CHAPTER 7

ANALYSES OF PRODUCTION FRONTIERS, TECHNICAL AND ALLOCATIVE EFFICIENCIES

The economic performance of the two systems can be physically and financially analyzed. In the previous chapter, economic performance was physically and financially analyzed with the support of budgeting analysis. This chapter embraces two main sections. The first section will focus on physical performance in terms of combination of the inputs used and shrimp yield, to see which inputs play important roles in production. The research method used in this section is stochastic production frontier. The second section is concerned with allocative efficiency. This section assesses how efficient farmers allocate their resources with respect to price conditions. As a consequence, the recommendations will be made in the next chapter based mainly on the results of these analyses.

7.1 The empirical models of production frontiers and technical inefficiencies

To consider the effects of the inputs used on shrimp yield per sao, the logarithmic transformed Cobb-Douglas production function is estimated for each of the two systems. The function is specified as follows:

$$\ln Y = \alpha_0 + \alpha_1 \ln LAB + \alpha_2 \ln FL + \alpha_3 \ln PRE + \alpha_4 \ln DIS + \alpha_5 \ln FD \\ + \alpha_6 \ln DEN + \alpha_7 RES + \alpha_8 \ln DST + v - u$$

In this study, the explanatory variables for the technical inefficiency (TI) equations for the two shrimp aquacultural systems are hypothesized as experience, education, and production scale (area).

The production frontier of each system is estimated simultaneously with the technical inefficiency equations written empirically as follows:

$$\mu = \delta_1 + \delta_2 EXP + \delta_3 EDU + \delta_4 SAO + \varepsilon$$

Where δ 's and ε are parameters and error terms, respectively. μ is technical inefficiency (TI).

The maximum likelihood method (MLE) is used to estimate the production frontier simultaneously with the TI equation for each shrimp system. The computer program used for these simultaneous equations is FRONTIER 4.1 (Coelli, 1996).

7.2 Definitions of the variables for the production frontiers and technical inefficiency models

7.2.1 The definitions of the variables included in the production frontiers

Shrimp yield (Y) is the total shrimp output harvested and calculated per sao. The unit of shrimp yield is kg/sao. Shrimp yield is assumed to be affected by the following variables.

Labor (LAB) consists of both family labor and hired labor. This is the total labor (man-days) spent during the crop, from the first activity of aquaculture until the harvest. In shrimp aquaculture, there are a lot of activities and labor must be allocated for the following: pond cleaning and preparation, water preparation, observing of and feeding shrimp, and harvesting. The more man-days spent on shrimp aquaculture the greater the likelihood of a higher yield. As a consequence, the expected relationship between shrimp yield and labor is positive. The unit of labor is man-days per sao.

Fuel (FL) is calculated by litre(s) per sao. In semi-intensive and intensive shrimp aquaculture, water pumps and aerators are essential. According to Chanratchakool *et al.* (1998), during the initial stages of culture (the first three weeks) the aerators are primarily used to keep the pond bottom clean. After this period, they also help maintain dissolved oxygen. The most efficient method of cleaning the pond is usually to concentrate the waste in the center of the ponds and aerators can help in achieving this. Aerators also perform the essential function of mixing the pond water to ensure all the plankton is exposed to sunlight. Delivery of dissolved oxygen to the pond bottom and removal of toxic ammonia and hydrogen sulfide from the pond bottom is another important function of aeration. Aerators operate using fuel and lubricant. Therefore, litres of fuel used per sao can be a proxy of aeration. The more fuel used the better the water quality. Consequently, the shrimp yield will be increased. The expected relationship between shrimp yield and fuel is positive.

Pond preparation costs (PRE) are calculated by VND1,000 per sao. These costs consist of expenses on materials and services used for pond preparation of each crop: bottom pond clearing and treatment (digging machines, cattle hiring, lime, dolomite, and other chemical substances); water preparation (chemical substances: calcium hypo chlorite, chlorine, tea seed powder, etc.) and coloring (chicken manure, urea fertilizer, N-P-K, bran, fish sauce, etc.). As known, the organic amount and content of the sediment that accumulate in the pond during the production cycle depend on the cultural system. This sediment must be removed to sustain production and prevent accumulation of organic materials. If the sediment is not removed from the high yield ponds, production will rapidly deteriorate with each successive cycle. Furthermore, treatment of water and fertilization encourage a healthy plankton bloom and prevent other species from entering the pond. Finally, coloring or plankton culture activity is necessary for several reasons: (i) it provides oxygen during daylight hours; (ii) it shades the pond bottom and prevents the growth of potentially harmful benthic algae; (iii) it provides a darker environment which the shrimp find less stressful; (iv) it utilizes the nitrogenous and/or phosphate waste within the pond, and (v) it reduces fluctuations in the water temperature.

As a result, it is hypothesized that there is a positive relationship between pond preparation cost and the shrimp yield. Since the applications of different farms were different from each other in terms of materials and services used, it is hard to use the physical units to measure this variable. So, monetary value (VND 1,000/sao) was selected as the measurement unit of this variable.

Disease prevention costs (DIS) consist of the expenses on materials which help shrimp become healthier to resist diseases or environmental changes. These materials are vitamins or nutritional feeds such as Vitamin C10% for shrimp, Vitamin C fremix, Maxone, Vitamax, Bcomax, etc. These materials not only help shrimp become healthier by enhancing the ability of shrimp to resist diseases but also help them enhance their anti-stress ability. Like pond preparation, this variable was measured in VND 1,000 per sao since the applications of materials among the farms were not uniform, either. It is also hypothesized that the relationship between disease prevention cost and shrimp yield is positive.

Feed (FD) is considered one of the most important factors of shrimp aquaculture. According to Chanratchakool *et al.* (1998), feed accounts for 45 to 50% of the operating cost in high yield systems and approximately 40% of the operating costs in lower yield systems. In this research, feed cost accounts for 49.8% of total cost in the two systems, 54.7% in SSAS and 45.5% in ISAS (Table 7.7). If shrimp are given more feed, they will gain weight and then output will increase. On the contrary, if feed is not sufficient, not only will they not grow but also the smaller and weaker shrimp will be eaten by bigger and stronger ones. Therefore, the expected relationship between feed and shrimp yield is positive.

The stocking density (DEN) is measured by number of post larvae per sao. The objective of shrimp aquaculture, like any other business, is to make a profit. It is however, a serious mistake to assume that stocking more shrimp will produce more profit. In many cases, overstocking can lead to loss of the whole population. Overstocking a system will invariably lead to trouble; shrimp are not economic units, they are animals.

In the two shrimp aquacultural systems in Phu Vang, the data of stocking density showed the average density, maximum density, and minimum density of the SSAS are 3,836; 7,000; and 1,500 post larvae per sao, respectively. Likewise, those of the ISAS are 10,076; 17,500; and 7,500 post larvae per sao, correspondingly. As compared to the benchmarks of the Philippine and Thai methods (Chapter 5), the stocking density of Phu Vang is still low. Hence, it is possible to assume that the relationship between shrimp yield and stocking density is positive.

A reservoir (RES) is useful for control of the pond environment. It is especially important in areas where the water quality is inconsistent or where the supply is intermittent. Reservoirs also have an essential role to play in preventing diseases entering the cultural ponds. As well as storing water, the reservoir can act as a large biological filter, improving the water quality. Then, RES is used as a proxy of water quality. A farm with reservoir is expected to have better quality water because the silt will precipitate in the reservoir. Reservoir is a dummy variable and this variable takes the value of 1 when farms own water reservoirs and otherwise.

Distance (DST) is the distance in meters from the shrimp ponds to the lagoon. The farther distance from pond to lagoon, the longer it takes for water to flow from lagoon to pond. Farms having water reservoirs facilitate easier exchange of water and get better quality water. On the contrary, farms without reservoirs use water in the main channel for exchange. This is pumped directly from the lagoon and into the cultural ponds. As discussed in Chapter 5, there were conflicts between aquaculture and aquaculture, especially between the two former shrimp aquacultural systems (TESAS and IESAS) and the two latter systems (SSAS and ISAS). The net ponds of the two former shrimp systems have prevented water exchange in the lagoon. Accordingly, the water quality nearby the offshore is likely to be poor. Owing to the long distance from the lagoon to the ponds in the two earthen pond systems, the waste in the lagoon water can be deposited or removed during the time that water flows from the lagoon to the farm pond. This process can improve water quality. Distance is, thus, selected as another proxy of water quality. Shrimp ponds farther from the lagoon are expected to have better water quality, which in turn affects shrimp yield.

Both RES and DST variables are included in the production frontier models. The reasons for including them in the models are:

Since reservoir is a dummy variable, there will be two cases:

First, if a farm owns a reservoir, water used for exchange in cultural ponds will be pumped from reservoirs. The quality of water in the reservoir is assumed to affect shrimp yield. However, the quality of water pumped into reservoirs is dependent on the water quality from the lagoon. In other words, the quality of water pumped into the reservoir is assumed to be dependent on the distance from the lagoon to the pond. The assumption is that the father the distance from the lagoon to the pond, the more suspended solids or waste in lagoon water will be deposited or removed. As a result, the water pumped to the reservoir will be cleaner and better.

Second, if farm does not own a reservoir, water used for exchange in an aquacultural pond will be pumped directly from the main channel which carries water from lagoon to pond. In this case, the farther distance is assumed to have better water quality as already assumed and explained in the first case.

In addition, only 40% of ISSAS farms and 10% of SSAS farms own reservoirs. In other words, 60% and 90% of farms in ISAS and SSAS, correspondingly used water directly from the lagoon. Therefore, both RES and DST variables should be included into the production frontier models of the two shrimp aquacultural systems.

The expected relations between shrimp yield and the two water quality variables, RES and DST, are positive.

7.2.2 The definitions of the variables included in the technical inefficiency models

Experience (EXP) is measured by number of crops which farmers have experienced since they started culturing shrimp. This is the accumulative experience during the aquacultural period. The higher the number of aquacultural crops farmers have experienced, the more experience those farmers have accumulated in shrimp aquaculture. The experienced farmer is predicted to use inputs efficiently and manage the farm well. The relationship between TI and experience is, hence, assumed to be negative.

Education (EDU) is the number of formal schooling years of education that the head of a farm has completed. Successful shrimp aquaculture and the management of its natural environment require new and advanced techniques and technologies to be applied. More highly educated farmers can understand and apply these better and target profit maximization. Therefore, a negative relationship is assumed and expected for the relationship between education and TI.

Area (SAO) is the total area of shrimp aquacultural ponds that each farm owns and it is calculated by sao (500m^2). Theoretically, if there is economics of scale when farms are larger, this can lead to TE. However, this is not true if the farm is too large, i.e. farm size is much over the farms' investment capacity. This would lead to TI. With these considerations, the relationship between TI and SAO can be negative or positive.

7.3 Descriptive statistics of the variables

The descriptive statistics of yield and variables affecting the yield; and the TI and variables affecting the TI of the SSAS and ISAS are as follows:

Table 7.1 Statistics for yield and variables affecting the yield of the SSAS

Variables	Minimum	Maximum	Mean	Std. Dev.	CV(%)
Y (kg/sao)	9.6	150.0	46.2	22.8	49.4
LAB (man day/sao)	3.8	44.2	14.8	7.4	50.0
FL (litter/sao)	3.7	85.7	24.1	15.8	65.6
PRE (VND 1,000/sao)	22.1	454.1	146.5	73.8	50.4
DIS (VND 1,000/sao)	0.0	350.0	58.7	92.1	157.0
FD (kg/sao)	27.4	260.0	106.9	50.5	47.2
DEN (Post larva/sao)	1,500.0	7,000.0	3,836.0	1,529.7	39.9
RES (Y/N)	0.0	1.0	0.1	0.3	300.0
DST (meter)	2.0	500.0	41.8	114.4	274.0

Source: Survey, 2002.

Table 7.2 Statistics for yield and variables affecting the yield of the ISAS

Variables	Minimum	Maximum	Mean	Std. Dev.	CV(%)
Y (kg/sao)	12.5	138.5	70.1	32.2	45.9
LAB (man day/sao)	6.3	52.8	20.4	10.4	51.0
FL (litter/sao)	5.0	177.9	48.2	32.4	67.2
PRE (VND 1,000/sao)	77.7	1,304.0	375.5	240.0	63.9
DIS (VND 1,000/sao)	0.0	560.0	125.8	139.7	111.0
FD (kg/sao)	42.8	269.2	126.2	53.4	42.3
DEN (Post larva/sao)	7,500.0	17,500.0	10,076.0	2,340.9	23.2
RES (Y/N)	0.0	1.0	0.4	0.5	125.0
DST (meter)	2.0	500.0	74.1	136.8	185.0

Source: Survey, 2002.

Table 7.3 Statistics for TI and variables affecting the TI of the SSAS

Variables	Minimum	Maximum	Mean	Std. Dev.	CV(%)
TI (%)	22.65	99.98	69.67	20.74	29.8
EXP (Crops)	1.0	20.0	6.3	4.0	63.5
EDU (schooling years)	0.0	16.0	6.7	3.5	52.2
SAO (sao)	5.0	55.0	13.1	8.7	66.4

Source: Survey, 2002.

Table 7.4 Statistics for TI and variables affecting the TI of the ISAS

Variables	Minimum	Maximum	Mean	Std. Dev.	CV(%)
TI (%)	24.95	99.99	79.48	19.11	24.0
EXP (Crops)	1.0	20.0	6.4	4.7	73.4
EDU (schooling years)	1.0	15.0	7.6	3.4	44.7
SAO (sao)	5.0	37.0	14.8	8.7	58.8

Source: Survey, 2002.

Table 7.5 Correlation matrix for variables in production frontier model of the SSAS

	lnY	lnLAB	lnFL	lnPRE	lnDIS	lnFD	lnDEN	RES	lnDST
lnY	1.00								
lnLAB	0.44	1.00							
lnFL	0.41	0.24	1.00						
lnPRE	0.12	0.45	0.27	1.00					
lnDIS	0.14	0.02	0.04	0.07	1.00				
lnFD	0.74	0.48	0.43	0.20	0.19	1.00			
lnDEN	0.17	-0.06	0.11	-0.03	-0.01	-0.02	1.00		
RES	-0.14	0.08	0.03	0.14	-0.02	-0.23	0.12	1.00	
lnDST	0.14	-0.04	-0.03	-0.04	-0.01	0.05	0.14	0.11	1.00

Source: Survey, 2002.

Table 7.6 Correlation matrix for variables in production frontier model of the ISAS

	lnY	lnLAB	lnFL	lnPRE	lnDIS	lnFD	lnDEN	RES	lnDST
lnY	1.00								
lnLAB	0.37	1.00							
lnFL	0.48	0.43	1.00						
lnPRE	0.11	0.41	0.42	1.00					
lnDIS	0.22	0.15	0.32	0.37	1.00				
lnFD	0.81	0.42	0.53	0.04	0.27	1.00			
lnDEN	0.15	0.26	0.24	0.02	0.35	0.19	1.00		
RES	0.14	0.33	0.08	0.16	0.22	0.03	-0.01	1.00	
lnDST	0.31	-0.01	-0.05	0.09	0.31	0.13	0.02	0.17	1.00

Source: Survey, 2002.

Table 7.7 Correlation matrix for variables in TI model of the SSAS

	TI	EXP	EDU	SAO
TI	1.00			
EXP	-0.28	1.00		
EDU	-0.16	-0.12	1.00	
SAO	0.15	0.23	-0.015	1.00

Source: Survey, 2002.

Table 7.8 Correlation matrix for variables in TI model of the ISAS

	TI	EXP	EDU	SAO
TI	1.00			
EXP	-0.08	1.00		
EDU	-0.03	0.11	1.00	
SAO	-0.30	0.20	0.05	1.00

Source: Survey, 2002.

7.4 The estimated production frontiers and technical inefficiencies

The results of production frontiers and TI of the two shrimp aquacultural systems are presented in Tables 7.9 and 7.10.

With production frontier, the significant variables (at 0.01level) explaining the variation of the semi-intensive shrimp yield are all factors included in the model except labor, pond preparation cost and reservoirs. That means fuel, disease prevention, feed, density, and distance are the significant variables explaining the variation of semi-intensive shrimp yield.

The production elasticity of the semi-intensive shrimp yield with respect to feed is highest with 0.576; followed by that of density with 0.257, that of disease prevention with 0.039, that of distance with 0.036 and that of fuel with 0.111. All these variables have the same signs as expected and they are all statistically significant at 0.01 level, except distance variable at 0.05 level.

Table 7.9 The production frontier and technical inefficiency of the SSAS

Variables	Coefficients	Standard error	t-ratio
I. Production frontier			
Constant	-1.395	0.469	-2.976***
lnLAB	0.047	0.071	0.663
lnFL	0.111	0.038	2.923***
lnPRE	0.036	0.059	0.600
lnDIS	0.039	0.009	4.333***
lnFD	0.576	0.067	8.646***
lnDEN	0.257	0.054	4.738***
RES	-0.007	0.070	-0.105
lnDST	0.036	0.015	2.411**
II. Technical inefficiency			
Constant	0.688	0.307	2.243**
EXP	-0.062	0.029	-2.117**
EDU	-0.065	0.025	-2.624**
SAO	0.015	0.010	1.451
Sigma-squared 1	0.201	0.051	3.819***
Gamma 1	0.9999	0.000	35,103.581***

Source: Estimated by FRONTIER 4.1.

*Note: *, ** and *** show the significance of the variables at 0.1, 0.05 and 0.01 levels, respectively.*

For the ISAS (Table 7.10), there are only two variables, which are significant in explaining the variation of shrimp yield, pond preparation cost and feed in kg. Of the two, the production elasticity of the intensive shrimp yield with respect to feed has higher magnitude with 0.914; followed by that of pond preparation cost with 0.176. These two variables are also statistically significant at 0.01 level.

Table 7.10 The production frontier and technical inefficiency of the ISAS

Variables	Coefficients	Standard error	t-ratio
1. Production frontier			
Constant	-1.369	0.984	-1.391
lnLAB	-0.044	0.255	-0.174
lnFL	0.159	0.110	1.450
lnPRE	0.176	0.037	4.796***
lnDIS	-0.052	0.033	-1.554
lnFD	0.914	0.145	6.284***
lnDEN	0.007	0.016	0.442
RES	0.011	0.131	0.088
lnDST	0.028	0.026	1.077
2. Technical inefficiency			
Constant	0.626	0.188	3.325***
EXP	0.020	0.026	0.785
EDU	0.008	0.078	0.103
SAO	-0.073	0.033	-2.249**
Sigma-squared 2	0.171	0.057	2.990**
Gamma 2	0.9999	0.000	257,494.970***

Source: Estimated by FRONTIER 4.1.

*Note: *, ** and *** show the significance of the variables at 0.1, 0.05 and 0.01 level, respectively.*

Density is one of the criteria used to distinguish the SSAS and ISAS. In the model of the ISAS, this variable has the correct sign as hypothesized. However, this variable is not statistically significant in explaining the variation of the intensive shrimp yield. On the contrary, this coefficient of the SSAS is significant and has the same sign as expected. In the ISAS, the stocking density is higher than in the SSAS. However, observation from the survey that the mortality in the ISAS may also be higher than in the SSAS, leads to the insignificance of the stocking density variable in the production frontier model of the ISAS.

Reservoir is another criterion used to distinguish between the two shrimp systems and it is also expected to play an important role in the shrimp production of both systems, especially for ISAS since this is a good proxy of water quality. It turns out that this variable neither plays an important role in the SSAS nor in the ISAS since they are both insignificant in the two production frontier models. It has been observed from the survey that the reservoirs in Phu Vang are too small in terms of water capacity requirements to supply for aquacultural ponds. In addition, some reservoirs are common properties (Chapter 5), hence the responsibility of every farm in protecting and treating water may not be very high. These might be the reasons that help explain why the reservoirs do not play an important role in either shrimp aquacultural system.

Another proxy of water quality is the distance. In the ISAS, this variable is insignificant. It makes no sense to explain the variation of shrimp yield with this variable. However, distance is significant in the SSAS with the positive sign at 0.01 level. In other words, the farther semi-intensive shrimp cultural ponds are from the lagoon the higher shrimp yield gained. As analyzed above, the reservoir variable is insignificant in both systems. In addition, a higher percentage (40%) of the intensive shrimp farms have reservoirs in comparision with semi-intensive farms (10%). In other words, 60% of the intensive shrimp farms and 90% of the semi-intensive shrimp farms exchange water directly from the main channels. This reason might make the DST variable insignificant in the ISAS but significant in the SSAS.

With respect to the technical inefficiency (TI) models, the estimated coefficients for experience and education of farmers are negative and statistically significant at 0.05 level for the SSAS, indicating that experienced and educated farmers are more technically efficient in shrimp production than the farmers who have just started to raise shrimp and have a lower education. On the other hand, in the ISAS, these coefficients have opposite signs as hypothesized but they are insignificant, making no sense in explaining the variation of the intensive shrimp TI. Nonetheless, the insignificance of these two variables in the ISAS can be explained as follows.

In terms of experience, this is true with the real situation in the research site where the ISAS has been developing for only two years. Some farmers accustomed to the SSAS have now turned to the ISAS. Some farmers who had never aquacultured have now began with the ISAS. Every thing would seem new to them. Before farms can become successful, farmers need time to become familiar with the new ISAS.

Regarding education, it is expected to play an important role in applying new techniques in shrimp aquaculture, especially in ISAS. However, in reality, it has been found that shrimp aquaculture is considered as one of the riskiest productions. "The higher the risk, the higher the profit". It might be possible that the higher educated aquaculturists are more cautious than the lower educated ones. This characteristic of the higher educated aquaculturists might not be appropriate in some cases of shrimp aquaculture, since shrimp aquaculture sometimes requires aquaculturists to decide what is needed for the shrimp and then invest at once. This can help explain why education has no effect on the variation of TI of the two shrimp aquacultural systems.

The coefficient of area is negative and significant for farms within the ISAS at 0.05 level, which indicates that farms with a larger area tend to be more technically efficient. However, this coefficient of the SSAS is insignificant. As mentioned in Chapter 6, total area of each farm can be divided into cultural ponds. In reality, the intensive shrimp cultural ponds are more uniform than those of the SSAS since cultural ponds with an average size of 10 sao (5,000 m^2) were built and then sold to the farmers; these ponds were mainly bought by the intensive shrimp aquacultural farmers. On the other hand, the semi-intensive shrimp ponds were mainly built by farmers. As a result, some ponds are very small (3 sao = 1,500 $m^{2)}$ and some are very large (15 sao = 7,500 m^2). The uniform pond size of 5,000 m^2 may be appropriate to manage and apply the resources, leading to the positive relation between TE and the pond area of the ISAS. On the contrary, either the very small or very large pond sizes of the SSAS are not appropriate for management.

Consider Gamma 1 and Gamma 2 in Tables 7.9 and 7.10. These parameters associated with the variance of the TI effects in the stochastic frontiers. They are statistically significant at 0.01 level implying the production frontiers of the SSAS and ISAS do exist. Then, technical efficiencies of these two systems are measured and presented in Table 7.11.

The TEs of farms within SSAS ranged from 0.2665 to 0.9998, with the mean TE estimated to be 0.6967. For the farms in the ISAS, the TEs ranged from 0.2495 to 0.9999, with the mean TE estimated to be 0.7948 (Appendices 7.1 and 7.2). These estimates indicate that, on average, the farms within the ISAS have higher TE than the farms within the SSAS, relative to their respective frontiers associated with the different technologies.

Table 7.11 Technical efficiency of shrimp farms in the two systems in Phu Vang

Technical efficiency		Semi-intensive		Intensive	
		Farm	*%*	*Farm*	*%*
Very low	0.0000 – 0.2000	0	0.0	0	0.0
Low	0.2001 – 0.4000	6	8.8	3	6.0
Medium	0.4001 – 0.6000	17	25.0	5	10.0
High	0.6001 – 0.8000	19	28.0	12	24.0
Very high	0.8001 – 1.0000	26	38.2	30	60.0
Total		68	100.0	50	100.0
Average (%)		69.67		79.48	
Min (%)		22.65		24.95	
Max (%)		99.98		99.99	

Source: Estimated by FRONTIER 4.1

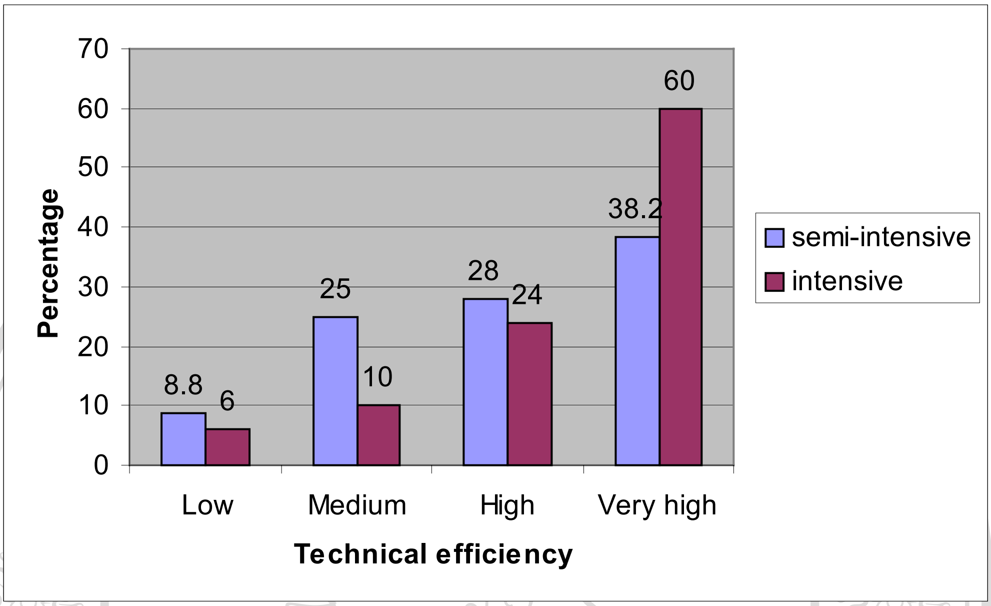

Figure 7.1 Technical efficiency of the two shrimp aquacultural systems

The frequency distribution of the predicted TEs within a range of 0.2 is given in Figure 7.1 for the two systems. It is clear that the distribution of the group of very high TE (0.8001 to 1.0000) for the farms within the ISAS (60%) is much higher than that of the SSAS (38.2%). Moreover, there is a larger gap between the groups of high and medium TE in the ISAS (24% and 10%) than in the SSAS (28% and 25%). It can be concluded that the variation in TE within ISAS farms was greater than in the SSAS farms.

7.5 Resource utilization and allocation analysis

Profit maximization could be the objective of every shrimp farm. There are two conditions to achieve this objective: (1) The value of the marginal product of every input is exactly equal to its input price. At this point, the farm is also at the point of allocative efficiency (pricing efficiency); and (2) The farm must be technically efficient. The second condition was analyzed in the first section of this chapter. To fully utilize the estimated production frontier, this section is devoted to analyzing the allocative efficiency (AE), the first condition of achieving the profit maximization of the farm.

All the resources used in shrimp production will be considered, e.g. fuel, feed, seed, labor, disease prevention costs (materials for disease prevention) and pond preparation costs (materials for pond preparation).

The descriptive statistics of resource utilization are presented in Tables 7.1 and 7.2. Using the Formulae (4.20) and (4.21) in Chapter 4, the MPs, MVPs are calculated and presented in the Appendices 7.3, 7.4, and 7.5.

To calculate the allocative efficiency, the prices of both inputs and output must be considered (Tables 7.12 and 7.13).

On the topic of output price, shrimp price of the SSAS is higher than that of the ISAS (84.014 thousand VND/kg and 80.566 thousand VND/kg, respectively). By principle and in reality, shrimp density, chemical fertilizers and chemical inputs used in the SSAS are lower in quantity than those in the ISAS. Accordingly, shrimps harvested in the SSAS are larger in size than shrimps in the ISAS. In addition, as analyzed in Chapter 6, shrimp diseases in the ISAS were more severe than in the SSAS. Consequently, shrimp price in the SSAS is higher than in the ISAS. Additionally, if the minimum and maximum shrimp prices of the two systems are observed, the minimum price of the ISAS (31.250 thousand VND/kg) is smaller than that of the SSAS (50.000 thousand VND/kg); in contrast, the maximum price of the SSAS (107.955 thousand VND/kg) is higher than that of the ISAS (105.652 thousand VND/kg).

Among the four main inputs, there are two inputs having fixed prices, fuel and labor. The remaining two inputs, feed and seeds, have variable prices. Owing to well-organized input services in the district, the price of fuel was, hence, uniform at a level of 4.2 thousand VND per litre. Input suppliers cannot sell at a higher price than the others, since the input market is considerably competitive.

Table 7.12 Statistics for main inputs prices and output price for the SSAS

Indicators	Fuel (VND1,000/litter)	Feed (VND1,000/kg)	Seed (VND1,000/PL)	Labor (VND1,000/man-day)	Output (VND1,000/kg)
Mean	4.200	13.559	0.053	27.500	84.014
Std. Dev.	0.000	1.703	0.038	0.000	10.463
Min.	4.200	10.388	0.020	27.500	50.000
Max.	4.200	18.327	0.140	27.500	107.955

Source: Survey 2002.

Note: 68 observations.

Table 7.13 Statistics for main inputs prices and output price for the ISAS

Indicators	Fuel (VND1,000/litter)	Feed (VND1,000/kg)	Seed (VND1,000/PL)	Labor (VND1,000/man-day)	Output (VND1,000/kg)
Mean	4.200	14.527	0.034	27.500	80.566
Std. Dev.	0.000	1.126	0.013	0.000	16.401
Min.	4.200	11.364	0.021	27.500	31.250
Max.	4.200	16.875	0.120	27.500	105.652

Source: Survey 2002.

Note: 50 observations.

Regarding labor wages, two wage levels are generally paid in the district, 25 thousand VND/man-day and 30 thousand VND/man-day. The difference between the two wage levels is based on the level of work related to shrimp activities. At the moment of the study, the average wage level of these two, 27.5 thousand VND/man-day, was chosen.

The feed types used among the farms are not uniform, either. There are many shrimp feed types in the market and farmers are free to select the one they prefer. However, in reality, besides feeding shrimp with processed feed, farmers also feed them with fresh feed, such as egg yolks, fish, meat and so on. The price of this fresh feed varies freely. Apart from this, the quantity of this fresh feed is beyond farmers' determination, too. In this research, the method applied to calculate the average shrimp feed price is: first total feed expenditure, then total processed feed quantity and its total expenditure, finally the expenditures on fresh feed are surveyed. When the total processed feed quantity and its expenditure are known, the average price of processed feed is derived. The average price of processed feed is considered as the average price of shrimp feed. The average shrimp feed price of the ISAS (14.527 thousand VND/kg) was higher than that of the SSAS (13.559 thousand VND/kg).

Average seed prices of the two systems are also different with 0.053 thousand VND/post larva in the SSAS and 0.034 thousand VND/post larva in the ISAS. In Phu Vang district in particular and in Thua Thien Hue in general, seed supply has been not enough for the seed demand of the farms. That is why farmers have to go to the adjacent provinces to buy. Accordingly, the prices of shrimp seed are not uniform.

Regarding disease prevention and pond preparation, since materials used for these two activities are not uniform, they both are measured by VND currency, thus the prices of inputs used for them are considered to be uniform and equal to 1.

Let $\frac{MVP_{X_i}}{P_{X_i}} = r_{X_i}$, the ratio between marginal value product of input X_i and the price of that input. These r ratios of the two shrimp aquacultural systems are presented in the following tables, Tables 7.14 and 7.15.

Finally, it is essential to test whether or not r_{X_i} is equal to 1. In other words, one would like to know whether input X_i was used in an allocatively efficient way by the farmers or not. The testing results are presented in Appendix 7.6.

Table 7.14 Statistics of r_{X_i} 's of the SSAS

r_{X_i}	Minimum	Maximum	**Mean**	Std. Dev.
Labor	0.267	0.576	**0.448**	0.056
Fuel	2.533	5.469	**4.257**	0.530
Pond preparation	0.568	1.226	**0.954**	0.119
Disease prevention	1.535	3.314	**2.579**	0.321
Feed	0.853	2.507	**1.574**	0.319
Seed	1.806	14.485	**6.813**	3.003

Source: Survey, 2002.

Table 7.15 Statistics of r_{X_i} 's of the ISAS

r_{X_i}	Minimum	Maximum	**Mean**	Std. Dev.
Labor	-0.581	-0.172	**-0.443**	0.090
Fuel	1.721	5.817	**4.436**	0.903
Pond preparation	1.027	3.471	**2.647**	0.539
Disease prevention	-3.061	-0.906	**-2.335**	0.475
Feed	0.992	4.101	**2.833**	0.621
Seed	0.037	0.180	**0.124**	0.031

Source: Survey, 2002.

It has been found from the analysis that, in the SSAS, no resource was allocated efficiently. As shown in Table 7.14, *r* ratios of fuel, disease prevention, feed, and seed are 4.257; 2.579; 1.574; and 6.813, in that order. These show that on the average, farmers under-used these resources and these also imply that an increase of 1VND for fuel expense, 1VND for disease prevention expense, 1VND for feed expense, and 1VND for seed expense would lead to an increase of VND4.257, VND2.579, VND1.574 and VND6.813, respectively. In contrast, *r* ratios of labor and pond preparation are 0.448 and 0.954, correspondingly, indicating that they were over-used. Hence, farmers should reduce labor used and materials and services for pond preparation.

Regarding the ISAS, for the present technology, farmers under-used fuel, pond preparation, and feed. An increase of 1VND for fuel expense, 1VND for feed expense, and 1VND for pond preparation expense would lead to an increase of VND4.436, VND2.647, and VND2.833, correspondingly. For this reason, aquaculturists should increase the level of those resources up to the optimal point. In contrast, labor, disease prevention and seed were used more than the optimal rates. Accordingly, it is suggested that aquaculturists can raise profit and achieve allocative efficiency by reducing labor, materials for disease prevention, and seed.

In short, among the inputs used in the two shrimp aquacultural systems, e.g. fuel, feed, seed, labor, disease prevention and pond preparation, no input was allocated efficiently. They were either over- or under-used. To explain the under utilization, the reasons can be: (1) In shrimp aquaculture, aquaculturists know that risk to shrimp is higher as compared to other products (diseases, floods, storms, etc.). Consequently, farmers do not dare to invest much. Or (2) Farmers consider input prices relatively high, so they could not afford sufficient quantities. As a result, that input is not used to the optimal point. In terms of input over-utilization, the reasons could be: (1) Farmers do not understand clearly the aquacultural techniques, characteristics of each development stage of shrimp, characteristics of inputs and so forth. Thus, they invest more than the optimal level. (2) Farmers are optimistic and they could think that "to invest more is to gain more". Accordingly, inputs can be used over the optimal level.