main sources of inefficiency. Smaller and newer firms are comparatively efficient than the larger and older ones. In order to improve production efficiency, large firms need to devise strategies for regular modernization through technological adaptation and modularization of the production units.

JEL Classifications: D21, D22, D24; L660

Keywords: Stochastic production function, Technical efficiency, Seafood processing firms, Production efficiency factors

1. Introduction

Manufacturing sector contributes about 30% of gross domestic product (GDP) of Bangladesh. It has been playing a significant role in the economic development, especially empowering women and generating employment in the country. However, this sector is characterized as a low productive, inefficient and slowly growing sector. Technical efficiency of the manufacturing sector has steadily been declining (Baten *et al*. 2009). In another study Baten *et al*. (2010) show the standard technical efficiency of the tea producing industry in Bangladesh is only 59%. Knitwear industry generates significant employment contributing towards poverty reduction in Bangladesh. Taking this social contribution into cognizance, Bakht, Salimullah, Tatsufumi, and Yunus (2008) observe that knitwear industry displays greater diversity in technical efficiency and profitability in comparison with the similar industry of other developing countries. In their view, both the agricultural and garment sector industries have the potentials to increase their productivity with the current set of inputs.

Fernandes (2008) observes that firm size and total factor productivity (TFP) are negatively correlated while the firm age and TFP exhibit an inverse U-shaped relationship in Bangladesh. He also finds that marginal quality and global inter-migration are positively associated with the firm's TFP. The 1990s average TFP of -0.6% has been improved to near zero during 2000-2007 (Bhaskara and Gazi 2009). However, the contribution of TFP to industrial growth is inadequate.

The food processing industry in Bangladesh also performs poorly due to low capacity utilization of many individual firms (Salim and Kalirajan 1999) though this sector enjoys technological progress and witnesses economic reforms. They also find that output growth is mainly due to input growth. In another study, Salim (2006) finds that there are wide variations in efficiency across the food processing firms of Bangladesh attributable to firms' heterogeneity. He also observes that there is an opportunity to increase productivity efficiency with the given inputs and technology. With the introduction of new technological advancement in Bangladesh, the share attributable to capital is rising in terms of total output, and labour intensity is declining (Kibria and Tisdell 1983). Ahmed, Ahmed and Moni (2010) use the marginal productivity technique to assess the allocative efficiency of the seafood processing firms in Bangladesh and observe that all the firms have the opportunity to use the best technique for achieving allocative efficiency. However, 80% of them are operating at decreasing returns to scale. This research studies various aspects of productivity of the seafood processing firms in Bangladesh examines their efficiency variation and identifies the leading sources of inefficiency in this sector.

Seafood industry, especially the shrimp processing sector, is one of the fastest growing manufacturing industries in Bangladesh and contributes 2.8% of the international shrimp market (DAI 2005). It is the seventh largest cultured shrimp producer in the world. It exports frozen shrimp and other fishes, and fish products to the USA, UK, Japan, France, Hong Kong, Singapore, the Kingdom of Saudi Arabia, Sudan and other countries. In fiscal year (FY) 2006-07 and FY 2007-08, Bangladesh earned Taka[1] 33,530 million and Taka 33,960 million by exporting 73,704 metric tons (MT) and 75,299 MT fish and related products respectively (GOB, 2009). Bangladesh had only 15 shrimp processing plants in 1973, which gradually grew to more than 8 folds (129 fish processing plants) in 25 years. In spite of this significant growth, only 50% of plants are currently in operation with an annual production capacity of about 260,000 MT, but they operate only at about 13% of their installed capacity due to shortage of raw materials (Haque, 2003).

Most of the shrimp processing firms in Bangladesh use almost the same set of technologies although their performance widely varies, which can be explained with the help of estimating technical efficiency of each firm. All the producers are not technically competent (Constantin *et al*. 2009) which implies that, with given available technology, all the producers cannot produce the maximum possible output from the given inputs. The traditional micro-economic textbook treats all the manufacturing firms as identical producing units, and assumes that they operate at the same level of efficiency. However, empirical studies often show that some firms are more efficient than the others in the real world (Caves, 1989). Sources of inefficiency of the manufacturing firms have been investigated in many literatures. For example, in a study of micro-, small-, and medium-sized Chilean manufacturing firms (1,091 firms from all manufacturing sectors in 1996), Alvarez and Crespi (2003) find that efficiency is positively linked with the workers' experience, modernization of physical capital and product innovation activity. Gumbau-Albert and Maudos (2002) observe from the study of 1,149 Spanish firms from 18 manufacturing sectors that the firm size and investment into tangible assets are directly related to technical efficiency. Efficiency is relatively

[1] Taka is the Bangladesh currency (approximately 1 US Dollar = Taka 70 in 2011).

high in firms that are subject to intense competitive pressure on the market. Efficiency can be related to the size of a company (Torii 1992) if maintaining or improving efficiency increases the company's management expense. Thus, the efficiency of the manufacturing firms depends on their size, investment on tangible assets, modernization, experience of the worker, product innovation and market competitiveness.

The term *efficiency* was introduced by Farrell (1957) based on the concept of Koopmans (1951). Debreu (1951), Kumbhakar *et al*. (1991), and Battese and Coelli (1995) propose the redial type of efficiency measurement and recommend that the factors responsible for inefficiency should be considered for measuring the performance or production efficiency. Caudill *et al*. (1995) observe that measures of inefficiency are based on residuals derived from the estimation of a stochastic frontier. The productive efficiency of the firm can be described as its ability to produce output with a certain bundle of inputs in a given technological context. A number of studies such as Bhandari and Maiti (2007), Jones *et al*. (1998), Shazali *et al*. (2004) and Jones and Makinen(2010) examined the technical efficiency of manufacturing firms of developing countries.

Stochastic frontier approach is also widely used in measuring technical efficiency, allocative efficiency, and economic efficiency for the agricultural sector. Moreira and Bravo-Ureta (2010), Idiong (2007), Kompas *et al*. (2004), Wadud (2003), Yao *et al*. (2001) and Li and Rozelle (2000) use this technique to estimate technical efficiency of this sector. This study uses the stochastic frontier approach to assess the technical efficiency of the seafood processing firms of Bangladesh with the assumption that the actual production cannot exceed the maximum possible output with the given input quantities (Aigner *et al*. 1977 and Meeusen and Broeck 1977).

Very few studies (e.g. Samad and Patwary 2002, 2006; Baten *et al*. 2009, 2010; Bakht *et al*. 2008) use estimating stochastic production frontier and deal with technical efficiency of manufacturing industries in Bangladesh. Thus, this article provides a valuable insight about the efficiency level of the manufacturing sector, especially the seafood industry of Bangladesh. This study concentrates on the following two key research questions.

Research question 1: *How does the level of efficiency vary over the study period?*
Seafood processing firms in Bangladesh is largely homogeneous. They are using almost identical set of inputs and technologies for production, but their level of competency is not quite equal. This research question focuses on the actual level of efficiency and its variation over time.

Research question 2: *Which factors are primarily associated with the source of inefficiency?*
This question focuses on the source of inefficiency of seafood processing firms in Bangladesh. Some internal and external factors such as firm age, size, management, experience of labor, input sourcing, output destination and financial market, affect the level of competency of the firms directly and indirectly. This research question tries to identify the factors that are significantly related to the inefficiency of the firms.

2. Analytical Framework

Stochastic production frontier is $f(X_i, \beta)\exp(v_i)$. This represents production of the maximum possible output with the input vector used by *i*-th firm, X_i, given the corresponding vector of technology parameters, β, and a random variable to capture all the random factors outside the control of the firms which are likely to affect the optimal output level, v. However, the optimum output of the firm may vary due to various reasons such as, low productivity of labor, poor management decisions or inadequate monitoring efforts (Ray, 2004).

The stochastic production function is developed by Aigner, *et al*. (1977), Meeusen and ven den Broeck (1977) and later by Battese and Coelli (1995). Following Haider, *et al*. (2011) the stochastic production function can be written as follows.

$$\ln Y_{it} = \beta_0 + \sum_{i=1}^{n} \beta_{it} \ln X_{it} + (v_{it} - u_{it}) \qquad (1)$$

In equation (1), *i and t* (*i* =1, 2, …, n, and *t* = 1, 2, …,T) represent the number of input and time respectively. The output variable 'Y_i' represents the output of the i-th firm, the explanatory variable 'X_i' represents a vector of K inputs, β represents a vector of K unknown parameters, and v_{it} is a random variable which is assumed to be $N(0, \sigma_v^2)$ as well as independent from $u_{it.}$, *the* farm specific error term which is attributed as the technical inefficiency effect in the model. Non-negative truncation of the distribution of u_{it} is assumed to be $N(\mu_i, \sigma_v^2)$. The variance parameter of the model can be parameterize as $\sigma^2 = \sigma_v^2 + \sigma_u^2$ and $\gamma = \sigma_u^2 / \sigma^2)$ where σ^2 is the variance of output (Battese and Corra, 1977). Here, γ lies between 0 and 1. A value of γ of zero indicates the deviations from the frontier are entirely due to noise and while the value is one it indicates all the deviations are due to technical inefficiency (Coelli *et al*., 1998). The model incorporates a simplified specification of the time-varying inefficiencies following Battese and Coelli (1992) as

$$u_{it} = \{\exp[-\eta(t - T)]\} u_i \qquad (2)$$

Here, u_i is the technical inefficiency effect in the model, the unknown parameter η needs estimation that determines whether inefficiencies are time varying or not. Positive, zero and negative values of η correspond to declining, constant and increasing technical inefficiency over time when η is negative.

Following Battese and Coelli (1995), the inefficiency distribution parameter which can be estimated from the OLS model can be written as

$$u_i = \delta_0 + \sum_{i=1}^{n} \delta_i Z_i + w_i \qquad (3)$$

Where, u_i is technical inefficiency, Z represents the controllable variables (shown in table 1) that can affect technical inefficiency and *w* represents the uncontrollable variable.

According to the Coelli *et al* (1998) the technical efficiency of the ith firm of tth period is as follows.

$$TE_{it} = \exp(-U_i) \qquad (4)$$

The range of TE is 0 to 1. TE = 1 implies that the firm is producing on its production frontier and is said to be technically efficient. Hence, (1–TE) represents the gap between actual production and optimal attainable production that can be achieved by moving the firm towards the frontier through readjusting inputs (Chavas and Aliber, 1993).

3. The Data and Variable Identification

This study collects primary data for the years 2006, 2007, 2008 and 2009 from shrimp processing farms in the south-eastern region of Bangladesh. There were 56 seafood processing firms in this region of which 20 were large scale firms and the rests were working as the supporting firm (Ahmed 2007). About 50% of these firms ranging from small to large were actively operating their production process in this region. Data were collected from all of them.

Production is a function of labor and capital. A number of other factors such as raw material, time, area and energy are closely related to the production process. Labor and capital are independent variables to the production function (Baten *et al*. 2009; Baten *et al*. 2010; Bhandari and Maiti, 2007; and Kehinde and Awoyem, 2009). This study considers total annual sales of finished products as the dependent variable, whilst labor, capital, raw material, and energy cost as the independent variables. Labor is measured on the basis of annual wage, and capital is measured on the basis of value of depreciated fixed assets.

In line with literatures reviewed above, this study considers a number of firm's specific characteristics such as age, size and management structure that contribute to its efficiency. Likewise, several other factors such as average educational qualification of the labor, alternate energy cost which is used as the proxy variable of interruption in energy supply, male-female ratio in the labor force and total marketing cost have been considered in the inefficiency model. Table 1 depicts these variables.

Table 1. Description of the Variables

Variables		Symbol	Unit of Measurement
Output		Y	Total Sale (BDT/Year)
Capital		X_1	Net value of Fixed Assets (BDT/Year)
Labor		X_2	Total Wage (BDT/Year)
Raw Material		X_3	Net Value (BDT/Year)
Energy		X_4	Total Energy Cost (BDT/Year)
Age of the firm		Z_1	Year
Firm Size		Z_2	Total Employee
Firm Size (Employee)	S-1	Z_{21}	$E \leq 150=1$ (E= Total Employee)
	S-2	Z_{22}	$150 < E \leq 300=2$
	S-3	Z_{23}	$300 < E \leq 450=3$
	S-4	Z_{24}	$450 < E=4$
Size of Management		Z_3	Number of Office Staff
Average Educational qualification of the labor		Z_4	1=0-3, 2=4-6, 3=7-12, 4=13+ (Year of Schooling)
Alternate energy cost		Z_5	BDT/Year
Male female Ratio in the labor		Z_6	Male Labor/Female Labor
Marketing Expenses		Z_7	BDT/Year

Note: S-1= Scale 1, S-2= Scale 2, S-3= Scale 3 and S-4= Scale 4.

Data Source: Authors' compilation

4. Results and Discussion

Market determines the price of the product as well as the inputs so that the market structure (imperfect competition) does not affect the level of efficiency. We assume that both the seafood product and factor markets are perfectly competitive and apply the ordinary list square (OLS) and maximum likelihood estimation (MLE) approaches to estimate the technical efficiency (TE) of the seafood processing firms. The intercept value of MLE is much higher than the OLS estimation which implies that the frontier production function lies above the traditional average production function.

Table 2 depicts that capital, labor and raw material significantly affect the production level in OLS estimation, whereas only raw material and energy have a significant impact on the production level in MLE estimation. In OLS model, capital is negative. This result articulates, if other things remain the same, an increase of capital only, decreases the output. According to the field survey due to shortage of raw materials and seasonality of raw materials, the firms cannot utilize their fully installed capacity. Therefore, further increase in capital increases the production cost and proportionately decreases the level of production. The value of variance parameters (σ, γ) and the mean value of u_i (μ) are positive and significant which implies that the inefficiency is existed in the model. The parameter γ measures the proportion of the total variability in output due to variation in TEs. The coefficient of γ is 0.85 which indicates that 85% variation in output occurs due to variation in technical efficiency. The value of η is marginally significant and negative which describes that the TE of the firms is slowly declining over the time. Baten (2009) also observes similar results.

Table 2. Estimation of Frontier Production Function

Variables	β_i	OLS coefficient	OLS standard-error	OLS t-ratio	MLE coefficient	MLE standard-error	MLE t-ratio
Constant	β_0	-0.02	0.39	-0.05	0.18	0.39	0.46
ln(*Capital*)	β_1	-0.05**	0.02	-3.06	-0.02	0.01	-1.12
ln (*Labor*)	β_2	0.07**	0.02	2.91	0.02	0.02	0.92
ln (*Raw material*)	β_3	1.01***	0.02	59.96	0.97***	0.02	44.45
ln (*Energy*)	β_4	-0.01	0.02	-0.27	0.05**	0.02	2.10

		coefficient	standard-error	t-ratio
Variance	σ^2	0.01**	0.00	2.43
	γ	0.85***	0.04	18.72
Mean (u_i)	μ	0.24***	0.05	4.23
Scalar Parameter	η	-0.03	0.02	-1.24

Source: Authors' compilation

Note: *** and ** represent 1% and 5% level of significance, respectively

4.1 Source of Inefficiency

This study considers several factors, which might have an impact on the efficiency level of the seafood processing firms. OLS estimation method has been used to identify the relationship among the firm level attributes and the technical inefficiency. Tables 3 and 4 present the results of inefficiency model (equation 3) of the firms. The value of R^2 is 0.59 and 0.65 for inefficiency models 1 and 2 respectively, which indicate that these two models are only 59% and 56% fit. Firm specific characteristics like age, size, educational qualification of labor, and gender mix in the labor are associated with positive movement whereas the size of management, alternative energy cost and marketing expenses impact negatively. Among these factors, only the firm size and age significantly affects the inefficiency level of the firms. Thus, the technical efficiency varies with firm-specific characteristics. These results are consistent with Bhandari and Maiti (2007). The estimated coefficients with a positive sign indicate that inefficiency increases with the increase of firm age and size. To identify the efficient firm size, second stage regression was run by dividing the firm size into 4 groups as shown in Table 1. Table 4 describes the second stage regression results which depicts the firm size should not be less than 150 employees, whereas Table 3 suggests that the firm size should not be much bigger.

Table 3. Inefficiency Model 1 (Dependent Variable: Technical Inefficiency, u_i)

Variables	δ_i	**Coefficient**	**Std. Error**	**p-Value**
(Constant)	δ_0	0.000	0.116	0.999
Age of the firm	δ_1	0.394**	0.002	0.032
Size of the firm	δ_2	0.527**	0.028	0.028
Size of Management	δ_3	-0.078	0.001	0.745
Average Educational qualification of the labor	δ_4	0.104	0.044	0.573
Alternate energy cost	δ_5	-0.220	0.000	0.215
Male female Ratio in the labor	δ_6	0.080	0.009	0.628
Marketing Expenses	δ_7	-0.235	0.000	0.137
R^2=0.59				

Note: ** Represents the 5% level of significance; **Data source**: Authors' compilation

Table 4. Inefficiency Model 2 (Dependent Variable: Technical Inefficiency, u_i)

Variable		δ_i	**Coefficient**	**Std. Error**	**p-Value**
(Constant)		δ_0	0.320	0.129	0.023
Age of the firm		δ_1	0.405**	0.002	0.034
	S-1	δ_{21}	-0.587***	0.063	0.009
Firm Size	S-2	δ_{22}	-0.042	0.042	0.819
	S-4	δ_{24}	0.178	0.067	0.358
Size of Management		δ_3	-0.064	0.001	0.791
Average Educational qualification of the labor		δ_4	-0.086	0.055	0.713
Alternate energy cost		δ_5	-0.353	0.000	0.071
Male female Ratio in the labor		δ_6	0.083	0.009	0.611
Marketing Expenses		δ_7	-0.174	0.000	0.263
R^2=0.65					

Notes: 1. *** and ** Represents the 1% and 5% level of significance, respectively;
2. Definition of firm size for this paper is available in Table 1;
3. S-3 has been excluded from the model due to collinearity problem.

4.2 Technical Efficiency Distribution

We have presented distribution of the technical efficiency (TE) of the firms on the basis of their age in Table 5 below. The age has been considered from the inception year of the firm to 2009. The most efficient firms are the young firms aged one to five years (7% of population size). During the study period, the minimum and maximum average TEs of the young firms are 85.3% and 86.5% respectively. TE of the firms aged between 6 to 10 years (20% firms) is behind the young firms narrowly. Minimum average TE of any firm in this group is 84.8%, but they may achieve as high as 86.1%. TE of the firms aged between 11-15, 16-20, and 20+ are ranked 3rd, 4th and 5th respectively. TE of the older firms' (20+ years) can be as low as 71%. These firms are likely to produce a substantial amount of wastage in outputs (29%) compared to young firms (15%). These trends show that the relatively older firms are less efficient than the youngest firms.

Table 5. TE Distribution according to Firm Age

Age (Years)		TE 2006	TE 2007	TE 2008	TE 2009
1-5	Mean	0.865	0.861	0.857	0.853
	N	2	2	2	2
	Percent (%)	6.90	6.90	6.90	6.90
6-10	Mean	0.861	0.856	0.852	0.848
	N	6	6	6	6
	Percent (%)	20.69	20.69	20.69	20.69
11-15	Mean	0.828	0.821	0.816	0.810
	N	3	3	3	3
	Percent (%)	10.34	10.34	10.34	10.34
16-20	Mean	0.789	0.783	0.776	0.770
	N	9	9	9	9
	Percent (%)	31.03	31.03	31.03	31.03
21+	Mean	0.734	0.727	0.719	0.711
	N	9	9	9	9
	Percent (%)	31.03	31.03	31.03	31.03
Total	Mean	0.796	0.790	0.784	0.777
	N	29	29	29	29
	Percent (%)	100	100	100	100
	Std. Deviation	0.080	0.082	0.084	0.087

Data Source: Authors' compilation

The TE distribution based on the firm's size is presented in Table 6. The firms (14%) having less than 150 employees achieved the highest level of technical efficiency (90.4%) in the first year of the study period which slightly, but gradually declined every year over the study period. About one-thirds of the firms grouped in S-2 achieved 2nd position with an average TE of 78% in 2006 and gradually declined during the next 4 years. The largest sized firms (S-4) with more than 450 employees achieved as low as 71% and as high as 73% TE within the study period.

About half of the surveyed firms, were larger than the average size and the other half were older than the average age. The study finds that both the larger and the older firms achieved lower technical efficiency.

The study reveals that the average TE of this seafood industry ranged from 77% to 79%. It produced only an average of 80% of its total expected output. This result is consistent with Salim (2006). This indicates that the seafood processing industry was almost technically inefficient, and it could produce more goods with the given set of inputs without increasing any production cost.

Table 6. TE Distribution according to Firm Size (Number of employees)

Firm Size		TE 2006	TE 2007	TE 2008	TE 2009
S-1(E≤150)	Mean	0.904	0.901	0.898	0.894
	N	4	4	4	4
	Percent (%)	13.79	13.79	13.79	13.79
S-2(150 <E ≤ 300)	Mean	0.789	0.783	0.776	0.770
	N	9	9	9	9
	Percent (%)	31.03	31.03	31.03	31.03
S-3(300< E≤ 450)	Mean	0.781	0.771	0.768	0.762
	N	13	13	13	13
	Percent (%)	44.83	44.83	44.83	44.83
S-4(450<E)	Mean	0.738	0.729	0.721	0.713
	N	3	3	3	3
	Percent (%)	10.34	10.34	10.34	10.34
Total	Mean	0.796	0.790	0.784	0.777
	N	29	29	29	29
	Percent (%)	100	100	100	100
	Std. Deviation	0.080	0.082	0.084	0.087

Data Source: Authors' compilation

5. Conclusion

In this study, we have estimated the stochastic production frontier and firm specific technical efficiency of seafood processing firms in Bangladesh. We collected primary data about the firm's organizational and production processes through interviews and investigation of operational data. We then analyzed and investigated the influence of the firm characteristics on the technical efficiency of the seafood processing firms. Ordinary least square (OLS), and maximum likelihood estimation (MLE) methods are used for data analysis. It measures technical inefficiency as the function of various firm level controllable factors. Seafood processing firms are homogeneous in product, factor and technology. In stochastic production function, random factors, which are not included in the model, are normally distributed, but the factors associated with technical inefficiency are exponential or half normal. Positive value of variance parameter ensures that technical inefficiency exists in the model, and it increases steadily over the study period.

From the empirical analysis, it is observed that average technical efficiency of almost half of the firms is 0.77 in 2009 and 0.79 in 2006. This indicates that firms can boost production with the same set of technology without increasing the cost. This study also finds that TE declines with the increase of age of the firms. More specifically, younger and smaller firms enjoy higher production efficiency than the larger and older firms.

This study identifies that firms' age and size are the key source of inefficiency of seafood processing firms in this region. Manufacturing firms in developing countries can hardly utilize their existing capacity properly due to lack of an adequate supply of raw materials. These firms are lagging behind technological adaptation, which makes them unable to maximize their production efficiency. Outdated machinery and technologies create a barrier on the process of achieving the higher level of efficiency. The older manufacturing firms need modernization of production processes through regular technological adaptation. The larger firms should organize their operation and production division into optimum sizable units that achieve maximum production efficiency.

This paper clearly delineates a noble process of identifying the bottlenecks of labour intensive and not-so-sophisticated manufacturing industries, especially agricultural sector, in the developing world through the scientific application of economic theory. In addition, this research identifies the key attributes of these firms that contribute towards under utilization of production capacity. However, due to its focus on the exploration and identification of these attributes, this research did neither study the optimum size nor propose a suitable framework of technology adoption in a given context and settings. In order to explore these, future researches may need to undertake multi disciplinary studies spanning over economics, production and operation management, and business process management.

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