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Full Length Research Paper

Does attending seminars affect technical efficiency of white shrimp (*Litopenaeusvannamei*) aquaculture?

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Measuring technical efficiency and examining the factors affecting technical inefficiency of brackish water white shrimp aquaculture in Malaysia are the objectives of the study. This study applies a parametric approach (stochastic production function, SPF) and a non-parametric approach (data envelopment analysis, DEA) to measure technical efficiency. The estimated average technical efficiencies of shrimp farms are 54.7 % (SPF) and 43.3 % (DEA). Labour, feed and fry are the three major inputs used and are also the independent variables applied in the models. Elasticities of labour, feed and fry are found to be -1.650, 0.686 and 1.52, respectively. These data show that excessive labour was hired and that feed used and fry stocked are deficient. Stochastic inefficiency model and to bit regression are the two approaches applied to measure the factors affecting technical inefficiency. The variable of "seminar attended" is the consistent core factor, which significantly and negatively affects technical inefficiency. This means that human resource development is playing a vital role to achieve a significant measurable and sustainable impact in Malaysian shrimp aquaculture.

Keywords: Data envelopment analysis, stochastic trans-log production function, aquaculture, technical efficiency.

INTRODUCTION

In this study, the term "seminar" used is broadly to mean a workshop, talk, meeting or discussion forum that is organised by public authorities or even private companies. Hence, seminar refers to a place whereby shrimp farmers may not only stand up and express their questions, difficulties and expectations, but the seminar is also a place for them to obtain the latest information on shrimp diseases, the latest practice or culturing methods and technology, and also to learn about effective and good farming practice. Organizing seminars for farmers is generally considered to be part of the program of the Training and Visit System (T & V), which is an agriculture extension system promoted by The World Bank and began more than 30 years ago (Hussain, Byerlee and Heisey 1994; Quagrainie, Amisah and Ngugi 2009). Both organizing of seminars and T & V share the same objective, which is to encourage knowledge transfer vertically as well as horizontally. In fact, these activities are

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also defined as efforts of human resource development (Hassanpour, Ismail, Mohamed and Kamarulzaman 2010). In Malaysia, attending seminars is familiar to aquaculture farmers, especially shrimp farmers, due to the efforts of the local aquaculture extension and service. Additionally, shrimp aquaculture always encounters a high risk of disease outbreak and thereby generally involves a higher financial investment and a need for more skilled labour as compared to fish aquaculture.

Since the late 1990s, the Malaysian government has realised the potential of shrimp aquaculture and started to develop it under the Third National Agricultural Policy (1998-2010) (Ministry of Agriculture Malaysia, 1998). Shrimp aquaculture produced only 17,231 tons in 2000, worth only RM506 million (USD125.6 million). After strong emphasizing and promoting from the government, the industry achieved its highest production of 87,822 tons in 2010, which was worth RM1.2 billion (USD298 million). White shrimp (*Litopenaeusvannamei*) production has increased dramatically from 354 tons in 2000 to 69,084 tons in 2010, with white shrimp being promoted aggressively. White shrimp is an important farmed panaeid shrimp with the highest output of its kind and is also a dominant variety farmed and produced globally (Sui, Luan, Luo, Meng, Lu, Cao, Li, Chai, Liu, Xu & Kong 2015). In 2010, production of white shrimp accounted for almost 80% of national total shrimp production. The Malaysian government's aspiration to accelerate the growth of shrimp aquaculture has continued since the historical high of 2010.

Under the National Agrofood Policy 2011-2020, the Malaysian government targeted the achievement of 214,000 tons of national shrimp production, equivalent to RM 6.5 billion (USD1.6 billion), in 2020 (Ministry of Agriculture and Agro-Based Industry Malaysia, 2011). Shrimp aquaculture (especially brackish water shrimp aquaculture) is an industry largely reliant on environmental goods and services (mangrove forest, coastal land, tides, weather and others) (Beveridge, Phillips and Macintosh 1997). Nevertheless, the industry has showed a declining trend after 2010 such that production in 2015 recorded 52,987 tons, worth RM1.16 billion (USD288 million). The declining trend of shrimp production may be caused by various factors, such as disease outbreaks in shrimp farms and the conversion of farming to fish farming as well as the conversion of land use to residential and industrial purposes. Additionally, massive development of shrimp aquaculture through intensification may also lead to waste products (nitrogen and phosphorus wastes and others) that contribute toward declining returns. In pond culture for example, shrimp only consume 15-30% of nitrogen in the feed and hence the leftover is lost to the pond water as ammonia and organic-N in the form of faeces and feed residue (Rajkumar, Pandey, Aravid, Vennila, Bharti and Purushothaman 2015). Ammonia production results from the decomposition of organic-N in faeces and unfinished feed. This compounding results in the tremendous negative impacts to environment. Apparently, the potential of shrimp aquaculture can only be realised completely when the fundamental problems are addressed. In fact, the aquaculture sector has to develop and grow in an economically viable and environmentally sustainable manner (Sharma and Leung 2000). Therefore, efficient utilisation of inputs used would be an ideal way to reduce waste (Iliyasu, Mohamed, Ismail, Amin and Mazuki 2014). Hence, it is vital to measure technical efficiency and examine factors affecting technical inefficiency for ensuring sustainable growth of the industry as well as to achieve the national target by 2020. In view of this background, the current study attempts to measure technical efficiency and examines the variable of attending seminar and other factors that affect technical inefficiency in Malaysian white shrimp aquaculture.

This study applied data envelopment analysis (DEA) and stochastic production function (SPF) to measure technical efficiency. Yield per cycle, labour, feed and fry are the dependent and independent variables used in DEA and SPF. SPF is a parametric approach while DEA is a non-parametric approach, which Coelli, Rao and Battese (1998) categorize as a mathematical programming approach. These two popular approaches are widely applied to measure technical efficiency in various fields. Many scholars have applied both approaches in their studies due to their containing their own specifications that neither approach could be claimed intrinsically superior to the other. Besides, this study applied a tobit regression inefficiency model and stochastic inefficiency model to examine factors that affect technical inefficiency. A number of farmer-specific and farm-specific variables, such as farmer's income source, experience, seminar attended, land status, pond age and fry age, are included in the inefficiency model to examine if these factors significantly affect technical inefficiency.

This study conducts two different procedures for parametric and non-parametric approaches analyses. Parametric approach analysis requires a one-stage procedure, SPF and its inefficiency model are estimated simultaneously. It is because factors affecting technical inefficiency may also significantly affect technical efficiency due to the specifications of a SPF and, thereby, both models should be estimated concurrently (Coelli*et al.* 1998; Sharma and Leong 1998). However, a non-parametric approach analysis requires a two-stage procedure, namely the DEA technical efficiency model and tobit regression inefficiency model are estimated successively. DEA technical efficiency model measures technical efficiency mathematically in the first stage. In the second stage, the estimated technical efficiency levels must be recoded differently (one subtract technical efficiency level of each farm) as a proxy of the dependent variable in the tobit regression inefficiency model.

Review of Literature

The concept of technical efficiency was proposed 60 years ago by Farell (1957). In general, technical efficiency consists of two types, input and output oriented technical efficiency. Input oriented technical efficiency reflects the ability of a firm to minimise quantity of inputs used as compared to the potential least input used in order to produce a targeted output. Output oriented technical efficient, on the other hand, is understood as the ability of a firm to maximise output produced as compared to the potential output that can be attained from a given set of inputs. Stochastic production function (SPF) was first independently proposed by Aiger, Lovell and Schmidt (1977) and Meeusen and van den Broeck (1977), attracting wide interest of scholars throughout the world. The concept of technical efficiency has then been further discussed and revised. Battese and Coelli (1988) proposed a random effect model that involved technical efficiency of farm specific activities. The random effect model is shown as the following,

$$Y_i = \beta X_i + v_i - u_i \quad (1)$$

Where Y_i denotes yield of shrimp farm i,X_i denotes inputs used in shrimp farm i production, β denotes coefficient of each input used, v_i denotes error term of shrimp farm production, u_i denotes inefficiency of shrimp farm production. Error term is used to capture all unobservable factors (weather, disease outbreak and others) affecting the dependent variable that the model has not accounted for. The error term could be either a negative or positive value, while u_i is always a non-negative value. Both v_i and $u_i$are assumed to be independently and identically distributed with mean zero and variances $v_i \sim iid\ N(0, \sigma_v^2)$ and $u_i \sim iid\ N^+(0, \sigma_u^2)$, respectively. u_i can be expressed as a technical inefficiency model to examine factors affecting technical inefficiency. The model can be addressed as follows,

$$u_i = \delta Z_i + w_i \quad (2)$$

Where δ denotes coefficient of each factor, Z_i denotes factors responsible for technical inefficiency and wide notes normally distributed error term of the model. Both function 1 and function 2 need to be examined simultaneously in order to obtain technical efficiency and significant factors affecting technical inefficiency.

Charnes, Cooper and Rhodes (1978) proposed a non-parametric approach that involves mathematical and linear programming. DEA constructs a piece-wise linear surface by employing least inputs of a shrimp farm due to input oriented technical efficiency analysis, which is applied in this study. Coelli, Rao, O'Donnell and Battese (2005) state that inefficient is assumed if there is any deviation from the piece-wise surface. The DEA technical efficiency model is presented as follows,

$$\begin{aligned} &\text{Min}_{\theta,\lambda}\theta, \quad (3)\\ &\text{subject to } -q_i + Q\lambda \geq 0\\ &\theta x_i - X\lambda \geq 0\\ &I1'\lambda = 1\\ &\lambda \geq 0 \end{aligned}$$

Where θ denotes technical efficiency index of shrimp farm i, q_i denotes yield shrimp farm i, x_i denotes input used of farm i, Q denotes output data for all shrimp farms, λ denotes I x 1 vector of constants, X denotes input data for all shrimp farms, N denotes number of shrimp farms in sample, Qλ and Xλ denote efficient estimations from DEA piece-wise surface (Coelli *et al.* 2005). Inefficiency of shrimp farm *I* can be measured with 1 – θ. For example, if θ is 0.65 for shrimp farm *i*, then the inefficiency index is 0.35 (where 1 – 0.65) as measured. I1' λ equal to one is the convexity constraint, I1 denotes I x 1 vector of ones. The authors define that the new constraint functions like a convey hull of intersecting planes making the comparison of shrimp farms from similar size possible, and the data can be enveloped more tightly.

METHODOLOGY

Study area and data collection

Malaysia, consists of thirteen states and three federal territories. All the thirteen states are located along the coastal areas in West Malaysia and East Malaysia. All of the states are engaging in white shrimp aquaculture activity and thereby are selected for the study. There are eleven states (Perlis, Kedah, Penang, Perak, Selangor, Negeri Sembilan, Malacca, Johor, Kelantan, Terengganu and Pahang) in West Malaysia, while two states (Sabah and Sarawak) are located in East Malaysia. Consequently, this study applies a stratified sampling method to divide the Malaysian white shrimp aquaculture by geographical feature.

A questionnaire type interview was conducted to obtain information from the selected Malaysian white shrimp farmers and their farms. The questionnaire consists of three sections asking about the background of shrimp farmers, background of shrimp farm and farm operational information (including daily practice, cost and yield). Information obtained was analysed and converted into suitable measurement units per culture cycle. Duration of Malaysian white shrimp culture cycle is approximately three to four months' period. Hence, Malaysian white shrimp farms usually produce two to three crops a year. The data information applied in this study is generally classified into dependent variable, independent variables and inefficiency determinants. Descriptions of these variables are presented in Table 1 and they are measured

Table 1. Description of variables.

Variables	Description	Unit
Dependent variable		
Yield (Y)	Quantity of shrimp harvested per pond size	Kilogram per hectare
Independent variables		
Labour (X_1)	Quantity of labour multiply culturing days per pond size	Days per hectare
Feed (X_2)	Quantity of feed per pond size	Kilogram per hectare
Fry (X_3)	Quantity of shrimp fry stocked in pond per pond size	Number per hectare
Inefficiency determinants		
Income source(Z_1)	Main source of income (1 = shrimp farm; 0 = otherwise)	Dummy
Experience (Z_2)	Years of farming experience of farmer	Year
Seminar attended (Z_3)	Seminar attended (1 = yes; 0 = otherwise)	Dummy
Land status (Z_4)	Status of farm land (1= owner; 0 = otherwise)	Dummy
Pond age (Z_5)	Average age of ponds	Year
Fry age (Z_6)	Average age of fry stocked	Year

per pond size (hectare) basis in order to accurately compute productivity of the shrimp farms, which is identical to Sharma and Leung (2000).

A total sample size of 117 respondents (15.8%) was randomly selected from the list of white shrimp farmers provided by the Malaysian department of fisheries for the purpose of achieving an ideal representation of population (740). However, due to incomplete information given, only data from 100 questionnaires was obtained for analysis in the present study. A summary statistic is presented in Table 2. An average yield harvested is 8356 kg/ha, with a maximum and minimum of 30000 kg/ha and 505.75 kg/ha, respectively. In addition, the average number of labour working days per culture cycle is 140.92 days/ha, which range from a maximum of 1000 days/ha to a minimum of only 6 days/ha. The small number of minimum working days is due to the extensive culture system practiced by the shrimp farmer who may even have another job working outside the shrimp farm. Feed is one of the important inputs in aquaculture. Also, feed cost constitutes the greatest proportion of shrimp production cost in Malaysia. Although the feed is locally made, but the main ingredient–soy meal–is imported and thereby the price of feed remains high and it is hard to reduce. This is unlike the practice of fish aquaculture in that some fish farmers do not consume commercial feed yet they culture the fish by feeding industrial feed like trash fish, kitchen waste and chicken intestine (Iliyasu *et al.* 2014). Malaysian shrimp farmers always consume commercial feed due to Malaysian shrimp aquaculture is extremely sensitive to disease, especially early mortality syndrome (EMS) and white spot syndrome (WSS). Consuming commercial feed by Malaysian shrimp farmers ensures the water contamination is of low level and thereby their shrimp farms can avoid the outbreak of diseases. Average quantity of feed purchased by the surveyed shrimp farmers is 10696 kg/ha. Furthermore, average shrimp stocking density is 840466 fry/ha, which is relatively low (84 fry/m^2). According to FAO (2004), *Litopenauesvannamei* can be easily cultured in a pond with a stocking rate of 60 - 150 fry/m^2 and even be as high as 400 fry/ m^2 in a controlled environment.

Average years of experience of surveyed shrimp farmers are 11 years, with a maximum and minimum of 30 years and 1 year, respectively. Most of these farmers (82%) have spent their full time devoted to working in their shrimp farms to earn a living but only a few of them (39%) are willing to spend time attending seminars. Besides, there is a small number of shrimp farmers (25%) owning the lands of their shrimp farms, meaning that most of them (75%) are operating their shrimp farming activities on rented coastal lands. Average pond age is 9.67 years and sample group ranges from a maximum of 28 years to a minimum of only 2 years. The high value of pond age is attributable to the practice of some shrimp farms rehabilitating the long-time abandoned ponds. Fry age is measured as PL (post larvae), then followed by numeric value. For instance, PL 8 refers to 8-day-old post larvae. Malaysian white shrimp farms commonly apply PL 5 to PL 13 in their farming. The average age of fry stocked by shrimp farmers is 9.57 days.

Empirical models

In the present study, two types of economic approaches were applied to measure technical efficiency, parametric approach and non-parametric approach. These economic approaches contain different properties leading to different characteristics, advantages and disadvantages. Using only

Table 2. Summary statistics of variables.

Variables	Maximum	Mean	Minimum	Standard deviation
Dependent variable				
Yield (Y)	30000	8356	505.75	5450.29
Independent variable				
Labour (X_1)	1000	140.92	6	121.42
Feed (X_2)	82962	10696	225	13556.25
Fry (X_3)	6000000	840466	17538	753518.86
Inefficiency determinants				
[a]Income source (Z_1)	-	82	-	-
Experience (Z_2)	30	11	1	6.88
[b] Seminar attended (Z_3)	-	39	-	-
[c] Land status (Z_4)	-	25	-	-
Pond age (Z_5)	28	9.67	2	5.55
Fry age (Z_6)	13	9.57	5	1.915

[a] Number of shrimp farmers whose incomes earned mainly from shrimp farming.
[b]Number of shrimp farmers who attended seminar.
[c]Number of shrimp farms whose land owned by shrimp farmers themselves.

one economic approach in any study would produce partial, debatable and unreliable findings and thereby would fail to convince the readers.

Stochastic trans-log production function is a parametric approach applied in this study. Trans-log production function is a log-quadratic function that is flexible in estimating output elasticity of every independent variable due to fewer restrictions on output and substitution elasticity. The empirical stochastic trans-log production function is presented as follows,

$$\text{Ln YIELD}_i = \beta_0 + \beta_1 \text{ Ln LABOUR}_i + \beta_2 \text{ Ln FEED}_i + \beta_3 \text{ Ln FRY}_i + 0.5\,\beta_{11} (\text{Ln LABOUR}_i)^2 + 0.5\,\beta_{22} (\text{Ln FEED}_i)^2 + 0.5\,\beta_{33} (\text{Ln FRY}_i)^2 + \beta_{12} [(\text{Ln LABOUR}_i)(\text{Ln FEED}_i)] + \beta_{13} [(\text{Ln LABOUR}_i)(\text{Ln FRY}_i)] + \beta_{23} [(\text{Ln FEED}_i)(\text{Ln FRY}_i)] + v_i - u_i \quad (5)$$

This study applies variables of average yield, labour hired, feed used and fry stocked as the dependent and independent variables (Table 2). Dependent variable refers to average yield of a farm, which is measured in kilograms per hectare. This study calculated the total yield of a shrimp farm per cycle and then divided by total pond size (harvested ponds). For instance, there are five shrimp ponds in farm A and only three ponds that are used for shrimp farming, thereby the output measured as total yield of shrimp farm divided by total size of the three ponds. The labour variable is measured in days. Labour variable is measured with number of permanent labours hired times total culture days in a cycle and then the value is divided by total size of all ponds in the farm. This is unlike the measurement of total yield due to the labourers are none the less working on the pond after final harvesting in order to prepare the ponds for the next cycle of shrimp farming. In addition, the feed variable is measured in kilograms per hectare due to all the Malaysian white shrimp farmers consuming shrimp feed. This study calculated the total weight of shrimp feed consumed of a farm per cycle and then divided by the total size of harvested ponds. Similarly, the fry variable is measured in quantity of fry stocked in pond per hectare and the calculation is an aggregate of the total quantity of fry that are stocked by a farm, then divided by the total size of harvested ponds. Second order condition (interaction with itself or square term) and interaction term of independent variables are part of the property in trans-log production function. There might be a situation that the second order condition and the interaction term are not significantly different from zero, which the generalised likelihood ratio test failed to reject the first null hypothesis ($H_0 : \beta_{11} = \beta_{22} = \beta_{33} = \beta_{12} = \beta_{13} = \beta_{23} = 0$). If it is in that way, Cobb Douglas production function should be considered. Cobb Douglas production function can be addressed as follows,

$$\text{Ln YIELD}_i = \beta_0 + \beta_1 \text{ Ln LABOUR}_i + \beta_2 \text{ Ln FEED}_i + \beta_3 \text{ Ln FRY}_i + v_i - u_i \quad (6)$$

Data envelopment analysis (DEA) is a non-parametric approach applied in the present study. This approach consists of input and output oriented data envelopment analysis. The input-oriented model is applied to determine how many of the inputs an inefficient decision making unit (DMU) can reduce in order to achieve an efficient level given the constant output. The output-oriented model is applied to determine how much of yield an inefficient DMU can increase in order to achieve the efficient level given the constant inputs. This study applied the input-oriented DEA due to the fact that shrimp farmers usually harvest their shrimps several times based on growth rate and size of the shrimp. Input-oriented DEA technical efficiency model can be addressed as follows,

Minimise $_{\theta,\lambda}$ θ,
subject to-$YIELD_i$ + ($YIELD_1\lambda_1$ + $YIELD_2\lambda_2$ + … + $YIELD_{100}\lambda_{100}$) ≥ 0
$\theta LABOR_i$ – ($LABOR_1\lambda_1$+ $LABOR_2\lambda_2$ + … + $LABOR_{100}\lambda_{100}$) ≥ 0
$\theta FEED_i$ – ($FEED_1\lambda_1$+ $FEED_2\lambda_2$ + … + $FEED_{100}\lambda_{100}$) ≥ 0
θFRY_i – ($FRY_1\lambda_1$+ $FRY_2\lambda_2$+ … + $FRY_{100}\lambda_{100}$) ≥ 0
I1' λ = 1   λ ≥ 0   (7)

Examining significant factors that affect technical efficiency is of great interest to the study as well as researchers in the field alike. In the stochastic production function, technical inefficiency, u_i is associated in equation 1 and it is assumed independently and identically half-normal distribution with zero mean and the variance, σ_u^2. However, technical efficiency is measured in equation 3 and the technical inefficiency, u_i is obtained with one minus technical efficiency. Technical inefficiency model can be addressed as follows,

$u_i = Z_0 + Z_1INCOME_i + Z_2EXPERIENCE_i + Z_3SEMINAR_i + Z_4LAND_i + Z_5POND_i + Z_6FRYAGE_i$ (8)

In SPF, equation 5 (or equation 6) and 8 are examined simultaneously, while DEA examines equation 7 and 8 separately by using tobit regression, identical to Alam (2011). This technical inefficiency model typically consists of farmer-specific variables and farm-specific variables. Income source, experience and seminar attended are considered to be the farmer-specific variables, whereas land ownership, pond age and fry are the farm-specific variables incorporated in the model. Variable of income source is a dummy variable. Some of the farmers spend most of their time in operating their farms throughout the year and thereby earnings of their farms are their sole incomes. In layman's terms, these farmers are called full-time farmers. These farmers are expected to have full attention on their shrimp farms and thereby should be more technically efficient. Aquaculture farmers are generally facing a lot of challenges and uncertainties throughout the cycle. Hence, experience earned by the farmers day-by-day and year-by-year, becomes an invisible asset for them to make the right decision during every challenge. Experience of farmers is measured in years. The variable of seminar attended is a dummy variable, which is broadly known as workshop, talk, meeting and discussion organised by public authorities or private companies for shrimp farmers. As mentioned in the introduction, a seminar is a place whereby farmers not only could present their questions, difficulties and expectations, but also is a platform from which they could obtain the latest information on shrimp diseases and the latest technology, and learn the effective and good farm practice as well. Therefore, variable of seminar attended is expected to positively affect technical efficiency. This variable is measured as one for those who have attended any seminar and zero otherwise.
Variable of land ownership is also a dummy variable that indicates whether the farmer owns the farm land or has rented it. Farmers who operate shrimp farms on their own lands are expected being more technically efficient than those operate on rented lands (Iliyasu *et al.,* 2014). Ponds that have been used for many years are expected to be technically inefficient because these ponds might be contaminated with faeces and feed leftovers that dissolved and penetrated the soil if treatments fail to be conducted. Liming is one of the common treatments applied to improve alkalinity of pond water and soil and thereby mitigate the effects of contamination. Hence, variable of pond age is applied to investigate the effect that affects technical efficiency of farm. Despite the difference in pond ages among ponds in a farm, average of pond age is applied in this study. Variable of fry age is of concern due to the belief in the older the fry, the higher the survival rate and thereby the higher the technical efficiency would be experienced by the farms. This is unlike fish aquaculture that the fry is measured in size (inches) (Alam 2011).
Null hypothesis testing is an essential part of stochastic production function analysis. Two hypotheses are tested in this study. The first hypothesis stated that Cobb Douglas production function is preferred in the study (H_0: β_{11}= β_{22} =$\beta_{33=}$=β_{12} = β_{13} = β_{23} = 0) and the second hypothesis stated that there is no technical inefficiency effect in the technical inefficiency model. These two hypotheses are tested using a generalised likelihood ratio test. Generalised likelihood ratio test statistic can be presented as follows (Coelli *et al.* 1998),
Generalised likelihood ratio test statistic, LR = -2 [$L(H_0)$ – $L(H_1)$]
Where $L(H_0)$ and $L(H_1)$ refers to the values of likelihood function under unrestricted (H_0) and unrestricted (H_1) hypotheses. In order to reject a null hypothesis or not, there are two conditions that refer to critical value (with a degree of freedom equal to the number of restrictions involved), namely chi-square distributed condition and mixed chi-square distributed condition. Mixed chi-square distributed condition is applied if H_0: γ = 0, where critical value of Kodde and Palm (1986) is referred. On the other hand, chi-square distribution is usually referred to compare with LR. If the calculated LR is greater than the critical value, then the null hypothesis is rejected.

RESULTS AND DISCUSSION

Hypotheses test

This study has tested two hypotheses by using the generalised likelihood ratio test. Results of hypothesis

Table 3. Generalised likelihood ratio test of hypothesis for stochastic production function.

Test of null hypothesis	Log likelihood of H_o	Log likelihood of H_1	Test statistic, λ	DF	Critical value	Decision
Cobb Douglas is preferred	-64.009	-48.877	30.264	6	10.645[a]	Reject H_o
No inefficiency effect	-57.524	-48.877	17.295	8	12.737[b]	Reject H_o

[a]Critical value is obtained from Table of chi-square distribution at the 10% statistical significant level.
[b] Critical value is obtained from Table 1 in Kodde and Palm (1986) at the 10% statistical significant level.

testing are shown in Table 3. The first null hypothesis that Cobb Douglas production function is preferred in the study was tested. The test involves investigating whether the second order (interaction with itself or square term) condition and the interaction term of the trans-log production function are significantly different from zero. A trans-log production function without all the square term and interaction term is simply noted as a Cobb Douglas production function. The result shows the test statistic (λ) of 30.264 {– 2 [–64.009 – (–48.877)]}, which is greater than the critical value (10.645), hence the null hypothesis was rejected. This finding shows that trans-log production function is more suitable than Cobb Douglas production function for describing the productive efficiency of aquaculture. The finding is in conformity with previous studies (Iliyasu *et al*., 2014; Asche and Roll, 2013).

The second null hypothesis that there is no technical inefficiency effect in the trans-log production function was also tested. If this hypothesis fails to be rejected, the investigations of technical efficiency performance and factors affecting technical inefficiency will become invalid. The result reveals that the second null hypothesis was rejected, the test statistic of (λ) 17.295 {–2[–57.524 – (–48.877)]}, which is greater than the critical value (12.737), hence this implies that the technical inefficiency indeed happens among the shrimp farms.

Estimated coefficients of stochastic trans-log production function

Maximum likelihood estimations of stochastic trans-log production function and technical inefficiency model are reported in Table 4. Estimated coefficient in the stochastic trans-log production function cannot be simply interpreted as output elasticity's with respect to the inputs, just as Codd Douglas production function does (Sharma & Leung, 1998). Output elasticities for all the three inputs applied were derived and presented in Table 5. Output elasticity for labour is negative, suggesting that a 1 % increase in the number of labour would, *ceteris paribus*, result in a 1.65 % decrease in shrimp harvesting. Logically, this would not really happen in reality. However, this finding provides important information that the employment of labour in most of the Malaysian shrimp farms has exceeded the optimal level. Malaysian shrimp aquaculture is a labour intensive industry; this phenomenon happens due to the lack of skilled permanent labours. For the past two decades, Malaysian shrimp farms highly depend on foreign labourers that come from the Malaysia's neighbouring countries. It is because the local people, including the shrimp farmers' children, are not interested to join this industry. Further, the Malaysian foreign labour turnover is high because these foreign labourers would return to their countries after working for a few years (3- 5 years) and before their working permits expire. These skilful foreign labourers would probably work elsewhere in Malaysia when they come again to work in this country. Also, some of them might even leave halfway through their contract with shrimp farms. Hence, the Malaysian shrimp farms tend to employ excess foreign labour to mitigate the impacts of some of them leaving prematurely.

Output elasticities for feed (0.686) and fry (1.52) are positive, meaning that these inputs have positive impacts on harvest in this study. Theoretically, it explains that 1% increase in the feed would, *ceteris paribus,* result in a 0.686% increase in harvest. This explains that feed used in Malaysian shrimp farms are approaching optimal level, which is any increase in feed would not increase in harvest. However, fry stocked is far less than the optimal level due to the shrimp farmers attempt to improve (or maintain) the high shrimp survival rate. Further, the estimated return to scale of white shrimp aquaculture is 0.556. The return to scale is measured as the summation of output elasticity's, which indicates that the shrimp farms generally perform a decreasing return to scale (stage 2 of production function) in their white shrimp farming activity. This situation assumes that the shrimp farms increase all the inputs of production (labour, feed and fry) by 1%, the harvest would only increase 0.556 %.

Technical efficiency (SPF versus DEA)

Technical efficiency analyses on Malaysian white shrimp aquaculture were conducted by using two different

Table 4. Results of stochastic production function and Tobit regression analysis.

Variables	Stochastic production function			Tobit regression analysis		
	Coefficient	#SE	T-ratios	Coefficient	#SE	P-value
Constant	-15.592	1.297	-12.018***			
Labour	1.965	0.993	1.978**			
Feed	-0.1760	0.635	-0.277			
Fry	2.400	0.358	6.695***			
(Labour)2	-0.334	0.096	-3.487***			
(Feed)2	0.072	0.063	1.143			
(Fry)2	0.061	0.047	1.285			
(Labour)(Feed)	0.339	0.098	3.450***			
(Labour)(Fry)	-0.257	0.099	-2.589***			
(Feed)(Fry)	-0.149	0.044	-3.352***			
Inefficiency model						
Constant	2.247	0.889	2.527**	0.666	0.103	0.000***
Full-time	-0.250	0.499	-0.502	-0.103	0.065	0.114
Experience	-0.006	0.036	-0.160	0.0004	0.004	0.931
Seminar	-0.888	0.475	-1.868*	-0.152	0.056	0.006***
Land ownership	-1.315	0.696	-1.889*	0.108	0.057	0.058*
Pond age	-0.074	0.046	-1.608	0.0002	0.006	0.977
Fry age	-3.730	1.600	-2.331**	0.023	0.165	0.889
Sigma-squared	0.337	0.121	2.784***			
Gamma	0.668	0.145	4.614***			
Log likelihood	-48.877					

\# Standard error
* Statistically significance at 1%
** Statistically significance at 5%
*** Statistically significance at 10%

Table 5. Elasticity of trans-log stochastic production function.

Inputs	Elasticity
Labour	-1.650
Feed	0.686
Fry	1.520
Return to scale	0.556

approaches (SPF and DEA). The estimated technical efficiency of the individual shrimp farms is presented in Appendix I. Results of DEA reveal that the technical efficiency levels (in percentage) of the shrimp farms range from the lowest of 3.5 % to the highest of 100 %. On the other hand, results of SPF reveal that the technical efficiency levels (in percentage) of the shrimp farms range from the lowest of 7.3 % to the highest of 87.4 %. The estimated average technical efficiency of shrimp farms is 54.7 % (SPF) and 43.3 % (DEA). Results of SPF reveal that the majority (82%) of the shrimp farms obtain the technical efficiency levels in the range of 40.1 – 80 % as presented in Figure 1. In detail, 41% of the shrimp farms obtain the technical efficiency levels in the range of 40.1 – 60% and 60.1 – 80%, respectively. However, results of DEA reveal that the majority (55%) of shrimp farms obtain the technical efficiency levels in the range of 20.1 – 40%. Both results consistently show that there is still opportunity for further utilising the inputs applied in white shrimp farming activity. Knowledge of fully utilising the inputs applied could be learned by the farmers from attending seminars, workshops, talks, meetings or discussions that held by public authorities, as well as private companies.

Technical inefficiency model (SPF versus DEA)

This study also applies two approaches to investigate factors affecting technical efficiency of Malaysian white shrimp aquaculture. Hence, there are two sets of results as presented in Table 4. In the table, the factors that obtain negative coefficients in the technical inefficiency models, positively affect technical efficiency of shrimp farms. Results of SPF shows that the coefficients of seminar attended, land ownership and fry obtain the statistically significant and have positive impacts on technical efficiency. On the other hand, the result of DEA shows that

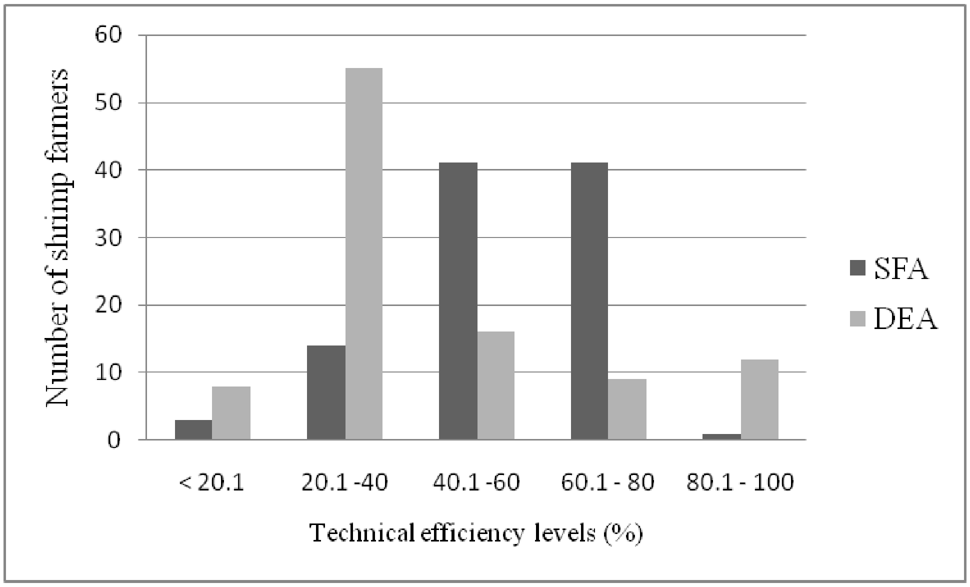

Figure 1. Technical efficiency levels of shrimp farmers.

the coefficient of seminar attended is found significantly and positively affecting technical efficiency while the coefficient of land ownership significantly and negatively affecting technical efficiency. As a result, the factor of seminar attended is absolutely the sole factor significantly and positively, as well as consistently affecting technical efficiency. Farmers, who have attended a seminar perform more technically efficient than those who have not attended any seminar. The farmers would obtain the latest information on diseases and disease handlings, as well as the knowledge of latest shrimp farming practices. Seminar would also motivate the farmers in fully utilizing the inputs applied in their shrimp farming operations.

CONCLUSION AND RECOMMENDATIONS

Malaysian white shrimp aquaculture has attracted attention from the Malaysian government and private sector to invest and develop this industry. It is because this industry could create great return on investment due to the great consumption from domestic and international markets. In using a parametric approach (SPF), two hypotheses have been tested regarding the validity of a model by using generalised likelihood ration test. The first hypothesis, the Cobb Douglas production function, is preferred as compared with trans-log production function, which was rejected. Furthermore, the second null hypothesis stated that there is no technical inefficiency effect in the trans-log production function, which was also rejected. This implies that stochastic trans-log production function associated with the technical inefficiency model is an appropriate and reliable model for the data given in this study.

White shrimp yield, labour, feed and fry are referred as the output and inputs applied in the study to measure the technical efficiency of Malaysian white shrimp farms. Results show that the shrimp farms obtain 0.547 (SPF) and 0.433 (DEA), which implies that they are respectively 54.7% (SPF) and 43.3 % (DEA) technically efficient. This reveals that the shrimp farms have been operating at least 45% below the production frontier. Hence, some improvements have to be done to further utilise the inputs applied in white shrimp aquaculture, especially knowledge and skill enhancement among Malaysian shrimp farmers.

Technical inefficiency model incorporates the variables of farmer’s working status, farmer age, educational background, experience, land ownership, average pond size, quantity of ponds, average pond age, fertiliser practice, fry size and per-cycle culturing days in the study. The second hypothesis that there is no technical inefficiency effect in the trans-log production function was rejected in the generalised likelihood ratio test. Therefore, the variables of technical inefficiency model are essential to explain the variations of inputs applied among the shrimp farms. However, results (SPF and DEA) reveal that the variable of seminar attended is the unique variable significantly, positively and consistently affecting technical efficiency among the variables. In order to practice the policy of fully utilise the endowed resources, the government should provide the shrimp farmers with more knowledge sharing, planning and management seminars that would expectedly deliver the latest knowledge on diseases and handling, and even the latest knowledge of shrimp farming practices among the shrimp farmers and thereby motivate the shrimp farmers to fully utilise the inputs applied in their shrimp farming operations. As a result, with the great human resource development the Malaysian white shrimp aquaculture would eventually achieve a sustainable development.

This study applied cross-sectional data for the analysis and thereby contribution to the knowledge and Malaysian white shrimp aquaculture development is restricted. This study suggests that at least a 5-year panel data of the Malaysian white shrimp aquaculture would be ideal for researchers to contribute more to the knowledge and the development of the industry. However, to construct a 5-year panel data set of this industry is time consuming, costly and difficult task for researchers to conduct. The limitation would be improved if the Malaysian government could impose on all the shrimp farmers to be registered and provide their annual shrimp farm operating information as a compulsory practice (Iliyasu *et al.*, 2014). Although white shrimp (*Litopenaeusvannamei*) aquaculture is most commonly cultured in Malaysia, brackish water Asian tiger prawn (*Penaeusmonodon*) is also cultured in Malaysia. Therefore, future research should consider estimating the technical efficiency of Malaysian tiger prawn aquaculture in order to understand and describe the practice of Malaysian brackish water shrimp aquaculture.

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