Management of the traditional milkfish culture in Indonesia: an approach using technical efficiency of the stochastic frontier production

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Abstract. As the need of food steadily increases, the government has put emphasis on improving fish production as a source of protein to achieve one of the purposes of food security policy. The choice being taken has considered many related aspects to the development of fishery in Indonesia especially traditional milkfish culture. However, little has been paid to the management aspect of how to improve the production of traditional milkfish culture. The aim of the study was to analyze the efficiency of technical production of milkfish in Indonesia. Stochastic frontier of production function was applied to analyze the efficiency of the technical production of milkfish in brackish ponds. The result showed that the value of the technical efficiency of individual fisheries is distributed from 59.30 to 94.27 percent with the average score of efficiency is 85.20 percent. The average of the efficiency score suggested that the traditional techniques to increase milkfish production in Indonesia are generally inefficient as, potentially, the output could still be increased by using certain inputs in a certain combination. The study recommends the implementation of the value chain systems approach to milkfish farming system in order to increase the production and post-production effectively and efficiently.
Key Words: fishery, brackish ponds, traditional milkfish culture, technical efficiency, stochastic frontier models.

Introduction. Recently, there has been a shift in the pattern of consumption from red meat (animal meat) to white meat (sea/fresh waterfish) firstly introduced by Japan and followed by other developed countries, such as the United States of America and Western European Countries. As a result, fish becomes one of the world's strategic commodities expected to be greatly increased as the future demand increases. Therefore, the increase of the world needs upon the white meat has to be anticipated especially by countries like Indonesia which its natural resources provide excessive fish (Akbar 2014).

The potencies of Indonesia to be the source of fish in the world are supported by the fact that its natural sources of ocean has not been optimally explored, land to be used as both production and hatcheries is available, and climate to enhance the optimal growth of fish farming throughout the year is suitable. Currently, 303,810 hectares (33.2%) out of 913,000 hectares potentially for brackish fishpond have been used for fish farming; while, the rest 66.8% of brackish fishpond has been abandoned (Lelono & Susilowati 2010). The Ministry of Maritime Affairs and Fisheries (2013) reported that the number land used for brackish fish farming increased from 618,251 hectares in 2008 to 650,509 hectares in 2013. For example, DKP2SKSA (2015) reported that the volume of aquaculture productions in Cilacap was 380 tons of shrimps, 331 tons of milkfish (*Chanos chanos*), 840 tons of catfish (*Clarias* sp.), 456 tons of tilapia (*Oreochromis niloticus*), 3.47 tons of grouper (*Epinephelus pachycentrum*), 1,005 tons of carp (*Cyprinus carpio*), 229 tons of golden carp (*C. carpio*), patchauli (*Osteochilus vittatus*), and 353 tons of mujahir (*Oreochromis mossambicus*). Among those, milkfish is the most popular one as it is relatively easy to manage, has stable prize, and easy to market.

In regard to milkfish, several empirical studies on the technical efficiency of milkfish production using frontier function methodology have been done; yet, the results are inconclusive leading to different findings. Chiang et al (2004) claimed that translog model of stochastic production function is better and more suitable than Cobb Douglas production function model applied in milkfish production in Taiwan with the tendency of the declining of the economic scale. Meanwhile, Irz & Mckenzie (2003) who examined the technical efficiency of freshwater and brackish water aquaculture in the Philippines produced different findings. The empirical result of stochastic frontier of production function shows that the technical efficiency of aquaculture in brackish water is low with average level of efficiency of 53%, while the technical efficiency aquaculture in freshwater is high with the level of efficiency of 83% (Irz & Mckenzie 2003).

The aim of the present research was to analyze the technical efficiency of the traditional system of small-scale monoculture of milkfish farming in Indonesia. This research was different from the previous studies of Chiang et al (2004) who examined the technical efficiency of modern and large-scale brackish milkfish culture and Irz & Mckenzie (2003) who examined the technical efficiency of the traditional system of milkfish culture with polyculture system.

Material and Method. According to Daraio & Simar (2007), a production method will be more efficient than others' if the method produces greater output with the same level of input. They also stated that a production method using the smallest input is also more efficient than others' when it produces the same value of output. Meanwhile, the use of resources for production that still can be improved by a manufacture reflects the technical inefficiencies due to limiting factors. Therefore, identifying the source of the inefficiencies did not only provide information about potential sources of inefficiency, but also suggestions for the policy makers to make decision on how to achieve a total efficiency level.

The measurement method of frontier production function can be divided into four: (1) the deterministic nonparametric frontier; (2) the stochastic nonparametric frontier; (3) the deterministic frontier; (4) the stochastic frontier (Simar & Wilson 2015).

In general, the concept of efficiency can be approached from the side of the input allocated and that of the output produced.

The estimation approach of deterministic frontier of production function is proposed by Farrell (1957) through the upper limit of the output level on the input combinations; then, this approach is followed by Aigner & Chu (1968), Timmer (1970), and Afriat (1972). Further development of the estimation approach has been conducted using mathematical programming techniques (Farrell 1957; Timmer 1971; Fried et al 2008), parametric and non-parametric (Aigner et al 1977; Meeusen & van Den Broeck 1977; Fried et al 2008; Simar & Wilson 2015; Setiarso et al 2014; Suharno & Widayati 2015; Gigentika et al 2016), then econometric approach (Greene 1993; Fried et al 2008) to measure the technical efficiency (Greene 1993; Fried et al 2008; Simar & Wilson 2015). Measuring the technical efficiency of individual companies using model frontier estimation is the latest method in the econometric developed by Richmond (1974) and Schmidt (1976).

Meanwhile, Aigner et al (1977) applies the stochastic frontier production function (SFPF) that its function is different from the traditional production function (average). The traditional one has residual consisting of two components; the first component gives an indication of the technical inefficiency and the second one indicates other randomly component affecting production activities (Aigner et al 1977). Since stochastic frontier analysis has been applied, it has been widely accepted due to its advantages over non-frontier (see, Forsund et al 1980; Bravo-Ureta & Pinheiro 1993), and economics literatures had issued about the efficiency and analysis of stochastic frontier that had been widely expanded with some development. Several research papers by Forsund et al (1980), Schmidt (1985), Bauer (1990), Cornwell et al (1990), Battese (1992), Greene (1993), Kalirajan & Shand (1999), Murillo-Zamorano (2004), Coelli et al (1998), Kumbhakar & Lovell (2000), Coelli et al (2005), Fried et al (2008), and Mendes et al (2013) provide excellent surveys of literature on the frontier analysis.

Frontier production function describes the maximum output that can be produced in a production process. Frontier production function is the function of the production that describes the maximum production that can be obtained from a combination of factors of production variations on a certain level of knowledge and technology (Humphrey 1997). The model of deterministic frontier of production function proposed by Aigner & Chu (1968), Afriat (1972), Battese & Coelli (1992), Radam & Ismail (1999) is:

$$Y_i = f(X_i, \beta)\varepsilon^{e_i}$$

where Y_i is the output vector of the company i^{th} within the observation period, f (xi; ß) is the function that fit (Cobb-Douglas or Translog), X_i is the input vector in the observation period, parameter ß is the parameter of the predicted values being analyzed, and e_i is the random variable with non-negative value which is associated with company-specific factors that contributed to the failure to achieve the maximum efficiency of the production process.

Stochastic frontier known as the model of composed error for the error term e_i consists of two elements:

$$e_i = v_i + u_i$$

The downside of this model is that the model cannot breakdown the residual component of u_i to become efficiency influence and undetermined external influence (random shock) (Sampaio 2013). As a result, the value of the technical inefficiency tends to be high because it is influenced by two inseparable error components.

The stochastic frontier model is an extension of the original deterministic models to measure the effects of unpredictable (stochastic effects) within the production limits (Sampaio 2013). Stochastic frontier of production function model exhibits the parameters of v and of u that can be estimated by maximizing the log-likelihood function:

$$\ln (Y \sim \beta, \lambda, \sigma^2) = \frac{N}{2}\ln\left[\frac{2}{\pi}\right] - N\ln\sigma + \sum_{i=1}^{N}\ln\left[1 - F(e_i, \lambda, \sigma^{-1})\right] - \frac{1}{2\sigma^2}\sum_{i=1}^{N} e_i^2$$

Where:

$e_i = Y_i - f(X_i, \beta)$,

$\sigma^2 = \sigma_u^2 + \sigma_v^2$,

$\lambda = \sigma_u / \sigma_v$ ...,

F = standard function of normal distribution,

N = number of observations.

The variable e_i is the specification of error term of the i^{th} observation. The random variable v_i is useful to calculate the size of the error and the uncertain factors such weather, strikes, pests, and others in the value of the output variable together with the combined effect of the undefined input variables in the production function. The random variable v_i is the random shock variable that is identically distributed normally with the average (µi) of 0 and has a constant variance or $N(0, \sigma_v^2)$, symmetrical and free from u_i. The random variable u_i is a non-negative variable or $N(0, \sigma_u^2), u_i > 0,$ which is assumed to be freely distributed. The variable u_i is called one side disturbance functioned to capture the effects of the inefficiency of the model.

Meanwhile, Jondrow et al (1982) suggest a distribution assumption of u and v; so that, the average conditions of u to ε is:

$$E(u_i \mid e_i) = \frac{\sigma_u \sigma_v}{\sigma}\left[\frac{f(e_i \lambda \sigma)}{1 - f(e_i \lambda \sigma)} - \frac{e_i \lambda}{\sigma}\right]$$

where f is the standard normal density. The distribution function is calculated based on $e_i . \lambda / \sigma$, so the technical efficiency (TE) is calculated by:

$$TE_i = \exp(-E[u_i \mid e_i]) \text{ so that } 0 \leq TE \leq 1$$

The technical efficiency could be measured by the approach of output side and input side. The calculation of the technical efficiency from the output side (Timmer efficiency index) is done by measuring the ratio of the output observation to the output limit. The efficiency index is used as an approach to measure the technical efficiency in the stochastic frontier analysis, and the measurement of technical efficiency from the input side is done by calculating the ratio of the input or cost limit (frontier) to the input or observation cost (Sampaio 2013).

The equation of the stochastic frontier of the production function of Cobb-Douglas in the form logarithm is as follow:

$$Ln\ Q_i = ln\ \beta_0 + \beta_1 ln\ P_i + \beta_2 ln\ S_i + \beta_3 lnC_i + \beta_4 ln\ F_i + \beta_5 ln\ L_i + e_i$$

where the dependent variable Q is the production output (kg) of milkfish; the independent variables is P (pond area, m^2), S (fingerling, piece), C (chemical, litre), F (feed supplement, kg), and L (labor, man-day). Parameters β_0 is the level of the technical efficiency and β_i is the elasticity of the input variation based on output level respects. The summary of the data used is presented in Table 1.

Table 1

Summary of the data used

Variables	*Mean*	*Standard deviation*
Output (kg)	515.26	177.87
Size of Pond (m^2)	1,210.78	477.80
Fingerling (piece)	12,083.00	3,349.08
Chemical (litre)	3.82	3.55
Feed Suplement (kg)	59.72	44.03
Labor (man-day)	188.70	63.95

In this study, stochastic frontier production function introduced by Battese & Coelli (1992) was used following the model of Aigner et al (1977), and Meeusen & van Den Broeck (1977). The advantage of using stochastic frontier of production model is to find the disturbance representing noise, measurement error, exogenous shock outside the control of the production unit, and to identify the components of efficiency (Sampaio 2013). The estimation procedure of maximum likelihood was used to obtain estimation parameters. In this study, the stochastic frontier of production function of Cobb-Douglas estimated using data from 200 farmers applying traditional fish farming of milkfish in the brackish water in Cilacap 2016 was used.

Results and Discussion. Table 2 shows the two stages of the process using the model of stochastic frontier of production function of milkfish. The first stage applied Ordinary Least Square (OLS) method to estimate the parameters of the technology and production inputs, and the second stage used Maximum Likelihood Estimator (MLE) to estimate the overall parameters of the factors of production, intercept, and variance of the error component of v_i and u_i.

The “average” comparison of both stages of the estimation of production functions was presented using Ordinary Least Squares (OLS) and Frontier Likelihood Function. All coefficients have a positive sign as expected indicating that the increase in input ultimately improves the level of the output (Sampaio 2013). All independent variables in the stochastic frontier of the production function proved to be significant at 5 percent significance.

Based on Table 2, the “average” of the two comparisons had the estimation parameter of the production function and the stochastic function that are likely to be similar to the intercept and the input coefficient. Yet, there were intercept value differences between the two production functions indicating that the function of the stochastic frontier represents the neutral shift of the "average" of the production function (Sampaio 2013). Furthermore, the slope coefficient of the two functions was slightly different that possibly be due to the inefficiency of the OLS estimation. In addition, in the likelihood specification function, the difference between the production function estimated by OLS and the frontier function which was statistically significant at λ implied that there was a significant difference between the two production functions.

Table 2

The empirical estimation of the ordinary least squares (OLS) and frontier production function

Variables	*OLS*	*Frontier Production Function*
Intercept	1.6953	1.7124
	(0.0068)*	(0.0057)*
Size of the Pond	0.2718	0.2594
	(0.0000) *	(0.0000) *
Fingerling/nener	0.3565	0.3665
	(0.0000) *	(0.0000) *
Chemical	0.1073	0.1084
	(0.0005) *	(0.0002) *
Feed Suplement	0.0632	0.0674
	(0.0281) **	(0.0152) **
Labor (man-day)	0.2669	0.2653
	(0.0000) *	(0.0000) *
R^2	0.6984	
$\lambda = \sigma_u / \sigma_v$		1.0507
		(0.0000) *
$\sigma = \sqrt{\sigma_u^2 + \sigma_v^2}$		0.25585
		(0.0000) *
σ_v^2		0.03111
σ_u^2		0.03435
Log likelihood function		29.8871

Note: * Significance at 1 percent; ** Significance at 5 percent.

Table 2 reveals that the value of the parameter of the variance, σ^2, and λ clearly demonstrates that the value of the parameter is greater than zero. This result statistically confirmed the existence of the differences in the technical efficiency among fish farmers. As shown in Table 2, the forecasting variance error is σ_v^2 and σ_u^2 is 0.03111 and 0.03435. Thus, the random variables variance σ_u^2 is larger than that of the random error variance σ_v^2. The λ value ($\lambda = \sigma_u / \sigma_v$) which is more than one clearly showed the dominant share of the estimated variance of the random variable, u, over the estimated variance of the entire error term. Therefore, it can be concluded that the majority of the residual variation of the output is associated with the variation of technical inefficiency, and the "error measurement" related to uncontrollable factors is correlated with the production process.

The total variation in the output of the frontier caused by technical efficiency could also be estimated. According to Battese & Corra (1977), the total variation in the output of the frontier caused by technical efficiency is calculated using the parameters Ω, where Ω is equal to σ_u^2 / σ^2. Using this formula, the result, 0.1342, meant that approximately 13 percent of the difference between the output observed and the frontier output was due to the technical inefficiency. In other word, the lack of the output observed in the frontier output was mainly due to factors within the control of the company.

In Table 3, the technical efficiency index of Jondrow et al (1982) is presented. Table 3 shows the level of technical efficiency for each individual company in which e^{-u_i} is calculated by estimating the error component of the random variables ui. The calculation reveals that the total of the minimum efficiency is 59.30 percent, the maximum one is 94.27 percent, and the average of the technical efficiency is 85.20 percent. Grabowski et al (1990) stated that a company is considered doing a technical efficiency if the index of the technical efficiency of the company is 82 percent. Therefore, using this standard, the company observed was considered having a technical efficiency as its index was 77.00 percent from the total fish farmers in the sample studied. The result of the analysis also explained that the composed error of the stochastic frontier model could be applied to estimate the level of technical inefficiency to the sample of milkfish farmers in Cilacap. Analysis showed that 85.20 percent on average of the sample had a technical inefficiency.

Table 3

The results of the specific technical efficiency in the stochastic frontier of the production

Efficiency score	*Frequency*	*Percent*
Less than 10	0	0.00
10.00-19.99	0	0.00
20.00-29.99	0	0.00
30.00-39.99	0	0.00
40.00-49.99	0	0.00
50.00-59.99	1	0.50
60.00-69.99	2	1.00
70.00-79.99	35	17.50
80.00-89.99	115	57.50
90.00-99.99	47	23.50
100	0	0.00
Total	200	100.00
More than 82%	154	77.00
Minimum	59.30	
Maximum	94.27	
Mean	85.20	
Std. Dev	0.061	

Sources: Primary data is processed 2016.

The existence of the technical inefficiency reduces the output of a certain level of input, and in turn it reduces the profitability of milkfish farmers (Irz & Mckenzie 2003). The loss of the milkfish production due to technical inefficiency might be estimated as the different level between the frontier and the output observed was present. When the actual output of the milkfish farming is divided by the efficiency index, the frontier or maximum feasible output was estimated to be generated (Irz & Mckenzie 2003). In addition, the value of the milkfish production loss is calculated by multiplying the output loss to the price (Irz & Mckenzie 2003). The inefficiency of the technical production resulted that the average of the estimated loss of milkfish production was 259.33 kg. As a result, the total number of milkfish production loss in all ponds in Cilacap was 51,865.06 kg per season, which was equivalent to Rp. 471,920,000 assuming that the price of milkfish was Rp 9,100 per kg.

The technical inefficient index of the milkfish farming at individual level is 59.30 to 94.27 percent, which is caused by the unorganized structure of big fisheries and the scattered group of small fisheries. The production could be increased by merger the small scale of fish farming to be one big establishment in order to utilize all resource necessary, although this method is still debated from the perspective of economic principles of achieving economies scale.

This recommendation is proposed because the policy makers and the operators have to increase the production and post-production effectively and efficiently in a systemized approach across the value chain of milkfish. The finding of the research and its development across the value chain of milkfish is important in order to identify the problems to determine the necessary actions that cover adoption of technology, government intervention, environmental awareness, and fish farming organization.

Conclusions. The traditional milkfish culture in Cilacap has been operated for years; yet, the efficiency of the production is still at medium level or 85.20 percent (inefficient) according to the index of Grabowski. This inefficiency is caused by the inefficient utilization of the resources and of the potential input to improve the production. As a result, 51,865.06 kg per season or Rp 471,920,000 of milkfish production is lost.

Acknowledgements. We are grateful to the Directorate General of Research and Development Strengthening (Ministry of Research, Technology and Higher Education of the Republic of Indonesia), which has provided funding for this research through Directorate of Research and Community Service.

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Received: 28 March 2017. Accepted: 25 May 2017. Published online: 11 June 2017.
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How to cite this article:
Suharno, Susilowati I., Firmansyah, 2017 Management of the traditional milkfish culture in Indonesia: an approach using technical efficiency of the stochastic frontier production. AACL Bioflux 10(3):578-586.