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Comparative analysis of technical efficiency for different production culture systems and species of freshwater aquaculture in Peninsular Malaysia

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ABSTRACT

This study estimated the bias-corrected technical efficiency (BCTE) of different culture systems and species of freshwater aquaculture in Malaysia using bootstrapping data envelopment analysis (DEA). Data were collected from 307 respondents from three states in Peninsular Malaysia using a well-structured questionnaire as well as oral interviews. The findings indicate that all technical efficiency scores for all culture systems and species are below the optimal level (i.e. one). In addition, the results show that farmers' experience, contact with extension workers and household size have a positive and statistically significant impact on technical efficiency. This implies that farmers who have long tenure in fish farming and also the opportunity to meet with extension workers are operating close to the production frontier (technically efficient). On the other hand, the age of the farmers has a negative and statistically significant impact on technical efficiency. Although educational level and farm status have a positive impact on technical efficiency, they are statistically insignificant. Furthermore, all the inputs used in the production process of different culture systems and species contained slacks and need to be reduced accordingly. Feed, the major input in fish production and constituting over half of the production costs, is equally over-utilized. Thus, the government, in collaboration with research institutes and universities, should design a feeding formula for fish depending on species, culture systems and stages of growth. This could help to reduce production costs, increasing the farmers' income, as well as providing much needed animal protein to consumers at an affordable rate.

1. Introduction

Freshwater aquaculture, which has the potential to grow in Malaysia due to an abundance of natural resources, can play an important role in supplying protein to meet rising demand due to increases in consumers' income, changes in life style and population growth. In addition, freshwater aquaculture in Malaysia can be characterized as being very diverse, both in terms of culture systems and species. Catfish, carp, red tilapia, black tilapia, snakehead and prawn are produced in ponds, cages, ex-mining pools, cement tanks, canvas tanks, pens and many other systems. The total quantity of catfish produced in 2012 was approximately 73,816 tons, thereby making it the largest contributor to freshwater aquaculture production (47.08%). Another highly important species that has become increasingly vital in this sector is red tilapia, with total production of 38,841 tons (23.72%) in 2012. Carp species also play a significant role in freshwater aquaculture production, contributing 24,546 tons (14.99%). The contribution of black tilapia to freshwater aquaculture production accounted only for 12,713 tons (7.76%). Snakehead, giant freshwater prawn and other species contributed approximately 1,284 tons (0.78%), 318 tons (0.19%) and 12,239 tons (7.74%), respectively.

In terms of production culture systems, ponds are the major contributor of fish food to fresh water aquaculture, with total production of approximately 83,145 metric tons (63%) in 2013. This is followed by ex-mining pools, the production level of which dropped sharply from approximately 67,937 metric tons in 2012 to 32,582 metric tons in 2013. The next most important culture system is cages, which witnessed slight drop in production from 12,061 metric tons in 2012 to 10,854 metric tons (8.2%) in 2013. Cage culture systems involve the use of freshwater dams, lakes, reservoirs and—notably—abandoned ex-mining pools. However, as land becomes scarce and increasingly expensive due to urbanization and industrial use, cage culture systems are likely to attract

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Table 1
Description of the variables in DEA and OLS models.

Variables in the models	Description	Unit
Dependent variable		
Output	Total quantity of fish produced	Kilogram
Independent variables		
Stocking density	Fingerlings stocked in the farm per production cycle	Number
Feed	Total quantity of feed utilized per production cycle	Kilogram
Labor	Total number of family and hired labor used per production cycle	Man-day
Other costs	Represents costs incurred of other inputs per production cycle	Ringgit[a]
Technical efficiency determinants		
Age	Represents age of fish farmer/manager	Year
Experience	Represents number of years the farmer/manager spent in fish farming	Year
Educational level	Level of education of fish farmer/manager	Level
Farm status	Status of the fish farm and is dummy (1 = owner, and 0 = otherwise)	Dummy
Extension services	Extension visits to fish farm in the last three years (1 = yes; otherwise)	Dummy
Household size	Number of the fish farmer family	Number

[a] 1USD = 4.2 Ringgit (Malaysian currency).

more potential investors, thereby leading to an anticipated increase in production. Others culture systems, such as cement tanks, canvas tanks and pens, have played little role in contributing to freshwater aquaculture production. The total farmed food fish production from cement tanks, canvas tanks and pen culture systems in 2013 was approximately 4,827 metric tons (3.6%), 366 metric tons (0.3%) and 118 metric tons (0.1%), respectively.

Despite its wide diversification in terms of production culture systems and species, freshwater aquaculture production is relatively low compared to brackish water aquaculture. For instance, the total production from freshwater aquaculture in 2013 was a mere 132,892 metric tons (25%) compared to 397,313 metric tons (75%) from brackish water aquaculture. This low level of freshwater production could be attributed to technical inefficiency at the farm level. However, fish farmers may be facing different challenges in managing their farms and these may contribute directly or indirectly to technical inefficiency. Factors such as the farmer's age, experience, frequency of contact with extension workers, educational level, household size, farm status, access to credit facilities, adaptation of technology and water management techniques may be responsible for the technical inefficiency at farm level. Thus, it is against this background that the present study aims to estimate the technical efficiency of different culture systems and species in freshwater aquaculture. In addition, it aims to investigate those determinants that are responsible for technical inefficiency in freshwater aquaculture to formulate policy that will assist in improving this vital sector.

2. Efficiency measurement in aquaculture

There have been many theoretical developments in and practical applications of data envelopment analysis (DEA) since its invention, especially in the fields of banking, health, agriculture, transportation, education and manufacturing. Liu et al. (2013) reported that among the 4,936 published articles on DEA in citation journals, 1,802 (36.5%) and 3,134 (63.5%) are purely methodological and empirical applications, respectively. This wide application of DEA indicates its strength and capability in measuring the technical efficiency of firms.

However, stochastic frontier analysis (SFA) is predominantly used for estimating technical efficiency studies in the aquaculture industry (Appendix A), perhaps because DEA attributes all deviations from the production frontier to technical inefficiency, thereby making it an inappropriate technique in some sectors, especially in agriculture, in which the data collection process is sensitive to stochastic noise and other measurement errors (Coelli et al., 2005). This shortcoming of DEA led Simar and Wilson (1998, 2000) to propose a technique which allows the construction of confidence intervals for DEA technical efficiency scores with the help of bootstrapping procedures. The reason for bootstrapping is to estimate the bias-corrected technical efficiency (BCTE), which is more accurate estimates of efficiency scores than the conventional DEA.

Despite this development, the application of the DEA bootstrapping technique has thus far been limited in measuring the efficiency of aquaculture. Indeed, Chang et al. (2010) work is the only study to have used this technique to estimate BCTE in aquaculture. Most other studies have employed the conventional DEA model to estimate the technical efficiency of aquaculture (Appendix B). This therefore motivates the use of the DEA bootstrapping method to estimate BCTE in this study.

3. Methodology

This section presents the sampling technique, the method of data collection and the models employed in data analysis.

3.1. Sampling technique

Three states (Perak, Selangor and Pahang) of the 11 states in Peninsular Malaysia were purposively selected for this study based on two motives. First, they have the highest concentration of active pond fish farmers. Second, they produce a large share of fish in terms of freshwater pond aquaculture (41%). These states are further subdivided into clusters/districts using the cluster sampling method. Four, three and two districts were selected from Perak, Selangor and Pahang, respectively. The selection of districts was based on the large number of active fish farmers pertaining to particular culture systems present in these localities and their volume of production. Furthermore, a stratified sampling technique was employed to segregate the freshwater aquaculture from each selected area into strata, namely cages, ponds, tanks and pen cultures, to obtain a homogeneous distribution of the population. Finally, the sample respondents were then selected using simple random sampling from the list of freshwater fish farmers obtained from the Department of Fisheries, Malaysia.

3.2. Data collection

The data for this study were collected using a questionnaire and oral interviews with the selected fish farmers. Information was collected on their production input usage in a single production season, as well as the outputs produced. Initially, a pilot study was conducted to validate the questionnaire and all the necessary changes and adjustments were made. Subsequently, a total of 307