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TECHNICAL EFFICIENCY IN AQUACULTURE INDUSTRY USING DATA ENVELOPMENT ANALYSIS (DEA) WINDOW: EVIDENCES FROM MALAYSIA

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Abstract: Marine capture had been traditionally a major source of food supply and income for the Malaysian. This useful function has declined over the last decades because of a continuous pressure on the resource to feed the growing population and a constant increase in demand due to commercialization perspective. As supplement to the marine fisheries its counterpart the aquaculture subsector is becoming more important for the country in terms of the long term food security issue. Aquaculture activities can be planned and the potential species of high demand can be selected for the industry. Hence, the growth and commercialization of this industry begin to gain velocity partly due to the government policy on the future food demand. The objective of this paper is to review and identify regional areas representing by states that technically perform more efficiently than the others given the status quo of the existing infrastructures. The infrastructures could be in terms of management ability, suitability of the environment for large scale aquaculture undertakings, local fish species of high value, availability of natural or man-made water bodies and the potential market facilities and outlets. Evidently, richer states performed better than the poorer states. Johor has the highest score (0.718) and thus the most efficient farm in relation to all the thirteen decision making units (DMUs). Selangor scored 0.612, followed closely by Perak (0.570), Melaka (0.524), Sarawak (0.439), Pulau Pinang (0.430) and Terengganu (0.427). The least efficient DMUs include Kelantan (0.139), Perlis (0.152) and Kedah (0.167). Markets for the advanced states are well developed and necessities for the trade are generally more accessible. Farm operators are better exposed to latest techniques and facilities. This finding suggests that special attention should be given to poorer states in order to assist aquaculture development. The analyses include the static technical efficiency and time series data provide the necessary dynamic features for efficiency performance analysis between the states using DEA window.

KEYWORDS: Data envelopment analysis, window DEA, efficiency performance, decision making unit, aquaculture activity.

Introduction

Concern over marine depletion is an international agenda which is felt worldwide, especially following the issue relating to overfishing and the management problem of the commons. Now the issue is worsen with the increasing demand for marine fisheries due to the growing world population, the impact of climatic change and ecological damage as a result of rampant urbanization and industrialization waste. In Tasmania researchers felt that harvesting of small fish species will have a far reaching impact on the sustainability of future marine fisheries and their ecosystem (*The Fish Site News Desk* 2011). In Australia efforts are geared towards protecting the country's fish resources. Fast and efficient vessels are built to detect and patrol fishing zones from foreign encroachments that further contribute to fisheries depletion nowadays. China contributed about 67.3% of the World aquaculture production (FAO FishStat+ 2007, Subasinghe *et al.,* 2009).The Beijing symposium of 17 July 2011 recognizes the prospect of aquatic biotechnology since China has made major progress in various research projects along the genetically modified organisms (GMO). Cooperative efforts on aquaculture practice and agriculture by the Indonesian government with the experienced Viet Nam counterpart justify the need to divert attention from marine to aquaculture. With a large population Indonesia plans to become world's leading producer of aquaculture by 2015 and the focus will be both on the 'cultured species' and marine fisheries.

These scenarios witness some major plans to be implemented in the near future by several countries on aquaculture investment. Contrary to these prospective plans extreme impact on aquaculture production is likely to happen. One of these occurrences is the last earthquake and tsunami that hit Japan on 11 of March 2010. According to statistic, Japan aquaculture industry produced worth of 409.5 billion Yen in 2009. As reported, Japan's aquaculture suffered more than 100 billion Yen during the last natural catastrophe. Despite this devastating loss in asset and food stocks, Japan is developing probiotics useful for diseases resistance, simulating growth and other benefits for fish culture.

In Malaysia the Global Aquaculture Alliance (GOAL) Conference 17-20 October, 2010 looked at the potential of aquaculture in significant production shift among the Asian new emerging markets. With the adoption of new technology and advanced breeding techniques "new" fish species and shrimp farming that do not degrade the environment will be the targets. This aquaculture industry is expected to supplement the currently depleting marine captures. Although big projects are laid ahead, problems with price of imported fries have been raised by farmers. A sharp increase in fry prices around MYR 1.00-1.20 each has caused a temporary decline in their demand. Another relates to the marketing problem of oversized fish that consumed large quantities of pellets that can raise additional production cost between MYR90 and MYR112 for 20kg bag.

The importance of aquaculture industry is apparently clear with the government intervention supporting its growth to supplement the marine counterpart which is depleting. Since it is a general directive for all states the policy has instead overlooked the question of finding the most efficient individuals, firms, areas or regions that could undertake this task more effectively with the given scarce resources. The objective of this article is to identify the leading regional areas and to review their performance in terms of technical efficiency achievement. Advanced aquaculture industry can be used as a guidance to further improve the poorer regions within the limit of existing condition and infrastructure.

Background of Aquaculture Industry

Aquaculture industry has gained tremendous development in recent years following doubling of efforts from the Malaysian Fisheries Development Authority (LKIM) and the Department of Fisheries (DOF) currently responsible for the oceanic activities. In 2009 aquaculture production had reached a total of 472.3 thousand metric tons with a major portion 67.7 percent (319.7 MT) accredited to brackish water while the remaining 32.3 percent (152.6 MT) freshwater. In 2001 the total aquaculture production was only 177.0 thousand shared between freshwater 43.6 thousand metric tons and brackish water 133.5 thousand metric tons (Department of Fisheries, 2010). The retail value for aquaculture production was estimated at MR1,008,494.5 thousand (freshwater) and MR2,050,836.2 thousand (brackish water) respectively. The industry has provided for full and part time employment to a total of about 18,148 culturists for the year.

Figures 1 shows prices of freshwater for selected species sold on the Malaysian markets across the thirteen states. As observed there is a wide variation in price between these states which can be attributed partly to fish size, quality and differences in demand and supply forces. Freshwater fish that procured the highest price is goby which can go as high as RM69.00 per kg in Perak. Next in line is prawn which fetched the highest price in Selangor MR58.00 per kg. Goby is not reared in Perlis and Negeri Sembilan while giant freshwater prawn is raised throughout the states. Its price is the lowest in Sabah which is estimated less than MR20.00 per kg in 2009. For brackish water two of the species that generally fetch highest prices particularly in Penang (MR 40.00 per kg) and Perlis (MR45.00 per kg) are grouper and tiger prawn respectively. Grouper's price is the highest in Sabah close to MR70.00 per kg in 2009 while its price is extremely low in Perlis (MR14.00 per kg).

Other freshwater species of paramount importance to the industry next to freshwater prawn are river catfish, river carp and red tilapia. Most of these species except for freshwater red tilapia are not available in Penang. Price level for Hawaiian white shrimp appears to vary quite minimum across the states ranging between MR10.00 to MR20.00 per kg in 2009. Grouper (kerapu) is in high demand in Sabah during the year which could be attributed to the shortage of supply and that the species is regarded as specialty by serving restaurants.

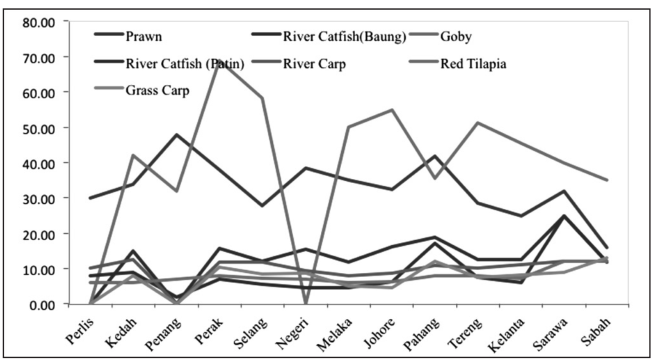

Figure 1: Freshwater Retail Prices in Major Cities of Malaysia by Species--2009.

Literature Review

Originally aquaculture analyses in economics were mainly focused on the estimation of the production function for selected species in order to derive level of production that yields maximum net return. The marginal analysis assumes that market operates in a perfectly competitive condition. Agricultural economist prefers production function estimation where the marginal physical product (MPP) is derived and equated to the input-output price ratio (c/p). This equation is interchangeably used in economics with MVP = c, where MVP=MPP*p is the marginal value product and c is the unit cost of input like wage (w) for labor. This optimal condition is often refers to input-space optimization which is similar to that of output-space profit maximization as used in microeconomics (MR=MC).

The growth of aquaculture industry in Malaysia is considerably speedy although not as fast as the global trend partly owing to the flourishing business activities and the need for food. In Malaysia part of the effort rests with the DOF and LKIM in an attempt to overcome poverty, provide employment and to initiate young entrepreneurs in the industry. Thus it forms the salient part of the current government policy as the program is a move towards diverting dependency on marine capture which had been overexploited for a long duration of time.

Aquaculture had been given special attention in the light of food security since the Seventh Malaysian Plan (1996-2000). Its significance to the economy as an export earner was recognized as the third engine of growth besides that of agriculture during the following Eighth Malaysia Plan (2001-2005).During the third National Agriculture Policy (NAP) (1998-2010) the sustained aquaculture development was among the national priorities showing a sharp increase in its projected production from 200 thousand (1998) to 600 thousand tones (2010) (FAO 2010). Some 40 thousand hectares had been allocated through Aquaculture Industrial Zone (AIZ) for aquaculture investment. As land is a limited resource it competes with other economic activities. Although prospect for export earning is high, the use of antibiotic residues on consignments are prohibited. High technical skill required in aquaculture management, rising cost of production and the environmental laws for sustained production are current issues which constrain the industry's development. Charnes, Cooper, and Rhodes (1978) was the first to introduce DEA using modified linear programming model to obtain estimates of technical efficiency from production functions in case of a single input-output relationship and efficient production possibility surfaces in case of multiple input-output relationships. Later DEA application had been extended to explore new insights into economic and non-economic analyses previously evaluated using other methods (Cooper *et al.,* 2000). Further development was initiated in performance evaluation that deals with excess utilization of inputs and outputs that contribute to inefficiency achievement (Zhu, 2002). For instance, Zhu used DEA analysis to remove excessive diet and Takamura and Tone (2003) to locate a new capital in Japan by discarding unnecessary government agencies from Tokyo.

As described in Charnes *et al.,* (1985) *window analysis* technique was applied to study the aircraft maintenance operations. The data were collected comprising 14 tactical fighter wings in the U.S. Air Force for a period of seven months. Using a three-month window length, the result seems to portray an overall equal efficient DMUs ranging from the lowest score of 89.37 to a perfect score 100. Kuang *et al.,*. (2007) uses DEA window in their study to evaluate the performance of six lines of Taipei Metro for the period 2000-2006. The rapid transit system was originally planned for Taipei in 1967 based on the constructed London Metropolitan Railway Company that run from Paddington Station to Farringdon St. the first world Metro built in 1863. The mass rapid transit system within the Taipei metropolis was put off because of huge budget needed for the construction. By 1970s the traffic volume in the Taipei metropolis was out of control as the economy prospered. To solve traffic congestion in February 1977, the Ministry of Transportation and Communications was commissioned and plans for Taipei metropolis were drafted. The Cumulative Average efficiency scores and Average by Term efficiency scores performed satisfactorily for the 6 lines of the Metro system. Zhonghe Line had the best performance while Muzha Line had the worst performance. On the average the efficiency through window had unsteady changes. The existence of shops is found to have a direct impact on managerial performance of these rapid rail transit systems.

Hemmasi *et al.,* (2011) applied DEA to evaluate the performance of the Iranian wood panels industry which is a very important industry for the country. The problem encountered by this industry is lack of production technology and raw materials which form the inputs to the industry's output. The authors utilize the results of DEA window to further assess its stability based on the standard deviation of 10 wood panels firms. Efficiency score showed that all DMUs in wood panel industry were stable (low standard deviations) but the firms time trends indicate that almost half of the DMUs were positive. The difference of average efficiency score shows that several DMUs were still inefficient over the period analyzed.

DEA is non-parameterization and therefore cannot be tested for statistical significant probability level. It is recognized for several output and input applications with easy methodology, particularly useful for handling problems in performance assessment and ranking of decision making units. Practically DEA application is well developed and used in many studies which include business, economic, engineering and other disciplines. These practical applications have prompted DEA to be used widely in economic studies and other quantitative investigations dealing with performance analyses.

Methodology

The data envelopment analysis uses virtual outputs and inputs. These outputs are defined as *the weighted sum of output* and inputs as *the weighted sum of inputs*. The technical efficiency is derived using the linear programming technique whose objective is to maximize the objective function that is, the ratio of outputs over inputs subject to the constraint that this ratio is equal to and less than unity. This fractional programming objective function is shown in equation (1.1) and is known as CCR model after Charnes, Cooper and Rodes (1978),

$$\text{Maximize} \quad \theta = \frac{\sum_{i=1}^{n} u_i y_{ij}}{\sum_{k=1}^{o} v_k x_{kj}} = \frac{u_1 y_{1j} + u_2 y_{2j} + \ldots + u_n y_{nj}}{v_1 x_{1j} + v_2 x_{2j} + \ldots + v_k x_{kj}} \tag{1.1}$$

$$\text{subject to} \quad \frac{u_1 y_{1j} + u_2 y_{2j} + \ldots + u_n y_{nj}}{v_1 x_{1j} + v_2 x_{2j} + \ldots + v_k x_{kj}} \leq 1 \quad (j = 1,2,\ldots,m) \tag{1.2}$$

$$u_1, u_2, \ldots, u_n \geq 0 \tag{1.3}$$

$$v_1, v_2, \ldots, v_k \geq 0 \tag{1.4}$$

The constraint is set such that the ratio of virtual outputs over the virtual inputs in (1.2) will be equal and less than one for every decision making unit (DMU) in DEA. The output weights u_i in (1.3) and input weights v_k in (1.4) representing the non-negativity constraints such that their values are either zero or positive. The objective is to estimate the numerical values of these output and weights that will satisfy the maximum value of the objective function θ* whose limit is one.

The fractional programming problem can be transformed mathematically to the usual linear programming problem. On the assumption that **v** as the row vector input weight and **x** input matrix are nonzero, the objective function of equation (2.1) is obtained by setting the denominator of (1.1) equal to one. This denominator is moved down as a constraint equation (2.2). The original constraint of (1.2) becomes the second constraint in (2.3) by multiplying (1.2) by the denominator as shown below:

$$\text{Maximize} \quad \theta = \mu_1 y_{1j} + \mu_2 y_{2j} + \ldots + \mu_n y_{nj} \tag{2.1}$$

$$\text{subject to} \quad v_1 x_{1j} + v_2 x_{2j} + \ldots + v_k x_{kj} = 1 \tag{2.2}$$

$$\mu_1 y_{1j} + \mu_2 y_{2j} + \ldots + \mu_n y_{nj} \leq v_1 x_{1j} + v_2 x_{2j} + \ldots + v_k x_{kj} \tag{2.3}$$

(j=1, 2, … , m)

$$\mu_1, \mu_2, \ldots, \mu_n \geq 0 \tag{2.4}$$

$$v_1, v_2, \ldots, v_k \geq 0 \tag{2.5}$$

Defining the optimal solution of the objective function θ as θ* and the output weight μ as μ* and input weight ν as ν* CCR efficient DMU requires that the optimal value of the objective function θ*=1 such that, "there exists at least one optimal value of μ* and ν* with μ* > 0 and ν* > 0 otherwise, DMU is CCR inefficient" (see Chapter 1 p. 24). The above linear programming problem written in multiplier form becomes (3.1) which is the primal linear programming problem. The dual linear programming problem of equation (3.2) yields the same optimal value of θ* from the primal CCR efficiency value. This dual optimal value of the linear programming problem is referred to as "Farrell Efficiency" in recognition of M.J. Farrell (1957).

$$\begin{aligned} &\text{Maximize} && uy_k \\ &\text{subject to} && vx_k = 1 \\ & && -vX + uY \end{aligned} \tag{3.1}$$

$v \geq 0, u \geq 0$

$$\begin{aligned} &\text{Minimize} && \theta \\ &\text{subject to} && \theta x_k - X\lambda \geq 0 \\ & && Y\lambda \quad \geq y_k \\ & && \lambda \geq 0 \end{aligned} \tag{3.2}$$

The DEA solver uses dual in (3.2) as Phase I in solving the objective function of the linear programming problem since a more precise result of estimated multipliers is expected. The problem with slack of input excess (s-) and slack of output shortage (s+) define as

$$\text{s–} = \theta x_k - X\lambda, \quad \text{s+} = Y\lambda - y_k \tag{3.3}$$

Phase II is performed with the objective to eliminate the slacks using the dual linear programming solution of the primal of maximization of sum of the input excess and the output shortfall slacks defined as ω = (es– + es+). This second Phase dual linear programming problem is presented as

$$\begin{aligned} &\text{Minimize} && -\text{es–} \ -\text{es+} \\ &\text{Subject to} && \theta x_k = X\lambda + \text{s–} \\ & && y_k = Y\lambda - \text{s+} \end{aligned} \tag{3.4}$$

$$\theta \geq 0, \quad \lambda \geq 0, \quad \text{s–} \geq 0, \quad \text{s+} \geq 0$$

"An optimal solution (θ*, λ*, s–*, s+*) of the second Phase is called min-slack solution. If the min-slack solution satisfies s–*= 0 and s+*= 0, then it is called zero-slack"(Cooper *et al.,* 2006: 45). The CCR-efficiency, radial efficiency and technical efficiency are defined in relation to the conditions of these slacks. "If an optimal solution to θ^*, λ^*, s^{-*}, s^{+*} of both phases of linear programming problems satisfies that $\theta^*=1$ and all slacks equal zero, that is $s^{-*}= 0$, $s^{+*}= 0$, then the DMU is called CCR-efficiency" (Cooper *et al.,* 2006:45). Otherwise, the DMU is called CCR-inefficient. Hence, CCR-efficient should satisfy both conditions $\theta^*=1$ and all slacks are zero.

An extension to that of static analysis DEA framework considers variation throughout the duration of analysis represented by annual data as appropriate to window analysis. The methodology provides a framework for DEA trend analysis which is claimed to be more satisfactory to that of statistical regression and time series analyses (Cooper *et al.,* 2006: 292). The results of window analysis using production (physical quantity in metric ton) or sales (retail value in MYR) with two inputs of aquaculture area and culturists can be broken up into at least one to a maximum of six windows. The performance of each state will be shown by the average score for the chosen one to six windows. Figures in the column illustrate the stability of scores for the analysis of chosen window while those figures in the row demonstrate the variation in trend for a data set of the selected window. One of the deficiencies of window analysis is that the first year and the last year DMUs are not being utilized and tested frequently as the other four DMUs. DEA solver provides solution for a complete "round robin" as suggested by Sueyoshi (1992). In the final presentation results of DEA with four-period window will be utilized for the analysis and discussion.

D.B. Sun (1988) provides a formula for deciding on the number of window and the calculation for other properties relating to window analysis (Cooper *et al.,* 2006: 295). The formulae for number of windows, number of DMUs in each window, number of "different" DMUs, and the number of DMUs are as follows:

Number of window: $w = k - p + 1 = (9\text{-}5)+1 = 5$

Number of each DMUs in each window: $np/2 = (12\text{x}5)/2 = 30$

Number of "different" DMUs: $npw = 12\text{x}5\text{x}6 = 360$

Increment in number of DMUs: $n(p-1)(k-p) = 12(5\text{-}1)(9\text{-}5) = 192$

where w = number of window

k = number of periods (number of years selected for the analysis: 9 years)

n = number of DMUs (number of states utilized for performance: 12 states)

p = length of window ($p \le k$) (number of chosen window: 5 years)

The decision on the number of window is derived from the total number of "different" window equation after Charnes and Cooper (1990). The length of window for the current study is five (5) which is obtained from the following formula:

$$p = \begin{cases} \frac{k+1}{2} & \textit{when k is odd} \\ \frac{k+1}{2} \mp \frac{1}{2} & \textit{when k is even} \end{cases}$$

The data for the analysis is obtained from the Department of Fisheries Malaysia. For the one period DEA 2009, freshwater fishery data was used while the DEA window utilized the 2000 to 2008 time series data. The output data refers to the retail sale values of freshwater production and the inputs refer to the pond area in square meters and number of culturists associated with the pond operations for the respective years. The number of pond was highly correlated with the size of pond area and the fish production figures were correlated with total retail sale values, therefore these data were neglected in the final analysis of this study.

Results and Discussions

The result of static DEA, ranking of decision making unit (DMU) for the thirteen states in 2009 is shown in Table 1. The DMUs of Johor, Melaka, Pulau Pinang and Perlis evidently represent the four states which proved to be most efficient technically with perfect score (1) while the scores for the rest of the states are inefficient and varied considerably. In order to improve their efficiency scores reference set is given in the table. Based on 2009 efficiency performance scores Selangor (0.677) runs fifth and far down the score board is Pahang (0.244), Kedah (0.224), Negeri Sembilan (0.210), Perak

(0.203), Terengganu (0.192), Kelantan (0.179) and the remaining states are in relative terms inefficient freshwater operators. In general their efficiency scores account for only 25 percent of the perfect score.

Table 1: Ranking of Decision Making Unit (DMU) and Reference Set Freshwater 2009.

No.	DMU	Score	Rank	Reference set (lambda)					
1	Perlis	1	1	Perlis	1				
2	Kedah	0.22392	7	Perlis	0.73708	P. Pinang	0.00372	Melaka	0.25919
3	P. Pinang	1	1	P. Pinang	1				
4	Perak	0.20348	9	Melaka	0.11921	Johor	0.88079		
5	Selangor	0.67690	5	P. Pinang	0.03030	Johor	0.96971		
6	N. Sembilan	0.20963	8	Perlis	0.14651	Melaka	0.85349		
7	Melaka	1	1	Melaka	1				
8	Johor	1	1	Johor	1				
9	Pahang	0.24359	6	Perlis	0.11450	Melaka	0.88550		
10	Terengganu	0.19158	10	Perlis	0.75642	P. Pinang	0.24115	Melaka	0.00244
11	Kelantan	0.17872	11	Perlis	0.97300	P. Pinang	0.02700		
12	Sarawak	0.03790	13	Perlis	0.34068	Melaka	0.65932		
13	Sabah	0.162472	12	Melaka	0.65353	Johor	0.34647		

Table 2: DEA Input and Output Projections and Efficiency Recommendation for Freshwater 2009.

No.	DMU I/O	Score Data	Projection	Difference	Percent (%)
1	Perlis	1			
	Area	26.14	26.14	0	0
	Cult	117	117	0	0
	Rsale	1348.72	1348.72	0	0
2	Kedah	0.2239			
	Area	169.86	38.04	-131.82	-77.6
	Cult	599	134.13	-464.87	-77.6
	Rsale	11785.13	11785.13	0	0
3	P. Pinang	1			
	Area	61.12	61.12	0	0
	Cult	53	53	0	0
	Rsale	12135.05	12135.05	0	0
4	Perak	0.20347722			
	Area	944.61	192.21	-752.40	-79.7
	Cult	1226	222.76	-1003.24	-81.8
	Rsale	79742.11	79742.11	0	0
5	Selangor	0.67689559			
	Area	308.58	204.07	-104.51	-33.9
	Cult	329	222.69	-106.30	-32.3
	Rsale	82718.76	82718.76	0	0

Table 2 shows DEA input and output projections and efficiency recommendation for freshwater in 2009. For DMU Perlis which scored one, projection for area and culturist and output of retail sale are identical to that of original data. Therefore, the improvement in input and output allocation is not required. The freshwater farms on average have achieved technical efficiency in resource allocation. In the case of Kedah whose score is 0.224 reductions in both, area (77.6%) and culturist (77.6%) are recommended. The result suggests that aquaculture farming in Kedah is too congested with culturists that could be ascribed to culturist's reaction to the new aquaculture policy by providing financial support and extension assistance. Similarly, a reduction in input-use is also recommended for Perak and Selangor.

Table 3A: Result of DEA Window Aquaculture Production 2000-2008.

DMU	2000	2001	2002	2003	2004	2005	2006	2007	2008	Average	Cumulative Average
Perlis	0.1686	0.1377	0.1650	0.1376	0.1611					0.1540	
		0.0991	0.1177	0.0991	0.1147	0.2815				0.1424	
			0.1177	0.0991	0.1147	0.2815	0.2874			0.1801	
				0.0928	0.1074	0.2635	0.2690	0.3365		0.2138	
					0.0316	0.0775	0.0791	0.0989	0.0786	0.0731	0.1527
Kedah	0.2316	0.2455	0.2833	0.2081	0.2260					0.2389	
		0.1803	0.2072	0.1524	0.1666	0.1979				0.1809	
			0.2072	0.1524	0.1666	0.1979	0.2329			0.1914	
				0.1364	0.1500	0.1794	0.2114	0.1500		0.1654	
					0.0425	0.0497	0.0584	0.0575	0.0994	0.0615	0.1676
P. Pinang	0.5899	0.2910	0.3279	0.3693	0.6037					0.4364	
		0.2224	0.2533	0.2800	0.4598	0.6306				0.3692	
			0.2533	0.2800	0.4598	0.6306	0.6837			0.4615	
				0.2581	0.4255	0.5885	0.6327	1.0000		0.5810	
					0.1184	0.1747	0.1761	0.2940	0.7358	0.2998	0.4296
Perak	0.3779	0.3627	0.4597	0.4283	1.0000					0.5257	
		0.2841	0.3305	0.3142	0.7847	1.0000				0.5427	
			0.3305	0.3142	0.7847	1.0000	0.9886			0.6836	
				0.3031	0.7461	1.0000	0.9395	1.0000		0.7977	
					0.2618	0.3851	0.3282	0.3512	0.1799	0.3013	0.5702
Selangor	0.9086	0.6904	0.7600	0.7572	0.9908					0.8214	
		0.4063	0.4367	0.4557	0.5833	0.8529				0.5470	
			0.4367	0.4557	0.5833	0.8529	0.6377			0.5933	
				0.4557	0.5833	0.8529	0.6377	0.8916		0.6842	
					0.2293	0.4351	0.2760	0.4518	0.6734	0.4131	0.6118
Negeri Sembilan	0.1576	0.2016	0.2730	0.3246	0.3516					0.2617	
		0.1525	0.2078	0.2456	0.2659	0.3286				0.2401	
			0.2078	0.2456	0.2659	0.3286	0.3498			0.2795	
				0.2260	0.2446	0.3065	0.3204	0.4074		0.3010	
					0.0651	0.0906	0.0860	0.1114	0.1380	0.0982	0.2361
Melaka	0.4668	0.4928	0.5011	0.6006	0.8707					0.5864	
		0.3697	0.3592	0.4425	0.6406	0.7119				0.5048	
			0.3592	0.4425	0.6406	0.7119	0.6708			0.5650	
				0.3981	0.5757	0.6499	0.6208	0.8279		0.6145	
					0.1642	0.1762	0.1727	0.2312	1.0000	0.3489	0.5239

Table 3B: Result of DEA Window Aquaculture Production 2000-2008.

DMU	2000	2001	2002	2003	2004	2005	2006	2007	2008	Average	Cumulative Average
Johor	0.7059	0.8606	0.8000	0.9023	0.9750					0.8488	
		0.6155	0.5745	0.6455	0.7004	1.0000				0.7072	
			0.5745	0.6455	0.7004	1.0000	0.8587			0.7558	
				0.6259	0.6785	1.0000	0.8451	0.8597		0.8018	
					0.2462	0.4965	0.3157	0.3241	1.0000	0.4765	0.7180
Pahang	0.6120	0.4668	0.1235	0.2927	0.5172					0.4024	
		0.3553	0.0947	0.2160	0.3834	0.6360				0.3371	
			0.0947	0.2160	0.3834	0.6360	0.3456			0.3351	
				0.1946	0.3467	0.5778	0.3251	0.4550		0.3799	
					0.0969	0.1591	0.1034	0.1271	0.1114	0.1196	0.3148
Terengganu	0.1223	0.1111	0.1714	0.1712	1.0000					0.3152	
		0.0801	0.1235	0.1234	0.7205	1.0000				0.4095	
			0.1235	0.1234	0.7205	1.0000	0.9156			0.5766	
				0.1155	0.6745	0.9361	0.8301	0.6903		0.6493	
					0.1983	0.2752	0.2301	0.1913	0.0247	0.1839	0.4269
Kelantan	0.1101	0.1430	0.1514	0.1254	0.2551					0.1570	
		0.1021	0.1080	0.0896	0.1815	0.2219				0.1406	
			0.1080	0.0896	0.1815	0.2219	0.1974			0.1597	
				0.0839	0.1699	0.2028	0.1808	0.2960		0.1867	
					0.0500	0.0596	0.0532	0.0870	0.0133	0.0526	0.1393
Sarawak	0.1084	0.2871	0.6423	0.4748	0.8214					0.4668	
		0.2068	0.4627	0.3421	0.5918	1.0000				0.5207	
			0.4627	0.3421	0.5918	1.0000	0.2656			0.5325	
				0.3203	0.5540	1.0000	0.2487	0.3399		0.4926	
					0.1629	0.5723	0.0731	0.0999	0.0157	0.1848	0.4395
Sabah	0.1548	0.1238	0.1678	0.1662	0.1582					0.1542	
		0.0902	0.1221	0.1209	0.1149	1.0000				0.2896	
			0.1221	0.1209	0.1149	1.0000	0.0964			0.2909	
				0.1077	0.1026	1.0000	0.0861	0.1381		0.2869	
					0.0302	0.7417	0.0253	0.0406	0.0544	0.1784	0.2400
Average	0.3627	0.2915	0.2980	0.2948	0.4062	0.5764	0.3758	0.3792	0.3173		

Tables 3A and 3B above show the result of DEA window aquaculture production for 2000-2008. The DMUs represented by the thirteen states across annual duration on inputs; area of pond (in square meters) and the number of culturist. The output is represented by the aquaculture production (in metric tons). As noted the time duration for the analysis is nine years starting from 2000 to 2008. Based on the formula suggested above the length of window is five years (p = 5 ≤□ *=9)*. The cumulative average (C-Average) of window analysis in Table 3B shows Johor (0.718) has the highest score and thus the most efficient farm in relation to all the thirteen DMUs. The runner up is DMU Selangor which scored 0.612, followed closely by Perak (0.570), Melaka (0.524), Sarawak(0.439), Pulau Pinang (0.430) and Terengganu (0.427) in Table 3B. The remaining DMUs which are considered, "below average performance" include Pahang

(0.315). The DMU Pahang score is about 43.9 percent which is below that of the best performer Johor (0.315/0.718 *100). Hence, the remaining DMUs whose scores are smaller than Pahang are considered as below average performers. These DMUs include Pahang as well as Sabah (0.240), Negeri Sembilan (0.236), Kedah (0.162), Perlis (0.153) and Kelantan (0.139). The only East Coast state that qualifies for the "above average performance" is Terengganu since its score is 59.5 percent of the best performer while Pahang and Kelantan remain in the category of "below average performance".

DEA window also provides comparison for freshwater aquaculture performance over the nine year periods since its inception in 2000 to the end of 2008. As mentioned, there is only one data point for the beginning and ending year for each DMU analyzed. However, since all DMUs are considered here there will be an average for the starting and ending year. In general, the performance of freshwater aquaculture since year 2000-2003 was more or less consistent with an average score around 0.291 to 0.362. However, the performance had improved significantly during 2004-2007 scoring around 0.375 to 0.576

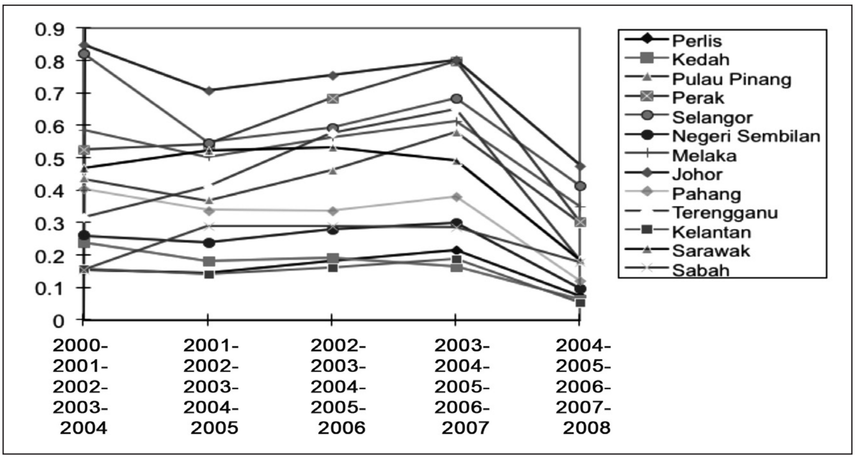

Figure 2: Variations through Window by State DMUs.

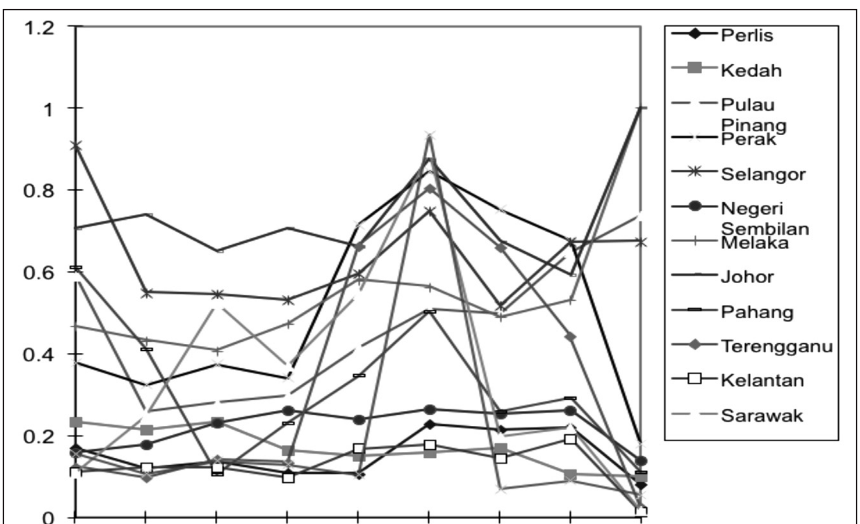

Figure 3: Variations by Term (Year) for State DMUs.

which reached a peak in 2005. The DMUs with a perfect efficiency score of one were recorded by Johor, Perak, Sarawak, Sabah and Terengganu. These states with perfect scores had undoubtedly contributed to the improvement in technical efficiency for the year. By 2008 freshwater aquaculture had experienced a slight downturn perhaps due to the impact of the economic crisis.

Figure 2 shows the variation of performance scores through window, that is, the average score for five series of 5-year window analysis for each DMU as illustrated in the column of Table 3. It can be observed that DMUs such as Johor, Selangor and Perak were among the top achievers throughout the years while all DMU scores took a downturn during the year of 2008.

Figure 3 shows DMUs performance score by term, that is, the annual average efficiency scores by each DMU for the duration of year 2000 to 2008. DMUs Johor, Selangor, Melaka and Pulau Pinang are among the top efficient performers throughout the years. The strength of their scores is partly attributed to the overall performance during 2005 which have shown outstanding achievements for the year. For instance, Terengganu and Perak have shown tremendous achievement in efficiency during 2005 but failed to sustain their performance during the later years. Several developed DMUs including Johor, Melaka, Selangor and Pulau Pinang had shown upward trends, in particular, during the later years of performance scores which were consistent with the economic growth of the country's economy.

Conclusion

The *FishSite* news on 19 January 2011 indicated that aquaculture production is targeted to reach 727,300 metric tons by 2015 valued at about RM 7 billion. In 2010 Malaysia's aquaculture industry produced some 478,245 metric tons worth of RM 2.4 billion. This information affirms the importance of aquaculture industry in this country as the government is given a big push to go beyond achieving not only food alternative for the nation's population but to transform the industry into a viable future economic investment. The current national aquaculture immediate goal is primarily focused on overcoming the problem of marine capture which is gradually depleting and to ease the pressure of the concerted effort of international fish management decision makers of the importance of sustaining the resource for the future. Malaysia has to abide to the majority rule of the global expectation as such less pressure is given to the plight of marine fisheries as common resource that has been drawn in years of open access. Now is the time to divert attention for the aquaculture investment prospect but the Agriculture Ministry reminds the investors to change their mindsets for agro-food sector with the highest potential for economic returns. The Ministry of Agriculture has promised to provide basic infrastructure, financial and technical support and delivery system. Despite the facilities, problems will continue to persist especially with the ones mentioned in the introductory section pertaining to quality, availability and price of fish fries and the oversized fish for marketing.

The findings from DEA window analysis revealed that the level of efficiency in production after matching it with input applications, that is, area and culturists vary greatly between states (number of ponds is disregarded because it is highly correlated with area. Total retail sale is not used as output because it is highly correlated with production). Technical efficiency of the operating farms apparently varied significantly between regions and overtimes.

Based on one year analysis of 2009, the best efficient states of Johor, Melaka, Pulau Pinang and Perlis have a score of 1.0 while the least efficient states Sarawak, Sabah and Kelantan have scores of 0.038, 0.162 and 0.179 respectively. The big difference in performance of the aquaculture farms across the states will be reflected in their production and productivity potential to generate income and thus the contribution to the nation's gross domestic product. Zoning of the prospective aquaculture region for technical and financial assistance would help improve those least efficient achievers. As apparent the presence of Fisheries

Stations in Johor, Melaka and Pulau Pinang had contributed to the performance of the culturists in these regions. These stations could have played the role of the extension agents in advising the culturists on their aquaculture problems. Aquaculture market varies between rich and poor states. For the advanced regions like the West Coast states the demand for aquaculture is expected to be high and the market is assured. There is also the difference in the percentage composition of the culturist ethnic backgrounds either be the Chinese, Malays or other races.

Based on the result of 2000-2008 DEA window analysis the performance of top efficient DMUs (states) goes to Johor with a score of 0.718 followed by Selangor scoring 0.612. Performance of the least efficient DMUs (states) goes to Kelantan with a score of 0.139 while Perlis and Kedah scores 0.152 and 0.167 respectively. Again the efficiency scoring gap between state DMUs varies greatly. This serious difference explains a significant variation in the management and development performance of the aquaculture industry in this country that need to be given special attention for a fair distribution of the nation's wealth. DEA window provides a time variant in the overall performance of the regions. It is least expected for the poor culturists of a poor state with limited assets, infrastructure, advice from the fisheries specialists on diseases or species to be reared to advance to a better performance over time. They will generally remain inefficient achievers especially with the status quo condition.

The findings disclosed the evidence leading to the hypothesis that efficiency performance among state DMUs is associated with the level of economic development of the state itself. The advance states of Johor, Selangor and Melaka generally performed better than those less developed states such as Kelantan, Perlis and Kedah. This means the state DMUs income (GDP) andthe efficiency score are expected to show a positive relationship. The DMUs with higher incomes would in general perform better than those with lower GDP and vice-versa.

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