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Hieu Truong Khac, Hong Hue Tran Thi Phuong, Cheng Ting Huang, and Sha Miao

Key words: production cost, profitability, bioeconomics, tiger shrimp.

ABSTRACT

Analysis of costs and returns for the tiger shrimp farming industry in Tra Vinh Province, Vietnam was carried out by considering different production scales. The production scale influenced not only the cost but also the profitability. Through the results of multivariate statistical analyses, this study showed that the production cost, benefit and earning capacity varied from extensive to semi-intensive and finally to intensive systems. By means of Cobb-Douglas production function analysis, it is revealed that net revenue from increasing the production scale would increase if the input intensities of the fixed, seed and feed costs rose. More investment should be made in the production scale and advanced techniques for extensive systems and the culturing period of the semi-intensive system should be longer to raise profits. In addition, the management of seed quality, feed and application of Better Management Practices (BMP) standards for the shrimp production industry should be reinforced in order to improve competitiveness in international markets.

I. INTRODUCTION

The tiger shrimp, *Penaeus monodon,* is one of the most important species of *Penaeus* currently being cultured commercially in Asian countries (FAO, 2011). In Viet Nam, tiger shrimp farming has developed mainly over the last decade, especially since Governmental Resolution No.09/NQ-CP dated 15th June 2000 which allows the transfer of ineffectively used agricultural land to aquaculture development (Binh et al., 2005). The area of tiger shrimp aquaculture increased from 250,000 ha in 2000 to 478,000 ha in 2001 (Cao, 2007) reaching 619,400 ha in 2012 (Fistenet, 2013). Although the production of the recently introduced Pacific white leg shrimp (*Litopenaeus vannamei*) is increasing rapidly, the tiger shrimp is still the dominant species cultured in Vietnam (Pham, 2010; Arie, 2012). In 2010, the export value of tiger shrimp was 1.4 billion US$ (116,160 tons) out of 2.1 billion US$ (240,000 tons) of shrimp exports (VASEP, 2010). In 2011, tiger shrimp production reached 319,206 tons with an export value of 1.43 billion US$, comprising 60% of shrimp export turnover (VASEP, 2011). Vietnam is one of the largest shrimp exporters in the world and its shrimp products are available in supermarkets in more than 150 countries, including very high-end markets in developed countries (Suzuki and Vu, 2013). Tiger shrimp culturing has played a determinant economic role contributing to the alleviation of poverty, provision of employment and earning foreign currency (Cao, 2007; Tran, 2012).

Tra Vinh is one of the nine provinces in the Mekong Delta and accounts for 91.8% and more than 90% of the tiger shrimp area and production of the whole country (DOA, 2011; Arie, 2012). From 2001 to 2010 and towards 2020, the Vietnamese government has executed several programs for sustainable shrimp culture development in Tra Vinh (DARDTV, 2010). As a result, in 2001, there were 5,668 ha, 4,864 ha and 30 ha of extensive, semi-intensive and intensive areas in the province, respectively, with corresponding productions of 777.3 tons, 2,517.1 tons and 75.9 tons. In 2010, the extensive, semi-intensive and intensive areas covered 16,291.54 ha, 5,690 ha and 2,004.7 ha, respectively, with corresponding productions of 5,908.8 tons, 7,982.5 tons and 7,554.9 tons. During the last decade, Tra Vinh's tiger shrimp culturing industry has generally experienced considerable development with more than two-fold growth in the culture area and six-fold increase of production (DARDTV, 2010). Although the production of shrimp is increasing, economic returns from unit areas are decreasing, due to increases in feed, fuel, and electricity costs, decreases in shrimp prices (MOFI, 2006), disease outbreaks, pollution of the water environment (Pham, 2008; Tran, 2012), and poor quality seed (Arie, 2012; Suzuki, 2013). Additionally, Vietnam was included as one of the lowest performing countries in terms of the management of food quality, safety and sanitation so the rate of rejected shrimp products at ports in the European Union, United States and Japan has been quite high (Suzuki and Vu, 2013). How to improve the production

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efficiency of the existing models is an important issue that needs to be addressed.

Production costs, including both fixed costs (farm construction, equipment costs, salary, etc.) and variable costs (seed, feed, labor, etc.), are major factors affecting profitability. Also, biological parameters like stocking density and survival rates are also very important factors relating to output. Efficient management from both sides is necessary to maximize farming profit. It is hoped that the analysis of costs and returns can provide guidelines for improvements in farming management.

The objective of this study was to evaluate the effect of three production systems on costs and returns for the shrimp grow-out business in Tra Vinh Province, Vietnam. In addition, information for a number of variables was obtained at each farm for research purpose. The variables were random and interrelated in such a way that their different effects could not meaningfully be interpreted separately. Statistical analyses were therefore carried out using multivariate techniques. The whole point of a multivariate analysis is to consider several simultaneously related random variables, each one being treated as equally important at the start of the analysis. Suggestions for improving farming management so as to increase productivity are finally proposed based on the findings.

II. MATERIALS AND METHODS

Primary data were collected through a structured questionnaire, farm visits and farmer interviews during the period of August-September, 2011 at Duyen Hai, Cau Ngang, Chau Thanh and Tra Cu districts where tiger shrimp has been farmed for many years. Forty five shrimp culturing farmers were randomly selected from each of the three culture systems (extensive, semi-intensive and intensive). Beside, relative information was also gathered from Government Offices such as Department of Agricultural and Rural Development, Statistic Department of Tra Vinh province, etc.

The data were classified into two types. The biological one consisted of water surface area (ha/farm), stocking density (post-larvae PL/ha), survival rate (%), feed conversion ratio (FCR), harvest size (grams/shrimp), grow-out period (months) and production (kg/ha/year). Stocking density was measured as the number of seed per ha and was obtained by dividing the total density by total water area. Survival rate was the percentage of shrimps which survived for given culture period. Feed conversion ratio (FCR) was the total amount of feed consumed to produce one kilogram of shrimp. Production was total amount of harvested shrimps in tons per hectare per year. The economic one included total revenue (according to selling price at farm gate and production collected) and production costs. The production costs were separated into two parts, fixed and variable costs.

Fixed costs comprised of pond construction capital depreciation and equipment capital depreciation and other fixed costs. Equipment capital was the capital invested in water pump, paddle-wheel aerator and water propeller turbine, boat, net, storage, etc. Other fixed costs consisted of technical engineer salary, land using cost and interest on initial investment. Land using cost was anticipated by using the concept of valuation of land at its rental price. Variable costs included shrimp seed, feed, labor, fuel-electricity, lime, fertilizer, probiotics, medication, harvest and interest costs. The interest on operating costs was calculated at a rate of 2.2% per month of a spent amount in cash for the shrimp farming period.

In this study, the straight-line method was used for calculating depreciation. The pond construction and equipment capitals were depreciated in 10 years and 5 years respectively with salvage value zero. These capitals were compounded into equivalent monetary value in 2011 according to conversion rate of The International Monetary Fund (IMF, 2011).

Two sets of variables were carefully determined according to production costs for evaluating the management performance. The first set was the input intensities which consisted of fixed, seed, feed, labor and fuel-electricity costs. These input intensity variables were measured by their corresponding input expenses based on one ha water surface area (in VND/ha/year – Vietnamese dong per hectare per year, 1 US$ = 20,800 VND as in 2011). The other set was the profitability variables. The varied profitability variables which were defined as the ratios of net revenue to the costs of corresponding input items. The net revenue was obtained by subtracting the production cost from the total revenue. Consequently, a profitability variable was measured with the net revenue that was produced at one VND cost based on a certain input item.

A one-way (production scale) multivariate analysis of variance (MANOVA) was applied to examine the effects of different farming systems on the management and economic performances (Miao, 2011). A principal component analysis (Johnson and Wichern, 2002) was further conducted to evaluate individual economic performances with quantitative comparisons. As a result, a resolution on how to improve the present profitability would be achieved by considering a set of the best principal components in combination with different farming managements. Finally, a Cobb-Douglas production function was used to study a quantitative relationship between the input and output of the production system (Miao, 2012; Wikipedia, 2013). Carefully evaluating this quantitative relationship would help to measure the responsiveness of output to unit increase of inputs. This function could also describe as a production surface that demonstrates increasing, unitary or decreasing returns to scale depending upon the data. A computer software developed by SAS Institute (2009) was used for the preceding analyses with a significant level set at $P = 0.05$.

III. RESULTS

Fig. 1 shows the distribution of input intensities in percentages for the three farming systems. Percentages of lime, fertilizer, probiotics, medication, interest and harvest costs were negligible (9.4% of total production costs), therefore,

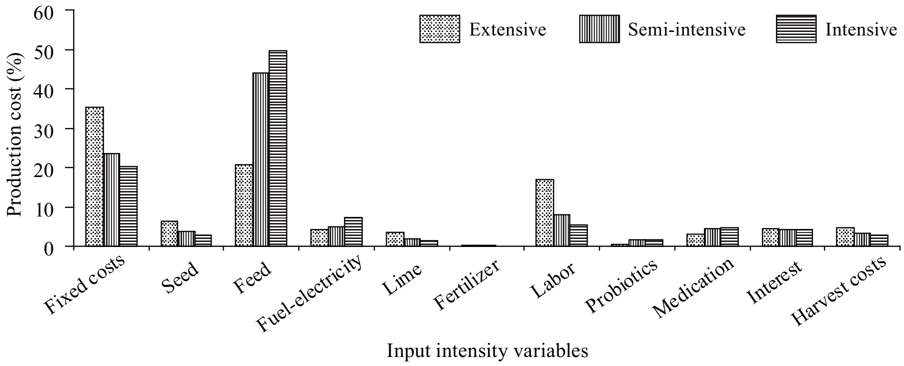

Fig. 1. Distribution of production costs in percentages for three shrimp culture systems.

Table 1. Statistics of input intensities (VND/ha/year) for three farming systems.

Input costs	Farming systems								
	Extensive			Semi-intensive			Intensive		
	Mean ± SD	Minimum	Maximum	Mean ± SD	Minimum	Maximum	Mean ± SD	Minimum	Maximum
Fixed	25,499,798 ± 5,261,610^a	19,353,111	44,156,791	62,196,772 ± 11,639,732^b	33,194,414	92,082,415	105,618,663 ± 9,723,554^c	70,084,944	186,906,206
Seed	4,571,842 ± 3,215,282^a	946,667	14,200,000	10,163,428 ± 2,478,769^b	2,727,273	13,404,255	14,953,565 ± 1,517,402^c	12,000,000	18,571,429
Feed	15,023,324 ± 15,966,562^a	1,100,000	73,614,796	116,487,889 ± 18,649,296^b	82,500,000	159,600,000	260,003,526 ± 1,525,258^c	181,929,688	315,747,508
Fuel-electricity	3,061,500 ± 2,417,489^a	400,000	12,000,000	13,383,763 ± 5,712,023^b	2,889,143	32,300,000	38,574,869 ± 14,139,253^c	17,842,424	67,400,000
Labor	12,244,453 ± 5,591,535^a	4,050,000	31,250,000	21,448,433 ± 11,466,673^b	9,090,909	72,916,667	27,926,918 ± 11,574,832^c	12,500,000	66,000,000

SD: Standard deviation
Values (expressed as Mean ± SD) with different letters in the same row are significantly different from each other ($P < 0.05$)

Table 2. Statistics of profitability variables for three farming systems.

Varied profitabilities	Farming systems		
	Extensive Mean ± SD	Semi-intensive Mean ± SD	Intensive Mean ± SD
Fixed	1.67 ± 0.94^a	3.64 ± 0.96^b	5.02 ± 0.93^c
Seed	11.61 ± 8.12^a	24.43 ± 12.46^b	34.98 ± 6.32^c
Feed	9.11 ± 9.43^a	1.94 ± 0.50b^c	4.03 ± 0.24b^c
Fuel-electricity	23.77 ± 25.32^{abc}	20.72 ± 12.84^{abc}	15.62 ± 6.95^{abc}
Labor	3.93 ± 2.52^a	12.13 ± 4.88^b	22.03 ± 10.38^c

SD: Standard deviation
Values (expressed as mean ± SD) with different letters in the same row are significantly different from each other ($P < 0.05$)

they are not mentioned in this study. Fixed, seed, feed, fuel-electricity and labor costs (90.6% of total production costs) are considered in further analyses. Tables 1 and 2 present the statistics for production cost and profitability variables for the three shrimp farming systems. There were significant differences ($P < 0.05$) in production costs as well as profitabilities, excepting feed and fuel-electricity profitabilities among the three systems. Expenditure and profit increased from extensive to semi-intensive and finally to intensive systems. The results of two multivariate analyses of variance (MANOVA) indicate that the production systems had a significant effect ($P < 0.0001$) not only on input costs but also on varied profitabilities (Table 3). Table 4 displays significant differences ($P < 0.05$) in production costs, gross returns, net returns, rates of income, benefit cost ratios and profitabilities between the three farming systems. Because of having the lowest inputs, extensive farms demonstrated the relatively lowest production, gross returns and net returns, while intensive farms had highest inputs to obtain the highest outputs. Moreover, the rate of income, benefit cost ratios and profitabilities of intensive systems were the largest, while those of the extensive system were the smallest. This clearly reveals that the extensive system was not economically viable while an increase in production scale had a positive impact on economic performance.

Table 5 reveals that there were many significant difference ($P < 0.05$) derived from the biological variables among the three systems, especially for stocking density, survival rate, yield and FCR which increased from extensive to semi-intensive and finally intensive farms. This could also be identified from the significant correlation coefficients between the

Table 3. One-way MANOVA of input costs and varied profitabilities for three culture systems.

Statistical criteria	Input costs[1]		Varied profitabilities[2]	
	F value	*P* > *F*	*F* value	*P* > *F*
Wilks' Lambda	107.12	<.0001	35.72	<.0001
Pillai's Trace	32.87	<.0001	25.33	<.0001
Hotelling-Lawley Trace	275.50	<.0001	48.27	<.0001
Roy's Greatest Root	553.06	<.0001	90.84	<.0001

[1] Input costs are shown in Table 1
[2] Varied profitabilities are shown in Table 2

Table 4. Average economic efficiency indicators for three farming systems.

Indicators	Farming systems		
	Extensive Mean ± SD	Semi-intensive Mean ± SD	Intensive Mean ± SD
Fixed cost (VND/ha/year)	25,499,798 ± 5,261,610[a]	62,196,772 ± 11,639,732[b]	105,618,663 ± 19,723,554[c]
Variable cost (VND/ha/year)	46,756,797 ± 31,517,901[a]	203,028,861 ± 34,665,226[b]	418,771,546 ± 57,602,330[c]
Total cost (VND/ha/year)	72,256,595 ± 34,751,920[a]	265,225,633 ± 41,807,890[b]	524,390,209 ± 66,137,666[c]
Farm-gate shrimp price (VND/kg)	202,778 ± 25,149[ac]	183,667 ± 21,063[b]	195,000 ± 0.00[ac]
Gross revenue (VND/ha/year)	114,872,890 ± 50,307,782[a]	487,153,728 ± 78,127,115[b]	1,043,362,192 ± 108,781,489[c]
Net revenue (VND/ha/year)	42,616,295 ± 24,611,540[a]	221,928,094 ± 53,237,683[b]	518,971,984 ± 81,462,894[c]
Rate of Income (RI %)	36.53 ± 12.87[a]	45.19 ± 6.31[b]	49.64 ± 4.85[c]
Benefit cost ratio (BCR)	1.64 ± 0.34[a]	1.85 ± 0.21[b]	2.0 ± 0.19[c]
Total profitability	0.64 ± 0.34[a]	0.85 ± 0.21[b]	1.0 ± 0.19[c]

SD: Standard deviation
Total cost = fixed cost + variable cost
Gross revenue = selling price x production
Net return = Gross revenue – Total cost
Total profitability = Net revenue/Total cost
Values (expressed as mean ± SD) with different letters in the same row are significantly different from each other ($P < 0.05$)

Table 5. Summary of the biological variables among production systems.

Items	Farming systems		
	Extensive (Mean ± SD)	Semi-intensive (Mean ± SD)	Intensive (Mean ± SD)
Water area (ha)	1.38 ± 1.13[a]	0.74 ± 0.71[bc]	0.65 ± 0.36[bc]
Stocking density (Post Larvae/ha)	137,699 ± 85,704[a]	168,172 ± 21,043[b]	237,882 ± 24,679[c]
FCR	0.59 ± 0.45 [a]	1.33 ± 0.15 [b]	1.47 ± 0.09[c]
Harvest size (g/shrimp)	26.28 ± 6.47[ac]	23.22 ± 3.13[b]	25.77 ± 3.14[ac]
Growth period (months)	5.76 ± 1.54[a]	3.69 ± 0.58[bc]	3.82 ± 0.48[bc]
Survival rate (%)	19.29 ± 9.29[a]	69.00 ± 6.86[b]	87.93 ± 3.69 [c]
Yield (ton/ha/year)	0. 57 ± 0.24[a]	2.65 ± 0.25[b]	5.35 ± 0.56[c]

SD: Standard deviation
Values (expressed as Mean) with different letters are significantly different from each other ($P < 0.05$)

stocking density with FCR ($r = 0.2294$, $P = 0.0079$) and yield ($r = 0.2578$, $P = 0.0027$), between the survival rate with FCR ($r = 0.4034$, $P < 0.0001$) and yield ($r = 0.3620$, $P < 0.0001$) (Table 6). It can be seen in Table 7 that many of the correlation coefficients between fixed and feed costs ($r = 0.3255$, $P = 0.0001$), fuel-electricity and labor costs ($r = 0.3191$, $P = 0.0002$), seed and feed costs ($r = 0.2904$, $P = 0.0007$), etc. are significant. Table 8 also shows many significant correlation coefficients between the profitabilities of fixed and seed costs, fixed and fuel-electricity costs, fixed and labor costs (r = 0.4112, 0.3712, 0.4593 at $P < 0.0001$, respectively), fuel-electricity and feed costs ($r = 0.5078$, $P < 0.0001$) and so forth. The results of further study of the correlation matrix of production cost variables (Table 7) shows that the principal

Table 6. A correlation matrix* of biological variables between three farming systems.

Items	Water area	Stocking density	FCR	Harvest size	Farming period	Survival rate	Yield
Water area	1.0000						
Stocking density	-0.2679 (0.0018)	1.0000					
FCR	-0.5294 (<0.0001)	0.2294 (0.0079)	1.0000				
Harvest size	0.0988 (0.2580)	-0.5854 (<0.0001)	-0.3488 (<0.0001)	1.0000			
Farming period	0.5230 (<0.0001)	-0.2287 (0.0081)	-0.7045 (<0.0001)	0.3710 (<0.0001)	1.0000		
Survival rate	-0.2738 (0.0014)	0.2975 (0.0005)	0.4034 (<0.0001)	0.0827 (0.3439)	-0.2467 (0.0042)	1.0000	
Yield	-0.2385 (0.0057)	0.2578 (0.0027)	0.2574 (0.0028)	0.0911 (0.2967)	-0.0728 (0.4051)	0.3620 (<0.0001)	1.0000

* Each correlation coefficient (r) is followed by a probability of H_0: $|r| = 0$ shown in parentheses.

Table 7. A correlation matrix * of input intensities between three farming systems.

Input costs	Fixed	Seed	Feed	Fuel-electricity	Labor
Fixed	1.0000				
Seed	0.1342 (0.1235)	1.0000			
Feed	0.3255 (0.0001)	0.2904 (0.0007)	1.0000		
Fuel-electricity	0.2066 (0.0170)	0.0482 (0.5816)	0.1493 (0.0864)	1.0000	
Labor	0.1011 (0.2468)	-0.0274 (0.7543)	0.0724 (0.4074)	0.3191 (0.0002)	1.0000

* Each correlation coefficient (r) is followed by a probability of H_0: $|r| = 0$ shown in parentheses

Table 8. A correlation matrix * of varied profitabilities between three farming systems.

Varied profitabilities	Fixed	Seed	Feed	Fuel-electricity	Labor
Fixed	1.0000				
Seed	0.4112 (<.0001)	1.0000			
Feed	0.0804 (0.3579)	0.2078 (0.0164)	1.0000		
Fuel-electricity	0.3712 (<.0001)	0.2308 (0.0075)	0.5078 (<.0001)	1.0000	
Labor	0.4593 (<.0001)	0.1900 (0.0285)	0.0431 (0.6227)	0.2955 (0.0006)	1.0000

* Each correlation coefficient (r) is followed by a probability of H_0: $|r| = 0$ shown in parentheses

Table 9. The eigenvalues[1] and eigenvectors[2] computed from a correlation matrix of input intensities.

Principal component	Eigenvalue	Account for in %	Eigenvector, coefficient of input costs				
			Fixed (FI)	Seed (SE)	Feed (FD)	Fuel-electricity (FE)	Labor (LR)
I_1	3.895	77.90	0.478	0.451	0.487	0.460	0.343
I_2	0.634	12.68	-0.180	-0.301	-0.198	0.012	0.915
I_3	0.255	5.10	-0.062	0.650	-0.003	-0.727	0.211
I_4	0.153	3.06	-0.671	0.495	-0.245	0.492	-0.029
I_5	0.063	1.26	0.533	0.192	-0.814	0.127	-0.009

[1] The eigenvalue for a principal component indicates the variance that it accounts for out of the total variances of 5.0000. Therefore, the first principal component (I_1) accounts for (3.895/5.0000) 100% = 77.90%, I_2 accounts for (0.634/5.0000) 100% = 12.68%, etc.

[2] The eigenvectors give the coefficients of the standardized variables (input intensities), for example, I_1 = 0.478 FI +0.451 SE +0.487 FD +0.460 FE +0.343 LR

component eigenvalues of total variances were 5 (Table 9). The first principal component (I_1) had a variance of 3.895, accounting for 77.90%, the second component (I_2) had a variance of 0.634, accounting for 12.68%, the third (I_3) for 5.10%, the fourth (I_4) for 3.06% and the fifth (I_5) for 1.26%. Clearly the two principal components I_1 and I_2 were more important than the others and were statistically accepted due to their significance. These two principal components were linear combinations of the respective input intensities as follows (see Table 9):

$$I_1 = 0.478\ FI + 0.451\ SE + 0.487\ FD + 0.460\ FE + 0.343\ LR; \quad (1)$$

$$I_2 = -0.180\ FI - 0.301\ SE - 0.198\ FD + 0.012\ FE + 0.915\ LR; \quad (2)$$

Table 10. The eigenvalues[1] and eigenvectors[2] computed from a correlation matrix of varied profitabilities.

Principal coponent	Eigenvalue	Account for in %	Eigenvector, coefficient of varied profitabilities				
			Fixed (FIP)	Seed (SEP)	Feed (FDP)	Fuel-electricity (FEP)	Labor (LRP)
P_1	2.521	50.4	0.591	0.538	-0.236	-0.035	0.553
P_2	1.454	29.1	0.087	0.131	0.654	0.732	0.105
P_3	0.501	10.0	-0.052	0.446	0.631	-0.615	-0.147
P_4	0.356	7.1	-0.017	-0.583	0.309	-0.271	0.701
P_5	0.170	3.4	0.801	-0.394	0.151	-0.100	-0.413

[1] The eigenvalue for a principal component indicates the variance that it accounts for out of the total variances of 5.0000. Therefore, the first principal component (P_1) accounts for (2.521/5.000) 100% = 50.40%, P_2 accounts for (1.454/5.000) 100% = 29.1%, etc.

[2] The eigenvectors give the coefficients of the standardized variables (profitabilities), for instance, P_1 = 0.591 FIP +0.538 SEP -0.236 FDP -0.035 FEP +0.553 LRP

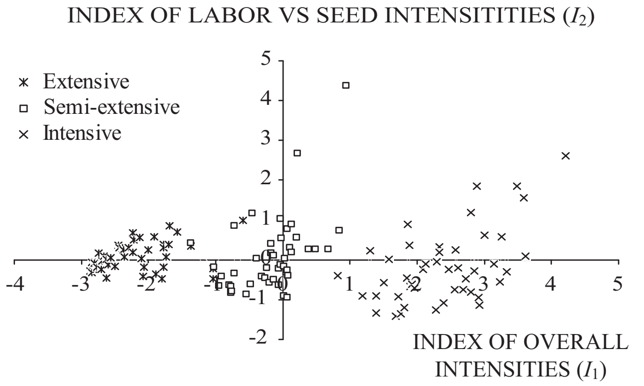

Fig. 2. Distribution of 135 tiger shrimp farms from three different farming systems based on 2 principle components (I_1 and I_2) as functions of standardized input intensity variables.

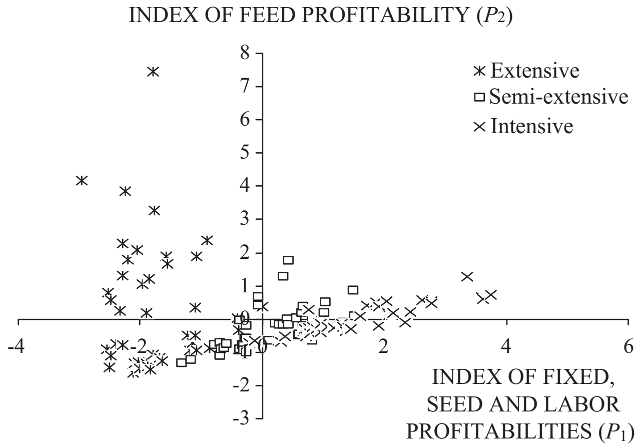

Fig. 3. Distribution of the of 135 shrimp farms from three different farming systems based on 2 principle components (P_1 and P_2) as functions of the standardized varied profitabilities.

A Plot of I_1 against I_2 (Fig. 2) shows the distribution of production costs (VND/ha/year) for 135 shrimp farms (as calculated with a one ha water surface area) on a two dimensional plane. Every farm possessed a unique score for I_1 and I_2 as the results of these two principal components.

The principal component eigenvalues were further computed from the correlation matrix of varied profitabilities (Table 8) for total variances of 5 (Table 10). The first principal component (P_1) had a variance of 2.521, accounting for 50.4%, the second (P_2) had a variance of 1.454, accounting for 29.1%, the third (P_3) for 10.0%, the fourth (P_4) for 7.1% and the fifth (P_5) for 3.4%. Therefore, the two principal components P_1 and P_2 were more important than the others. According to the eigenvectors of the correlative variables, P_1 and P_2 functions can be rewritten as (Table 10):

$$P_1 = 0.591\ \text{FIP} + 0.538\ \text{SEP} - 0.236\ \text{FDP} - 0.035\ \text{FEP} + 0.553\ \text{LRP}; \quad (3)$$

$$P_2 = 0.087\ \text{FIP} + 0.131\ \text{SEP} + 0.654\ \text{FDP} + 0.732\ \text{FEP} + 0.105\ \text{LRP}. \quad (4)$$

A plot of P_1 against P_2 for 135 tiger shrimp farms, as shown in Fig. 3 helps to visualize the unique profitabilities on their own.

The Cobb-Douglas function was estimated using varied methods of model selection including forward selection, backward elimination, stepwise selection, adjusted R^2 selection and Mallows' C_p selection. All methods agreed that:

$$NR\ (\text{Net return}) = 0.0004\ \text{FI}^{1.0752}\ \text{SE}^{0.2681}\ \text{FD}^{0.1856}, \quad (5)$$

with significant probabilities of <0.0001, 0.0113 and 0.0008 for corresponding partial elasticities (Table 11).

Some relative information from respondent interviews is recorded in Table 12 and information related to water environment parameters was collected from shrimp culturing sites within Tra Vinh Province from November, 2010 to April, 2011; see Table 13.

IV. DISCUSSION

1. Discussion of the Production Cost Analysis Results

Production cost is one of the major concerns in business management. The production costs in aquaculture can be divided into two parts, fixed and variable costs. Our findings show the production scale had a highly significant effect on

Table 11. Cobb-Douglas production function[1] estimated by relating[2] unit net return to input intensities.

	Intercept Log β_0	Fixed cost (FI) β_1	Seed cost (SE) β_2	Feed cost (FD) β_3
Estimated parameter	-3.4156	1.0752	0.2681	0.1856
Standard Error	0.7354	0.1271	0.1044	0.0538
F Value	21.57	71.59	6.60	11.91
P > F	<0.0001	<0.0001	0.0113	0.0008

[1] This function is determined as $NR = \beta_0 (FI)^{\beta 1} (SE)^{\beta 2} (FD)^{\beta 3}$, where NR is a unit net revenue (VND/ha/year), $\beta_0 = 0.0004$ and input intensities have a unit of VND/ha/year.
[2] Adjusted *R*- Square = 88.16% and *R*- Square = 88.43%

Table 12. Background information of respondents interviewed in different shrimp farming systems.

	Farming methods							
	Extensive (*n* = 45)		Semi-intensive (*n* = 45)		Intensive (*n* = 45)		All culture systems (*n* = 135)	
	(n)	%	(n)	%	(n)	%	(n)	%
Polluted and unfavorable water environment	32	71.11	20	44.44	14	31.11	66	48.89
Reduced seed quality	38	84.44	32	71.11	26	57.78	96	71.11
Increased shrimp diseases	40	88.89	34	75.56	30	66.67	104	77.04
High production costs	38	84.44	40	88.89	39	86.67	117	86.67
Lack of technical assistance	28	62.22	8	17.78	3	6.67	39	28.89
Lack of credit facilities and high interest	39	86.67	40	88.89	40	88.89	119	88.15
Price and market problems	30	66.67	39	86.67	16	35.56	85	62.96
Hired aquaculture engineer	0	0	34	75.56	45	100	79	58.52
Tested seed by PCR	19	42.22	38	84.44	45	100	102	75.56
Sedimentation pond	0	0	35	77.78	40	88.89	75	55.56
Tested water environment parameters everyday	10	22.22	38	84.44	45	100	93	68.89
Exchanged water daily	37	82.22	0	0	0	0	37	27.41
Only used commercial feed	0	0.00	45	100	45	100	90	66.67
Only used flesh prey or combined home-made feed or (and) commercial feed	45	100	0	0	0	0	45	33.33
Used electricity for water paddle-wheel aerator and pump	0	0	15	33.33	5	11.11	20	14.82
Used petroleum for water paddle-wheel aerator and pump	0	0	35	77.67	40	88.89	75	55.55

* *n* indicates the sample size of interviewed farmers

Table 13. Water environment parameters following months at shrimp culture places in Tra Vinh province, Viet Nam.

Time	Parameters	Places									
		Co Chien river	Vinh Kim bridge	Hiep My river	Thau Rau culvert	Long Toan river	Lang Chim river	Dao Canal	La Bang culvert	Đinh An estuary	Average
Nov, 2010	pH	7.5	7.3	7.6	7.3	7.8	8.3	7.6	7.7	7.6	7.63
	Alkanility (ppm)	54	56	56	84	84	90	58	54	54	65.56
	Salinity (‰)	0	0	1	5	9	9	3	1	1	3.22
Dec, 2010	pH	7.5	7.3	7.6	7.5	8	8.2	7.6	7.6	7.6	7.66
	Alkanility (ppm)	54	57	61	82	90	90	65	54	54	67.44
	Salinity (‰)	1	1	2	5	13	13	6	3	3	5.22
Jan, 2011	pH	7.6	7.6	7.8	7.7	7.9	8.2	7.6	7.7	7.6	7.74
	Alkanility (ppm)	72	79	77	95	90	90	77	63	65	78.67
	Salinity (‰)	5	5	11	14	18	18	12	8	8	11.00
Feb, 2011	pH	7.7	7.7	7.8	7.6	8	8.2	7.6	7.9	7.8	7.81
	Alkanility (ppm)	77	86	81	90	90	90	88	68	70	82.22
	Salinity (‰)	7	6	15	18	20	21	15	14	13	14.33
Mar, 2011	pH	7.9	7.6	7.7	7.6	8	8.2	7.6	7.9	7.8	7.81
	Alkanility (ppm)	80	66	74	92	90	90	90	72	68	80.22
	Salinity (‰)	8	7	17	20	23	24	20	19	17	17.22
Apr, 2011	pH	8	7.6	7.8	7.8	8	8.2	7.6	7.9	7.9	7.87
	Alkanility (ppm)	86	74	88	99	90	90	90	74	72	87.78
	Salinity (‰)	10	8	16	19	23	24	20	21	17	17.56

Source: Aquaculture Division of Tra Vinh province, Viet Nam, 2011.

the input intensities at $P < 0.0001$ (Table 3). The study results agree with those obtained by Shang (1990) and EC (2002) that the fixed costs and variable costs per hectare increase alongside the intensification level (Table 1) and the percentage of fixed cost normally decreases with increasing production scale (Fig. 1). Although percentages differ between farming systems, variable costs such as feed, seed, labor and fuel-electricity usually account for high percentages of the production cost structure (Fig. 1). This is similar to the study results of Miao and Tang (2002) and EC (2002). Two principal components, I_1 and I_2, are accepted to make clear important input intensities in the three production systems (Table 9).

Considering function I_1 (1), the eigenvectors of all cost variables are rather highly positive ranging from 0.343 to 0.487. This indicates that I_1 is mainly determined by overall input intensities and therefore, can be defined as the index measuring a sum of all input intensities of shrimp culturing farms for the three systems. Through the distribution of the I_1 scores (Fig. 2), it can be seen that intensive farms spent the highest input intensities and were driven to the far right in I_1; in contrast, extensive farms disbursed the lowest input intensities and were driven to the left. Semi-intensive farms had intermediate scores because of the intermediate input intensities.

Commercial feed is one of the most essential inputs for increasing shrimp production, especially in semi-intensive and intensive systems. According to the survey, the average feed cost decreased from intensive to semi-intensive and finally extensive systems, being 260,003,526 VND/ha, 116,487,889 VND/ha and 15,023,324 VND/ha, respectively, (Table 1). A significant reduction in the use of feed is a feature distinguishing extensive farms from semi-intensive and intensive farms (Ling et al., 1999). In Vietnam, 60% of shrimp feed production is controlled by foreign companies and there is a lack of locally available feed ingredients, which made feed prices about 15-20% higher than other countries (Nguyen, 2010; Arie, 2012). In addition, 86.67% respondents noted that production costs had increased significantly in recent years, especially feed costs (Table 12). The cost of feed was largest among input intensities for semi-intensive and intensive farms, accounting for 43.92% and 49.58% of total production costs, respectively (Fig. 1). This finding was similar to the study results obtained by Chanratchakool et al. (2002) and FAO (2011). A necessary solution to reduce the feed cost is to limit the importing of raw materials as much as possible. Also, two other options to lower feed cost are (1) to decrease the FCR through policies such as imposing feed quality assurance standards, and requiring clarity in labeling and (2) to reduce feed prices by eliminating tariffs on ingredients (FSPS II, 2010).

There was a significant difference in fuel-electricity costs between the production systems. Extensive farms are invariably located in mangrove forest areas where water exchange is mainly dependent on the tides. In contrast, semintensive and intensive farms are built in coastal zones above the high tide line; therefore, energy resources such as electricity and petroleum have to be used for exchanging water, circulating internal water and supplying oxygen for both shrimps and phytoplankton (Boyd, 1990; FAO, 2011). That leads to the average fuel-electricity costs for semi-intensive and intensive farms amounting to 13,383,763 VND/ha and 38,574,869 VND/ha, respectively, higher than for extensive farms, 3,061,500 VND/ha (Table 1). Fig. 1 shows that fuel-electricity costs made up the fourth and the third highest costs of semi-intensive (5.05% of total production costs) and intensive farms (7.36%), respectively, but was only ranked the seventh highest cost for extensive farms (4.23%). Fuel-electricity energy is very important for semi-intensive and intensive systems. In addition, 77.67% of semi-intensive farmers and 88.89% of intensive farmers (Table 12) still used petroleum which was more expensive than electricity. In order to reduce such costs, the local government could provide credit at a low interest rate for farmers to encourage them to use electricity instead of petroleum.

Regarding the function I_2 (2), the eigenvectors of labor and seed costs are 0.915 and -0.301, respectively, much higher (regardless of plus or minus sign) than those of fixed cost (-0.180), feed cost (-0.198) or fuel-electricity cost (0.012) (Table 9). This means that, if the labor cost increased, I_2 would increase, and I_2 would decrease with the growth of seed cost. It is fair to say that I_2 is considered the index showing the contrast between labor and seed costs. As can be seen in Fig. 2, many intensive farms had higher I_2 scores due to higher labor costs than semi-intensive or extensive farms. Some intensive farms possessed smaller I_2 scores because of higher seed costs than semi-intensive or extensive farms. One semi-intensive farm spent the most on labor costs (VND 72,916,667/ha) as shown by its having the highest I_2 score (Table 1 and Fig. 2), however, the labor profitability of the farm was low (4.17) compared to the average labor profitability of the semi-intensive system (12.13) (Table 2). In brief, the average labor and seed costs were reduced from intensive to semi-intensive and finally extensive systems (Table 1).

In real conditions, labor resources include (a) familial labor, for which no payment is made, and (b) hired labor, for which farmers have to pay in cash. The opportunity cost principle was adopted to determine the unpaid familial labor cost. Average labor costs were calculated to be 12,244,453 VND/ha, 21,448,433 VND/ha and 27,926,918 VND/ha for extensive, semi-intensive and intensive farms, respectively (Table 1). As in Olivier and Roel (2009), semi-intensive and intensive farms used mainly hired laborers while extensive farms utilized family laborers.

Seed costs differed due to dissimilarity in the stocking density among the different production systems: 137,699 post larvae (PL)/ha for extensive system, 168,172 PL/ha for semi-intensive system and 237,882 PL/ha for intensive system (Table 5), being 4,571,842 VND/ha, 10,163,428 VND/ha and 14,953,565 VND/ha, respectively (Table 1). Seed cost was also affected by PL quality. If the PL met the standards of the Polymerase Chain Reaction (PCR) test, the price would be 55-70 VND/PL, otherwise the price would be 20-45 VND/PL.

From the survey, 100% of intensive farmers and 84.44% of semi-intensive farmers bought PL which were tested by PCR, while only 42.22% of extensive farmers bought tested seed (Table 12). Consequently, survival rates varied very considerably from extensive, semi-intensive to intensive systems with corresponding rates of 19.29%, 69.00% and 87.93% (Table 5). 71.11% respondents stated that seed quality was poor (Table 12). In Vietnam, too many shrimp farmers had to purchase poor quality seed from private hatcheries, most of which are small-scale farms with poor infrastructure conditions, unstable production technologies and lack of strict quarantine (Arie, 2012; Suzuki, 2013). The success rate in shrimp farming in Vietnam is about 30%, lower than that in Thailand (70 percent), primarily because Vietnam's supply and quality of seed were poor (VASEP, 2012). Therefore, the local government should reinforce seed quality management to guarantee disease free seed stocks for farmers.

2. Discussion of the Profitability Analysis Results

Profitability is another core issue for business management. The evidence obtained from the three types of culturing systems strongly suggests that the different production scales did have significant effects on the various profitabilities at $P < 0.0001$ (Table 3). According to EC (2002), in brackish water shrimp farming, a good technical performance does not always correspond to a good economic performance. However, in this study, we realized a positive relation between technical investment and economic efficiency. Intensive farms applied advanced techniques to obtain the highest stocking density, survival rate, yield (Table 5) and the best economic indicators with the exception of feed and fuel-electricity profitabilities, while extensive farms used traditional techniques, so they had the lowest economic efficiency, and semi-intensive farms had intermediate characteristics (Tables 2 and 4). The structure of the profitability by statistically determining the principal components of P_1 (3) and P_2 (4) as defined in Table 10.

For function P_1 (3), the eigenvectors of fixed, seed and labor profitabilities had highly positive values (0.591, 0.538 and 0.553, respectively), while the eigenvectors of feed and fuel-electricity profitabilities had small negative values (-0.236 and -0.035, respectively) (Table 10). Therefore, P_1 could be treated as the index of the earning power of fixed, seed and labor profitabilities. In addition, there was a significant difference in the profitabilities of the fixed, seed and labor costs between the three systems (Table 2). As a result, the farm which had the greatest P_1 score, would have the highest overall earning power. An examination of Fig. 3 makes it clear that intensive farms, which were driven to the far right in P_1, had the highest earning power compared with the other ones. In contrast, extensive farms that were driven to the left possessed the lowest earning power.

From the distribution of the P_1 scores for the fixed, labor and seed profitabilities, it can be concluded that the business management of intensive farms was the best while that of extensive farms was the lowest. Semi-intensive farms were characterized by intermediary business management. According to the survey, responses for management performance for water environments, showed that feeding as well as technical assistance was better in semi-intensive and intensive systems than extensive systems.

The results for water environment management showed that 77.78% of semi-intensive and 88.89% of intensive farms had sedimentation ponds and only exchanged water when necessary (Table 12). Conversely, none of the extensive farms had sedimentation ponds with 82.22% exchanging water daily directly from canal to shrimp ponds meaning there was a good chance of disease transmission from one farm to another (Cao, 2007; Pham, 2008). Many semi-intensive (84.44% respondents) and intensive farmers (100% respondents) often tested the parameters for the water environment, while only some extensive farmers (22.22% respondents) did so (Table 12). In addition, most extensive farmers stocked seed from November to December - 2010 when pH, alkalinity and salinity values were unsuitable for shrimp culturing (Table 13), whereas, semi-intensive and intensive farmers began stocking from March to April - 2011 when these parameters had optimal values for culturing juvenile shrimp (Table 13) (Chanratchakool et al., 2002).

In terms of feeding management, in extensive farms, shrimp were only fed after one month from the stocking day and during the period of shrimp culturing, most farmers did not supply enough feed for the shrimp. Additionally, they were fed trash fish which could bring shrimp into contact with harmful viruses and pollute the water environment (Nguyen, 2013). Semi-intensive and intensive farmers, on the other hand, fed the shrimp with commercial feed after stocking, four times a day (FAO, 2011) and approximately every 7-10 days, farmers tested the weight of the shrimp to calculate the quantity of daily feed needed (Chanratchakool et al., 2002).

As can be seen in Table 12, 0%, 75.56% and 100% of extensive, semi-intensive and intensive farmers, respectively, hired aquaculture engineers to help them with technical management. Moreover, 62.22% of extensive farmers lacked technical assistance, while those rates were only 17.78% and 6.67% for semi-intensive and intensive scale farmers (Table 12). It is noted that technological investment could reduce the vulnerability to disease outbreak and thus reduce the risk usually associated with shrimp farming (Olivier and Roel, 2009).

For function P_2 (4), the coefficients of feed profitability (0.654) and fuel-electricity profitability (0.732) were much higher than the others (Table 10). Therefore, the index of P_2 stood for feed and fuel-electricity profitabilities. As can be clearly recognized this was not significantly different from fuel-electricity profitability in the three systems (Table 2). This implied a significant difference in the P_2 scores which was almost entirely determined by feed profitability and the index of P_2 relates to the earning power of feed costs. A higher feed profitability would mean a higher P_2 score. The feed profitability of extensive farms was higher, while the feed profitabilities of semi-intensive and intensive farms were lower and not significantly different (Table 2). As a result, many extensive system farms had higher P_2 scores and were driven above in P_2 (Fig. 3).

In fact, 19 out of the 45 extensive farms surveyed utilized natural food in pond and captured trash fish (*Acetes, Corbiculidae, Nereidae, etc.*) to feed their shrimp. Sometimes, they also fed shrimp farm-made or commercial feed. On the other hand, all semi-intensive and intensive farms (100%) fed shrimp using commercial feed. Consequently, the FCR of the extensive system was very low (0.59) while the FCRs of the semi-intensive and intensive systems were much higher, 1.33 and 1.47, respectively (Table 5). Feed profitability for extensive farms was very high (9.11) while those for semi-intensive and intensive farms were much lower, 1.94 and 4.03, respectively (Fig. 3 and Table 2). An FCR below 2.0 is necessary for a profitable farm (FAO, 2011). Therefore, it is a reasonable expectation that the feed used in semi-intensive and intensive systems had highly effective biochemical and economic aspects.

Shrimp price and market demand had a large effect on the profits of the production system. There was a significant difference in shrimp weight as well as price among the three systems. The average weight and the price for extensive and intensive farms were 26.28 g, 25.77 g per shrimp and 202,778 VND/kg and 195,000 VND/kg, respectively, significantly higher than those of semi-intensive farms, which were 23.22 g per shrimp and 183,667 VND/kg (Tables 4 and 5). One of the reasons for the small size of the shrimp in semi-intensive farms was their shorter culturing period than those of extensive and intensive farms, corresponding to 3.69, 5.76 and 3.82 months (Table 5). The culturing period for semi-intensive farms should be as long as that of intensive farms to increase the shrimp size and to earn more profit.

Based on the above discussion, extensive farms need to increase the intensification scale (given suitable conditions) and improve the business management to improve their earning power.

3. Discussion of the Cobb-Douglas Production Function Results

The Cobb-Douglas production function (5) results presented in Table 11 indicate that a unit of net return (Vietnamese dong/ha/year) is strongly determined by the input intensities of fixed, seed and feed costs. The production elasticities (coefficients) were 1.0752, 0.2681 and 0.1856, respectively, for input variables of fixed, seed and feed costs (Table 11). Consequently, an increase in the input intensities of fixed, seed and feed costs of 1%, resulting from an increase in the production scale, would result in 1.0752%, 0.2681% and 0.1856% increases, respectively, in unit net return. The sum of the coefficients was 1.5289 and thus greater than unity, which showed that returns to scale were increasing (Shang, 1990). As a result of the existence of positive economies of scale, many more advantages would be gained if the degree of intensity were increased in the near future. From Table 4 it can be seen that the profitability of intensive farms was excellent, involving a net return of one Vietnamese dong for every single dong invested.

V. CONCLUSION

Stocking density and survival rate increased being lowest for extensive farms (137,699 PL/ha and 19.29%), greater for semi-intensive farms (168,172 PL/ha and 69.00%) and finally largest for intensive farms (237,882 PL/ha and 87.93%). The production cost, production, and net revenue varied in increasing order, beginning with extensive farms (72,256,595 VND, 0.57 ton, 42,616,295 VND per ha), then semi-intensive farms (265,225,633 VND, 2.65 tons, 221,928,094 VND per ha) and finally intensive farms (524,390,209 VND, 5.35 tons, 518,971,984 VND per ha). The profitabilities also increased from extensive to semi-intensive and finally intensive systems (0.64, 0.85 and 1.0, respectively). This shows that the business management performance of the intensive system was the best while that of the extensive system was the lowest. Although feed profitabilities for intensive and semi-intensive farms were lower than for extensive farms, there was a reasonable expectation that the feed used in semi-intensive and intensive systems was more effective in the bioeconomic aspect. The scale of production would benefit from increase investment and more advanced techniques, especially for extensive systems. The culturing period for semi-intensive farms should be longer to increase shrimp size and thus profits. Also, the shrimp production industry should apply Good Agricultural Practices and Better Management Practices standards to improve competitiveness in the most lucrative markets because regulations concerning food safety and animal welfare are becoming more stringent in importing countries (FSPS II, 2010; Arie, 2012).

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