PROFITABILITY AND TECHNICAL EFFICIENCY OF BLACK TIGER SHRIMP (*PENAEUS MONODON)* CULTURE AND WHITE LEG SHRIMP (*PENAEUS VANNAMEI*) CULTURE IN SONG CAU DISTRICT, PHU YEN PROVINCE, VIETNAM

NGUYEN THI HOAI AN

Master Thesis in Fisheries and Aquaculture Management and Economics FSK-3911
(30 ECTS)

The Norwegian College of Fishery Science
University of Tromso, Norway
&
Nha Trang University, Vietnam

May 2012

Acknowledgements

I would like to express sincere gratitude to my supervisor Prof. Terje Vassdal and Dr.Long for their full support and supervision both during the preparation of the proposal and the write up of the thesis.

I would like to thank all the Professors and Coordinators that have contributed to making these two years here at Nha Trang Unviversity very memorable and educational.

My sincere gratitude goes to the NOMA- FAME for funding the two years I have spent in Nha Trang University.

I would also like to thank Nguyen Thai Toan, Nguyen Hai Anh, Do Viet Chuong, Huynh Dinh Vu, Nguyen Van Sau for their support in secondary data and primary data collecting.

I dearly thank my family for their love and moral support.

Special gratitude goes to my friend for their sharing valuable research techniques.

Nguyen Thi Hoai An

2012

CONTENT

LIST OF TABLES

LIST OF FIGURES

ABSTRACT

The research measure the profitability and technical efficiency of Black tiger shrimp farms and White leg shrimp farms in Song Cau district, Phu Yen province, Vietnam. Cross-sectional data of 62 Black tiger shrimp samples and 88 White leg shrimp samples were used for comparison two production systems. The profitability analysis shows that White leg shrimp farms achieved an average profit per hectare of 78,883,209 VND ($3,944.16), which was approximately 4 times as much as Black tiger shrimp farms. A nonparametric data envelopment analysis (DEA) approach reveals that the estimated mean technical efficiency of the Black tiger shrimp system under assumption of constant returns to scale, variable returns to scale and scale efficiency were measured to be 0.82, 0.95 and 0.87, respectively. In White leg shrimp system, the farms achieved a mean efficiency level of 0.88, 0.94 and 0.95 under condition of constant returns to scale, variable returns to scale and scale efficiency, respectively. The findings also show that there was positive correlated between profit and technical efficiency.

Key words*: Black tiger shrimp farms, White leg shrimp farms, profitability, data envelopment analysis, technical efficiency.*

1. Introduction

1.1. Problem statement

Vietnam has a 3,260km coastline, 12 lagoons, straits and bays, 112 estuaries, canals and thousands of small and big islands scattering along the coast. These conditions combining with climate, water source, and hydrological cycle have made great potential to develop aquaculture and make Vietnam become one of the biggest fishery suppliers of the world. In various species cultured in Vietnam, shrimp is the main species because of its high economic value. Therefore, shrimp cultivation is a main sector of the Vietnamese economy, which plays an important role in poverty reduction, livelihood enhancement for many people.

Phu Yen is a coastal province in the South Central Coast of Vietnam with 868,500 residents (General Statistic Department of Phu Yen province, 2010). The total labor worked for aquaculture was 21,865 people, in which labor in brackish water shrimp, lobster cage, lobster nursery and seed production were 43%, 29% and 23%, respectively (Agricultural and Rural Development Department of Phu Yen province, 2005). Phu Yen has advantages in development of coastal aquaculture due to brackish tidal areas, estuaries, and rich nutrient creeks. The aquaculture area annually increased 1.84% from 2000 to 2002. The cultured species also were diversified, which is from intensive Black tiger shrimp (*Penaeus Monodon*) to new species such as White leg shrimp, Areola Babylon (*Babylonia Areolata*), sea weed, oyster, grouper, etc. However, in recent years, brackish cultured area has been declining because the disease of Black tiger shrimp occurs but no remedies have been found. This is the reason why many farmers shift from Black tiger shrimp culture to White leg shrimp (*Penaeus vannamei*) culture. According to statistic of Agricultural and Rural development Department of Phu Yen province, from 2004 - 2010, there was a significant decrease of 5 times in the cultured area of Black tiger shrimp (from 2,390 ha to 464 ha), while the cultured area for White leg shrimp increased 8 times (from 198 ha to 1,645 ha). Similarly, the yield of Black tiger shrimp reduced sharply, where as yield of White leg shrimp grew remarkably (615 tons in 2004 to 6,726 tons in 2010).

Song Cau is one of four coastal districts of Phu Yen province with total population of 99,609 people (27,442 households) in 2011. The number of households operating on aquaculture was 3,852 households, in which cage culture and pond culture were 2,312 and 1,540 households, respectively (General Statistic Department of Song Cau district, 2011). Song Cau has strong aquaculture development with average growth rate of 16% per year from 2000 – 2005. It possesses 80 km coastline, including 13,000 ha surface area of Xuan Dai bay and 2,650 ha of Cu Mong lagoon, which is the habitat of high economic value species. The human resource and favorable natural condition are a great advantage to make aquaculture becoming the main economic sector of this district (Truong, 2005). Like the trend of total province, farmers in this district mostly changed their cultivation activity from Black tiger shrimp into White leg shrimp. The main motivation of this movement is that the posterior species has brought more profit than former species.

Farmers, who directly invest their finance and labor to shrimp farming, always try to expand profit of their farms as soon as possible. They neither know how to effectively use input for producing nor understand actual profitability of their operation. Unlike farmers, scientists would like to focus on researching technical efficiency without caring profitability. Researchers only want to employ the optimal resources for sustainable development. Therefore, it is necessary to explore the profitability and technical efficiency to meet the need of farmers and scientists.

In recent years, a few studies have been hold to analyze the level and determinants of farm level technical efficiency in aquaculture sector in some regions in Vietnam as Hanh (2009), Au (2009), Quang (2010), Tung (2010). However, in my knowledge, no study has been conducted to measure profitability and technical efficiency of Black tiger shrimp and White leg shrimp in Song Cau district, Phu Yen province. Hence, studying on profitability and technical efficiency will be useful for farmers as well as researchers in Song Cau district and nearby about utilizing their resources.

Figure 1.1: Map of Vietnam

Figure 1.2: Map of Phu Yen province, Vietnam

[Source: http://khudothimoi.com/tintuc/van-ban-chinh-sach/947-thanh-lap-thi-xa-song-cau-tinh-phu-yen.html]

1.2. Objectives of the thesis

The overall objectives of the study are to analyze the profitability and technical efficiency of two aquaculture groups: Black tiger shrimp and White leg shrimp. In particularly, the thesis tries:

- To know the current status of Black tiger shrimp and White leg shrimp farms in Song Cau district, Phu Yen province, Vietnam

- To estimate and compare the profit of Black tiger shrimp cultivation and White leg shrimp cultivation of interviewed farms
- To measure the technical efficiency at farm level in study site
- To ascertain the relationship between profitability and technical efficiency

1.3. Hypotheses

- Hypothesis 1: Profit of Black tiger shrimp farms is equal to White leg shrimp farms.
- Hypothesis 2: Profitability and technical efficiency is positively correlated

1.4. Structure of thesis

The remaining study is organized into five chapters. Chapter 2 gives information of aquaculture in Phu Yen province and Song Cau district. Chapter 3 is devoted to discussing the norms of profitability, definition of technical efficiency and its measurement after summarizing some empirical researches relating to these issues in aquaculture. Chapter 4 characterizes methodology using in this thesis. Chapter 5 expresses the result from surveyed data. Chapter 6 winds up this study with discussion and conclusion. References and appendices are given at the end.

2. Overview of aquaculture in Phu Yen Province

Phu Yen has a quite complex geography with alternative mountains and plains. It lies between latitudes 12°42'36" to 13°41'28" North and longitudes 108°40'40" to 109°27'47" East. Tropical monsoon, hot, humid climate influenced by the oceanic climate make Phu Yen province has two distinct seasons: dry season from January to August and rainy season from September to December. The annual average temperature is 26.5^{o}C, and the annual average rainfall is about 1,600 – 1,700mm.

2.1. Aquaculture in Phu Yen province

Phu Yen province has advantages in aquaculture development thanks to its natural conditions. The fresh water cultured area was not considered to develop much, just 197 ha in 2005, equally 3.3% compared to its potential. Meantime, brackish water cultured area rapidly grew at 2% per year from 2000 – 2005 and concentrated on intensive cultured areas such as Cu Mong, Xuan Dai, O Loan, Ban Thach river downstream, etc. Cage aquaculture on the lagoons, bays, and coastal areas has continuously developed and brought high economic efficiency. There were 6,970 cultured cages for lobster and grouper in 1999. This figure expanded nearly 3 times in 2005 and developed with many new cultured species such as: Cobia, lobster combined blue mussels, Red snapper, which gathere in Cu Mong lagoon, Xuan Dai bay, Vung Ro bay. Fresh water cage culture began to flourish in 2001 with 320 cages of eel. The technology adoption process, site selection and food selection were not good because this culture was new. Therefore, the disease spread occurred and the economic efficiency was not high. In 2005, the number of estimated cage was 30 cages and was mostly located in the reservoirs, hydropower for eel, snakehead, and mud-cat. Generally, freshwater cage aquaculture initially brought high economic efficiency (Report of Agricultural and Rural development Department of Phu Yen province 2005).

Table 2.1: The aquaculture area in pond and cage from 2000 – 2010 in Phu Yen province:

Year	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Cultured area in pond(ha)	2664.8	3071.7	2668	2683	3005	2309	2590	2325	2352	2756	2694
Brackish, marine	2525.6	2909.2	2527	2487	2808	2090	2361	2042	2071	2467	2409
Fish			18	14		5	7	26	47	83	30
Shrimp	2513	2896.6	2507	2469	2588	1761	2025	1747	1738	2062	2109
+ Black tiger shrimp	2513	2896.6	2507	2469	2390	1605	1638	1410	1100	466	464
+ White leg shrimp					198	156	387	337	638	1596	1645
Others	12.6	12.6	2	4	220	324	329	269	286	322	270
Fresh water	139.2	162.5	141	196	197	219	229	283	281	289	285
Fish	139.2	162.5	139	195	197	219	229	283	276	288	285
Shrimp			2	1							
Others									5	1	
Cage culture (number of cage)	7,635	10,156	10,587	15,050	18,338	17,962	19,728	20,623			19,973
Fish	75	229	470	380	385	450	280	634			1,506
Shrimp	7,560	9,927	10,117	14,670	17,920	17,500	19,434	19,975	19,414	30,180	18,467
Others					33	12	14	14			

[Source: Agricultural and Rural Development Department of Phu Yen province, 2010]

In 2001, much Black tiger shrimp farming regions in Phu Yen province were affected by shrimp disease, which caused considerable losses to farmers. To have earning for daily expense and debt covering, many people left their farms and went to another place for living. Then in 2004, some households reinvested their pond for newly founded species White leg shrimp *(Luu, 2009).* In the period 2004 - 2010, there was significant decrease in the Black tiger shrimp aquaculture part, almost 5 times (from 2,390 ha to 464 ha), while the area for White leg shrimp culture increased 8 times (from 198 ha to 1,645 ha). Similarly, the yield of Black tiger shrimp sharply reduced, where as yield of White leg shrimp grew remarkably. The motivation of this movement is that the later species has many gains such as less disease, lower feed conservation ratio, higher density culture, higher productivity, etc. Therefore, White leg shrimp was rapidly cultured in a lot of places that led to quickly enlarge in the yield (615 tons in 2004 to 6,726 tons in 2010).

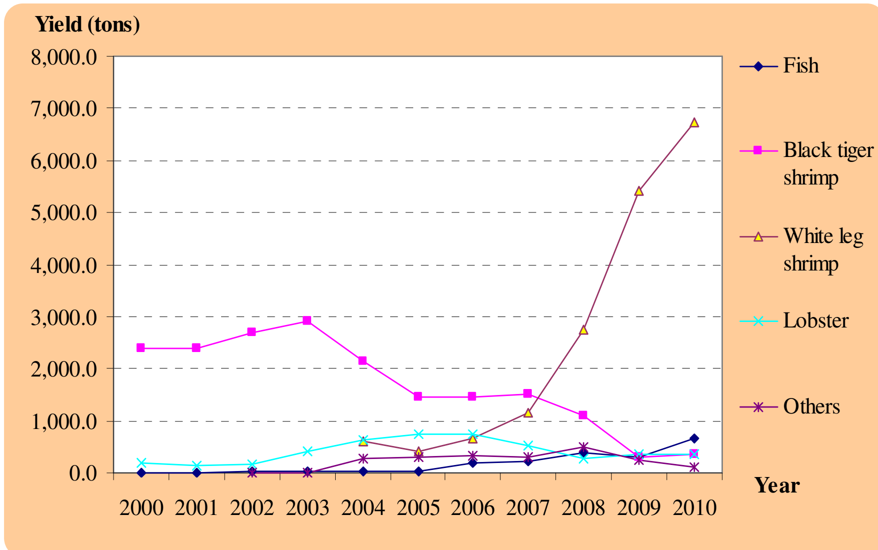

Figure 2.1: Yield of brackish and marine water in pond from 2000 – 2010 in Phu Yen province

[Source: Statistic of Economic Department of Song Cau district]

In 2000, total aquaculture yield of Phu Yen province was estimated about 2,628 tons, in which fresh water yield was 111 tons, brackish and marine water yield were 2,517 tons. In 2005, total aquaculture yield reached approximately 3,856 tons, increased 46.7% compared to the year of 2000, in which fresh water yield got 200 tons, brackish and marine water gained 3,656 tons. However, yield of Black tiger shrimp nearly obtained 2,000 tons in 2005, dropped 16.8% compared to the year of 2000. The reason of this reducing is that farmers shifted to another species like seaweed, grouper, oyster, etc.

2.2. Aquaculture in Song Cau district

Song Cau district is located in the North of Phu Yen province. It has the longest length of coastal line about 80 km. Aquaculture in Song Cau appeared in the 90s of the last century with a major farming is Black tiger shrimp one. Xuan Hai and Xuan Loc communes are two focal areas of district in total 12 aquaculture areas. Aquaculture has contributed to employment solving and income improvement for many people living in the coastal zone as well as mainland in this district. Nowadays, with the new technology, aquaculture in this district has diversified with varietals species such as: lobster, grouper, Black tiger shrimp, White leg shrimp, red snapper, sea slug, sea weed, crab, etc.

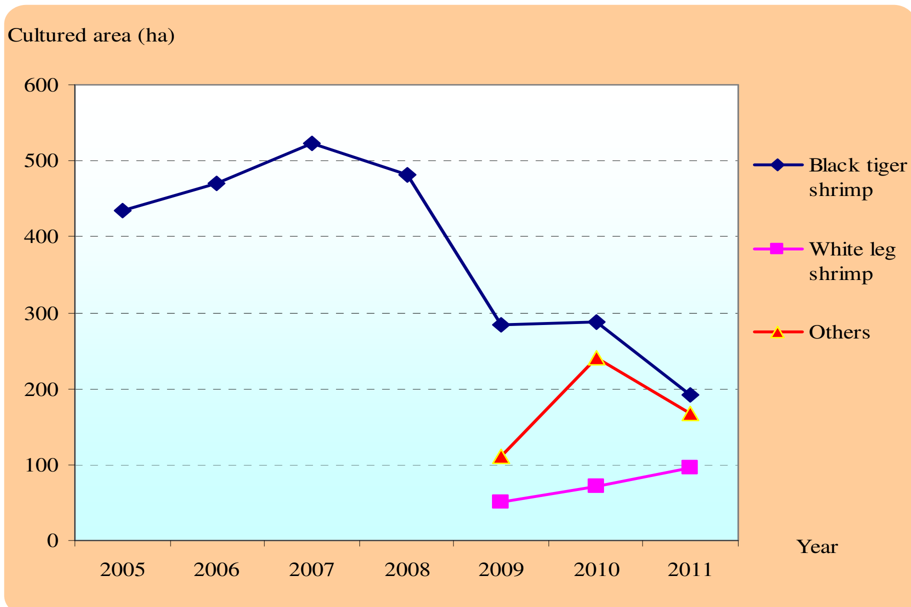

Figure 2.2: Aquaculture area in pond in Song Cau district from 2005 – 2011

[Source: Statistic of Economic Department of Song Cau district]

The aquaculture area in pond reached 550.3 ha in 2011. Black tiger shrimp was cultured in one crop per year with 191.7 ha, equally 68% compared to the year of 2010. White leg shrimp was put into production twice a year with total area of 190.6 ha, nearly 2.68 times compared to the year of 2010. The rest area (used for cultured various species: grouper, sea bass, crab, Areola Babylon, gracilaria, etc.) was 168.1 ha, got 75.3% in the year of 2010. Besides, Song Cau district has also developed in marine cage culture. The total number of cage and float in 2011 were 27,015 and 722, respectively. Lobster and grouper are the most species that the number of cage increased quickly with 25,500 cages for nursery and commercial lobster and 1,515 cages for grouper.

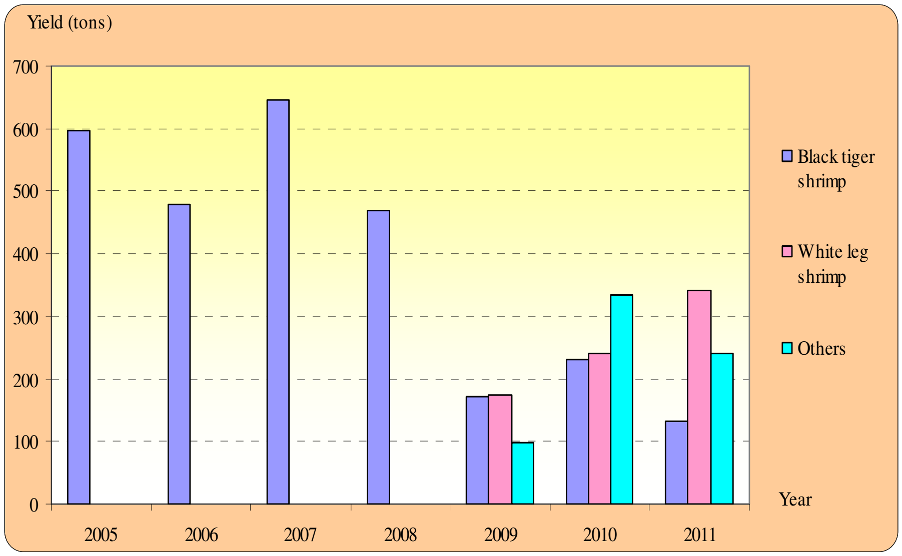

Figure 2.3: Aquaculture yield in pond in Song Cau district from 2005 - 2011

[Source: Statistic of Economic Department of Song Cau district]

The yield of Black tiger shrimp in 2011 also decreased with the reduction in cultured area. It just reached 132 tons, almost 57.6% in the year of 2010. The average productivity was 0.69 tons/ha, reduced 0.11 tons/ha compared to the year of 2010. Although the yield of White leg shrimp increased 1.41% compared to the year of 2010, average productivity was still low at 3.57 tons/ha/crop and decreased 0.13%. The yield of other species also dropped in 2011. In addition, the yield of lobster, grouper, Areola Babylon was 450 tons, 97 tons, and 48 tons, respectively.

Generally, in the favorable weather, Song Cau has a great potential to develop aquaculture. Furthermore, rich human source and management, monitoring of local officers are the main factors that have been contributed to help aquaculture more and more grow. Therefore, aquaculture has been regarded as a key sector for social-economic development of this district.

3. Theory

3.1. Some financial norms

3.1.1. Revenue

Revenue is defined as the total money that farmers received from selling their shrimp. It equals volume of final marketable product times average farm level price. Farmers operated two crops for White leg shrimp (3 months/crop) in one year. However, producers just cultured one crop (4 – 5 months) for Black tiger shrimp and used the rest time in year for culture of crab, blue crab and rabbit-fish. To keep the analysis simply, the study calculated the revenue from Black tiger shrimp farms and White leg shrimp farms in the first crop of year 2011.

3.1.2. Cost of production

In general, the cost of producing shrimp is the sum of the payments made to acquire resources. Costs are derived by applying input prices to the factors of production. Total cost (TC) is the amount of money that must be expended to obtain various levels of production. Total cost is divided into two groups, fixed cost (FC) and variable cost (VC) (Jolly and Clonts 1993).

3.1.2.1. Fixed cost

Fixed costs (FC) are those that must be paid regardless of whether the farmer engages in production. These costs include pond lease, pond treatment, repair and maintenance, depreciation of machineries, equipments, and guard houses, non-depreciation assets (balance, bucket, basket, and net). Cost for land is not included in fixed costs because majority of farmers own their land. The depreciation was calculated by a linear depreciation plan for machineries, equipments, and guard houses.

3.1.2.2. Variable costs

Variable costs (VC) include payments for items used in production. These costs include payments for item such as preparation pond, seed, feed, fuel, electricity, drug and chemical for disease treatment, test kit for water monitoring, labor cost, harvesting cost, and telephone.

3.1.3. Profitability

All surveyed farms operated shrimp culture by their own finance source. Therefore, the cost of financing was not mentioned here. The profit of the farm is simply calculated as the revenue minus total costs. To keep the analysis simply, profitability of shrimp farming has been estimated as follow:

$$\text{Profitability} = \text{Revenue} - \text{Total costs}$$

3.1.4. Return on investment (ROI)

Return on investment is one way of considering profits in relation to capital invested. For a single-period, the Return on investment can be expressed (http://en.wikipedia.org)

$$\text{Return on investment (\%)} = \frac{\text{Net profit}}{\text{Investment}} * 100\%$$

3.1.5. Profit margin

Profit margin refers to a measure of profitability. It is computed by finding the net profit as a percentage of the revenue (http://en.wikipedia.org)

$$\text{Net profit margin (\%)} = \frac{\text{Net profit}}{\text{Revenue}} * 100\%$$

3.2. Technical efficiency

3.2.1. Concept of efficiency

Efficiency of a firm could be decomposed into two components: technical efficiency and allocative (or price) efficiency (Farrell 1957). Later Farrell and Fieldhouse (1962) added a third component, scale, as a possible source of inefficiency. The technical efficiency expressed the ability to acquire the maximum potential firm performance (output) from a given set of inputs. The allocative efficiency described the firm's ability to use the input in optimal proportions, given their respective prices and engaged technologies. Both above constituents are connected to give a total economic efficiency measure. Efficiency can be calculated in terms of input-orientation or output-orientation. In which input-orientated efficiency notices a target point maximizing the proportional reduction in inputs or produces a given level of output from a best possible combination of inputs. Meantime output-orientated efficiency looks for a projected point that maximizes the proportional augmentation in outputs or produces the optimal output from a given set of inputs. The analysis of efficiency carried out by Farrell (1957) could be clarified in terms of Figure 3.2

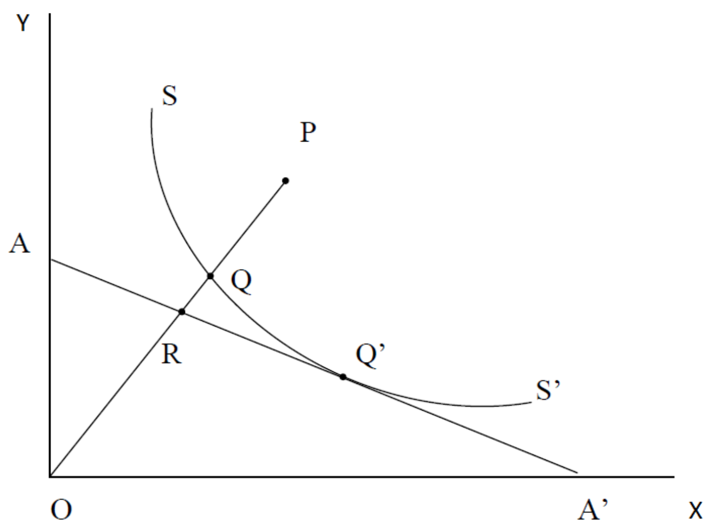

Figure 3.2: Technical and allocative efficiency measures

[Source: Farrell 1957]

Suppose a firm using two factors of production to produce a single product under conditions of constant returns to scale (CRS). The isoquant SS' characterizes the technological set that obtains the minimum combination of inputs needed to produce a unit of output. Therefore, every combination of inputs along the unit isoquant is considered as technically efficient. For this reason, Q and Q' are two technically efficient points and P is inefficient point. Consider a firm at point P, using quantities of input to produce a unit of output, the technical inefficiency of this firm could be explained by distance QP which QP is the input package that the firm at point P could save without decreasing the amount of output. The ratio QP/OQ indicates the percentage by which all inputs need to be reduced to achieve technical efficiency production. Hence, the technical efficiency (TE) of the producer under analysis (1-QP/OP) would be presented by the ratio OQ/OP.

TE = OQ/OP

If information on market prices is known, it would be possible to calculate the cost efficiency of the firm under deliberation. Assuming the prices of input x_1 and x_2 are known, we can denote the input prices for p_1 and p_2, respectively. The total cost will be: $C= p_1x_1+ p_2x_2$. Then an iso-cost line will be: $x_2=(C - p_1x_1)/p_2$. In this diagram, the line AA' represents iso-cost line, hence, R and Q' have the same total cost. However, the output at point R production is outside the technology set, this it is not reachable given the output we want to produce. Q', intersection between AA' iso-cost and SS' iso-quant (production frontier), is the combination of inputs that gives lowest total cost, and is simultaneously part of the technology set. Thus, point Q' is supposed to be technical efficient as well as allocative efficient. And the cost efficiency can be evaluated by the ratio:

CE = OR/OP

Then allocative efficiency and technical efficiency can also be designed by using the iso-cost line:

AE = OR/OQ

TE = OQ/OP

From those equations, the relationship between technical, allocative, and cost efficiency can be interpreted by:

TE*AE = (OR/OQ)*(OQ/OP) = OR/OP = CE

3.2.2. Efficiency measurements

There are four main approaches to measure and estimate efficiency. These are the nonparametric programming method (Charnes *et al.* 1978), the parametric programming reach (Aigner & Chu 1968; Ali & Chaudhry 1990), the deterministic statistical way (Afriat 1972; Richmond 1974; Schmidt 1976; Greene 1980) and the stochastic frontier production function approach (Aigner *et al.* 1976; Aigner *et al.* 1977; Meeusen & van den Broeck 1977). In which the stochastic frontier production function and non-parametric programming, recognized as data envelopment analysis (DEA), are the most famous approaches (Alam et al. 2011).

3.2.2.1. Stochastic Production Frontier (SPF)

The stochastic frontier production function was independently offered by Aigner, Lovell and Schmidt (1977) and Meeusen and van den Broeck (1977). This method estimate a production function based on the general model: y=f(x) +v-u where f(x) is a parametric production with parameters that must be estimated. The key advantage of this approach is that it takes into account stochastic variation, which is important when output is affected by random noise. The disadvantage is that the observed residuals must be separated into two components, one, v, that takes care of the "symmetric" random noise (having an expected value of zero), and u taking care of potential deviation random noise that can be interpreted as evidence of inefficiency. The problem with the approach is that both residuals must be explicitly defined. For v this is normally given as the normal distribution with zero mean and fixed standard deviation. For u, however, there are many potential candidates for distributions. Usually exponential or half-normal distributions are used. This approach also demands a particular functional form for production function such as a Cobb-Douglas, trans-log or quadratic function to evaluate the production function. It is essential to have some distributional assumptions to separate the stochastic constituent from the inefficiency factor. In addition, as production function, it is not available in multiple output situations. As a result, it will not truly describe the production set for any production situation with more than one output. Reformulated as a cost function it can handle several outputs, but this is seldom done in empirical study.

3.2.2.2. Data Envelopment Analysis (DEA)

Farrell (1957) firstly researched about the efficiency relied on the building of hypothetical firms as a weighted average of some of observed firms. Neither did he describe how the production possibility set should be estimated, nor did he describe how the efficiency index could be estimated for an individual producer. His basic idea and insight was very enlightening, and several authors tried to interpret his insights into a framework that could be used in empirical studies of companies or more generally decision making units (DMU). Since then, some valuable literatures have examined the efficiency based on his idea. Charnes et al. (1978) build up the efficient frontier as an envelopment of the data by using Linear programming methods. The consequential model is called Data Envelopment

Analysis, DEA. Unlike the SPF method, DEA can be applied in multi-output settings and no suppositions need to be made on the functional form of the model. The main shortage of DEA approach, nevertheless, is that it is deterministic, and hence does not take into account random error. Without taking into account the random error due to the deterministic nature, DEA can be applied in multi input – multi output situation. It is a non-parametric method, which use linear programming to construct an efficient frontier using the best performing farm of the sample and measure the efficiency. DEA approach scheme the frontier is calculated on the basis of the sample observations. DEA can also recognize sources and amounts of inefficiency in each input and each output for each farm, and determine the benchmark members of the efficient set.

The technique of data envelopment analysis (DEA) was first introduced by Farrell with the simple model of two inputs - single output under constant return to scale. Constructing on the ideas of Farrell (1957), Charnes, Cooper, and Rhodes (CCR) (1978) developed an approach to solving the problem identified by Farrell. The CRR models are widely employed for estimation of multiple input, multiple output production correspondences and the evaluation of the productive efficiency of decision making units (DMUs). They supplied the linear programming formulation to calculate the productive efficiency (CCR efficiency) of a DMU relative to a set of reference DMUs. Further, Banker, Charnes and Cooper (BCC) (1984) revealed that the CCR efficiency measure can be regarded as the product of technical efficiency (BCC efficiency) measure and a scale efficiency measure.

Technical efficiency could be measured in terms of the optimal package of inputs to obtain a given level of output (an input-orientation) or the optimal output produced from given a set of inputs (an output-orientation). The envelopment surface of the oriented models was defined into either constant returns-to scale (CRS) technology or variable returns-to-scale (VRS) technology. The outlines of the envelopment surface of the constructed production frontier are a conical hull and a convex hull under condition of CRS and under condition of VRS, respectively.

Consider the case of n DMUs (DMU_j : j = 1,2, …, n), which produce s outputs y_{rj} (r = 1,2,…, s) by using m different inputs, x_{ij} (i = 1,2,…, m). An input-oriented model under condition of CRS developed by Charnes, Cooper and Rhodes (CCR) (1978) and referred to in the literature as the CCR model can be presented as

$$
\begin{aligned}
& \text{Min } \theta_o \\
& \text{s.t} \sum_{j=1}^{n} \lambda_j x_{ij} \leq \theta_o x_{io}, \qquad i = 1,2, \ldots, m, \\
& \sum_{j=1}^{n} \lambda_j y_{rj} \geq y_{ro} \qquad r = 1,2, \ldots, s, \qquad\qquad (3.2) \\
& \lambda_j \geq 0, \qquad j = 1, \ldots, n,
\end{aligned}
$$

where, x_{io} and y_{ro} are respectively, the ith input and rth output for a DMUo under evaluation. The input-oriented VRS model is achieved from the CRS model by adding an additional convex constraint of $\Sigma\lambda = 1$ to the CCR model (3.2), can be expressed as

$$
\begin{aligned}
& \text{Min } \theta_o \\
& \text{s.t} \sum_{j=1}^{n} \lambda_j x_{ij} \leq \theta_o x_{io}, \qquad i = 1,2, \ldots, m, \\
& \sum_{j=1}^{n} \lambda_j y_{rj} \geq y_{ro} \qquad r = 1,2, \ldots, s, \qquad\qquad (3.3) \\
& \sum_{j=1}^{n} \lambda_j = 1, \\
& \lambda_j \geq 0, \qquad j = 1, \ldots, n,
\end{aligned}
$$

According to Banker et al., 1984 and Fare et al., 1985, the scale efficiency measures is calculated as the ratio of the measure of technical efficiency computed under the assumption of CRS to the measure of technical efficiency measured under the assumption of VRS. If SEj = 1, DMUo is considered as a scale efficient unit and this unit shows the constant returns to scale property (CRS). If SEj < 1, the production mix of DMUo is not scale efficiency.

Super-efficiency

Super-efficiency data envelopment analysis (DEA) model was originally researched by Andersen and Petersen (1993). The standard models in data envelopment analysis (DEA) measure the efficiency of an observation relative to a reference set including of all sample observations while the super-efficiency model in DEA excludes each observation from its own reference set. Therefore, in latter model it is possible to obtain efficiency scores that exceed one.

Based on Charnes et al. (1991), a set of DMUs could be separated into frontier DMUs and non-frontier DMUs where the frontier DMUs have $\theta^{*}o = 1$. To discriminate the performance of efficient DMUs, the super-efficiency DEA model was used where DMUo is not included in the reference set (Zhu 2001).

$$\begin{aligned}
\theta_0^{\sup er^*} &= \min\ \theta_0^{\sup er} \\
\text{s.t.}\quad & \sum_{j=1,\ j\neq 0}^{n} \lambda_j x_{ij} \leqslant \theta_0^{\sup er} x_{i0}, \\
& i = 1, 2, \ldots, m, \\
& \sum_{j=1,\ j\neq 0}^{n} \lambda_j y_{rj} \geqslant y_{r0}, \\
& r = 1, 2, \ldots, s, \\
& \theta_0^{\sup er},\ \lambda_j\ (j \neq 0) \geqslant 0.
\end{aligned} \tag{3.4}$$

In this study, the data envelopment analysis approach to measure efficiency is chosen for following reasons. Firstly, it is unnecessary to apply any functional form or any assumption on distribution of error, which is very necessary in stochastic frontier production. Secondly, this is the first study, to my knowledge, that used data envelopment analysis to measure technical efficiency of shrimp culture at farm level in Song Cau district, Phu Yen province, Vietnam. In this case, because operators have more control over their inputs than their outputs, the input-oriented model is used to estimate technical efficiency. Furthermore, due to some certain constraints of financing and the high costs for farming, especially the cost for feed, the choice of the DEA input-oriented models is suitable approach. One more important factor is that almost farms are not operating at optimal scale because of imperfect competition, constraints on finance, and socio-economic limitations of farmers. Therefore, VRS DEA model seems to be more appropriate for analyzing technical efficiency than CRS in this study.

3.2.3. Empirical studies on profitability and technical efficiency in aquaculture

3.2.3.1. Profitability in aquaculture

Okechi (2004) evaluated the profitability of catfish farming in the lake Vitoria basin, Kenya. The analysis formulated assumptions based on secondary data on catfish production. The results showed that NPV and IRR are acceptable with a pay back period of five years. The cash flow is adequate with a debt service coverage ratio of more than 1.5. Besides, it is also more economical to operate 12 ponds than one pond due to gains from economies of scale (Okechi 2004).

Brummett et al. (2008) analyzed the investment of semi-intensive fish culture in periurban Yaounde, Cameroon. The results showed that the profitability of farms varied considerably. Two farmers lose money each year and two farms can be considered solid investments. The net returns to management on profitable farms ranged from Fcfa 0.3 million to Fcfa 3.87 million (overall weighted average = Fcfa 0.99 million). Payback period for the initial investment on farms turning a profit ranges from 5 to 28 years (Brummett, Gockowski et al. 2008).

Sathiadhas et al. (2009) analyzed the break-even point and profitability of aquaculture farming in India. The results showed that the break-even price for the tiger shrimp were Rs.161/kg and Rs.126/kg for semi-intensive culture and improved extensive method, respectively. The break-even price of White shrimp culture worked out to Rs.166 /kg and Rs.88/kg in semi-intensive and improved extensive culture, respectively. For other farming systems like crab culture and crab fattening, the break-even price were Rs.107/kg and Rs.173/kg, respectively. Break-even price was Rs.3.35/kg in mussel culture. The net profit varies from Rs.49,060/ha for traditional paddy cum prawn filtration system, Rs.11.15 lakh/ha for crab culture and Rs.14.99 lakh/ha for crab fattening, Rs.23.94 lakh/ha for pearl culture, Rs.9.48 lakh/ha/ year to Rs.6.03 lakh/ha/year for longline mussel culture in Karnataka and Kerala, Rs1.85 lakh/ ha for rack and rein culture of edible oysters in Kerala and Rs.0.58/ha for the rope culture of Gracilaria edulis (Sathiadhas, Najmudeen et al. 2009).

Mehmet and Vedat (2009) calculated cost and profit of Trout and Sea Bass production in the Black Sea, Turkey. The main result revealed that the cost of trout and sea bass production per kg were $2.58 and $4.77, respectively. Furthermore, the net return per kg for trout and sea bass production were $0.16 and $0.48, respectively. Bass production has higher benefit cost ratio than trout production (1.1 and 1.06, respectively) (Mehmet and Vedat 2009).

Ogundari and Ojo (2009) examined the Income Generation Potential and resource-use efficiency of 120 aquaculture farms in Oyo, Nigeria**.** Result revealed that the farms were quite profitable with an average GM of N207,000 per annum. The elasticities of all considered inputs were positive and significantly different from zero obtained from the SFP model. Besides, an average technical efficiency estimate of about 81% was receiving from SFP model. Furthermore, education, stocking density, and credit significantly influenced technical efficiency of the farms (Ogundari and Ojo 2009).

Emokaro et al. (2010) analyzed the Profitability and Viability of Catfish Farming in Kogi State, Nigeria. The analysis was based on random sampling of 40 catfish farmers. The result showed that an estimated average initial capital of $2,283 per 0.5 hectare, at a prevailing interest rate of 17.5% /annum. The result also revealed estimated an average annual gross revenue of $5,723 and an average net profit of $2,576, a mean gross margin of $2945.16 and a net profit margin of 51.46%. Besides, the benefit cost ratio was estimated as 1.82 (Emokaro, Ekunwe, Achille 2010).

Son et al. (2010) examined the production and economic efficiencies of intensive black tiger prawn culture during different cropping seasons in the Mekong delta, Vietnam. The results revealed average stocking density of 17 PL m-2 with a survival rate of 55%, a crop yield of 2,470 kg/ha/crop and a net income of 6,768 USD/ha/crop. The average production cost was 3.4 USD/kg, in which feed cost accounted for 58% of the production cost. The probability of yield loss was 15.6 times higher in the wet than in the dry season. Technical efficiency with respect to prawn yield and survival rate was higher during the dry season than the wet season. (Son, Phuong et al. 2010).

3.2.3.2. Technical efficiency analysis in aquaculture

Jayaraman (1997) analyzed the economics of carp culture and ascertained the reasons for yield variations by using probabilistic frontier production function model (PFPF). Cross section data of 40 carp farms in Thanjavur district, Tamil Nadu state, India were used for the analysis. The analysis used Ordinary Least Square method and probabilistic frontier production function to estimate the average production function. The results showed that 23 out of 40 farms had technical efficiency; only one farm was technical efficiency (Jayaraman 1997).

Sharma et al. (1999) applied a nonparametric data envelopment analysis to measure economic efficiency and suggested optimum stocking density for Chinese fish poly-culture farms. The author investigated 115 fish poly-culture farms from eight provinces in China. The analysis was based on four output categories of fish, including: black carp, grass carp, silver carp and common carp and the combination of inputs such as: seed, feed, and labor. The mean economic efficiency was 0.74. The sample average technical, allocative, and economic efficiencies were 0.83, 0.87, and 0.74, respectively. The results also proposed that on average, farmers should increase grass carp and decrease black carp stocking rates. In addition, smaller farms and those from the developed provinces were relatively more technically and economically efficient (Sharma, Leung et al. 1999).

Iinuma, Sharma and Leung (1999) used stochastic production frontier (SPF) to measure the technical efficiency of carp pond culture in Peninsula Malaysia. There were 94 carp pond farms classified into intensive/semi-intensive and extensive cultures in analysis of research. The analysis was based on the production frontier, which was in Cobb Douglas functional form, involving output of total quantity of fish harvested in 1994 production year measured in kilograms per hectare and six input variables including seed, seed ratio, feed, feed ratio, labor and other inputs. The technical efficiency model included five farm-specific variables such as culture intensive, ownership, carp farming as a primary activity, pond area and pond age. The results showed that the mean technical efficiency was 42% and seed ratio has a significant effect on fish production. The findings also revealed that intensive/semi-intensive system was more technically efficient than extensive one with 0.565 and 0.236 on average, respectively. Besides, age and ownership were found to have positive effects on technical inefficiency. Meanwhile, there was a negative relationship between intensive culture and technical inefficiency (Iinuma, Sharma et al. 1999).

Sharma and Leung (2000) applied stochastic frontier analysis approach (SPF) to examine the technical efficiency of carp production in India. Cross section data of 906 carp farms in India classified into semi-intensive/intensive and extensive were used. The analysis was based on the Cobb Douglas production frontier involving one output of aggregated quantity of fish production in kilogram per hectare and six inputs: seed, labor, chemical fertilizer, organic manure, feed, and other input. The technical efficiency model including primary activity (dummy), farmer's experience, owner operated, pond area, fish management index, water management index, feed management index and location variables (dummy). The mean technical efficiencies were 0.805 and 0.658 for semi-intensive/intensive and extensive sample farms, respectively. Furthermore, the semi-intensive/intensive was found technically more efficient than extensive farms (Sharma and Leung 2000).

Chiang et al. (2004) estimated the technical efficiency of milkfish in Taiwan by using stochastic frontier production function (SPF) approach. Data from an investigation of 433 aquaculture milkfish farms between 1997 and 1999 were used. Authors used the maximum likelihood estimation method to estimated Translog and Cobb Douglas frontier production models. The production frontier based on the output of milkfish production quantity and inputs: pond area, fry cost, feed cost, water and electricity cost and other costs. The inefficiency factors included the data collecting time (dummy), monoculture farm (dummy), fresh water (dummy), location (dummy), pond size (dummy), education (dummy), experience, labor. Empirical results revealed that the mean technical efficiency was 0.84 in the Translog model and milkfish farming in Taiwan diminished return to scale. In addition, there was a positive relationship among fresh water, location variables, education, experience and labor and technical inefficiency (Chiang, Sun et al. 2004).

Dey et al. (2005) applied stochastic production frontier (SPF) approach to analyze the levels and determinants of farm-level technical efficiencies of freshwater pond poly-culture production in selected Asian countries. The data of 300 samples from China, 409 samples from India, 180 samples from Thailand, and 120 samples from Vietnam were used. Those freshwater pond poly-culture farms were classified into extensive, semi-intensive and intensive system. The production frontiers were Cobb Douglas function. The output was farm yield in kilogram per hectare. The inputs used in those production frontiers were specific, some of those related to common inputs (stocking density, feed, labor, chemicals), and others not (energy, protein, nitrogen, phosphorus, fertilizer and its dummy variables). The results showed that technical efficiencies of extensive and semi-intensive system were 0.77 and 0.84 in China, 0.65 and 0.86 in India, 0.72 and 0.91 in Thailand, 0.42 and 0.48 in Vietnam, respectively. The technical efficiency of intensive system in China had the highest score with 0.93 (Dey, Paraguas et al. 2005).

Kaliba and Engle (2006) used a weight-restricted data envelopment analysis (DEA) technique to measure the productive efficiency of small and medium-sized catfish farms in Chicot, Arkansas. 32 samples of catfish farms in this region in 2001 were used. The efficiency analysis was based on one output of live catfish in kilogram per hectare and inputs: labor, energy, quantity of fingerlings/stockers, quantity of feed, and other costs. The study also included 4 variables in the two Tobit models in the second stage such as: size of operation, experience of operator, extension services and land lessee. The results showed that the mean technical efficiency under constant return to scale (CRS) and allocative, scale efficiency were 0.57, 0.67, and 0.77, respectively. Meanwhile, the technical and cost efficiency under variable return to scale (VRS) were 0.73 and 0.49, respectively. Besides, operators' experience, extension contacts were found to have positive effects on the level of efficiency of those farms (Kaliba and Engle 2006).

Cinemre et al. (2006) applied two-stage DEA method to measure the cost efficiencies of trout farms in the Black Sea Region, Turkey. Cross section data of 73 trout farms were used. The analysis was based on a two inputs (feed and labor), a single output (trout) framework in the first stage. The second stage included variables such as: personal characteristics (education level and experience of the operators), farm characteristics (pond size and off-farm income), and accessing to institutions/public goods (credit and extension services) analyzing by Tobit model. The results showed that the mean technical, allocative and cost efficiencies were 0.82, 0.83 and 0.68, respectively. In addition, pond tenure, farm ownership, experience as well as education level of the operators, contact with extension services, off-farm income and credit availability were found to have positive effects on cost efficiency; feeding intensity, pond size, and capital intensity were found to have negative effects on cost efficiency (Cinemre, Ceyhan et al. 2006).

Den et al. (2007) used stochastic production frontier (SPF) approach to examine the technical efficiency of prawn farms in the Mekong Delta, Vietnam. Cross section data of 193 prawn farms classified into extensive and intensive farms in 2004 were used for analyzing. The first step of the analysis was based on the Cobb Douglas production function involving one output of kilogram prawn per hectare per year and inputs: fingerlings, commercial feed, chemical, fuel, hired labor, type of prawn (dummy). In the second step, the farm specific technical inefficiency was estimated involving four inputs: farm area, experience, age, education of the operators. The mean technical efficiency was 46 percent. The extensive farms were technically more efficient than intensive farms with 0.48 and 0.35, respectively. Furthermore, experience was found to have positive effect on technical efficiency. However, it was found that the younger operators had more technically efficient than older ones (Den, Ancev et al. 2007).

Alam and Murshed-e-Jahan (2008) estimated the resource allocation efficiency of prawn-carp poly-culture systems using data envelopment analysis (DEA) approach. Cross section data of 105 prawn-carp farms in Bangladesh were used. The analysis was based on two outputs (prawn and carp) and four inputs (labor, fingerlings, inorganic fertilizers, organic fertilizer and feed). The main results revealed that the mean technical, allocative, cost and scale efficiency of prawn-carp poly-culture in Bangladesh were 0.85, 0.58, 0.49, and 0.88, respectively. Besides, there was a positive relationship between pond size and technical and cost efficiency. However, pond size was found to have negative effect on allocative efficiency; feed application negatively effect on technical, allocative and cost efficiency (Alam and Murshed-e-Jahan 2008).

Huy (2009) analyzed the technical efficiency analysis for commercial Black Tiger Prawn (*Penaeus monodon*) aquaculture farms in Nha Trang City, Vietnam. The study used a minimizing input-oriented CRS DEA model with two outputs (the size of the shrimp, the total shrimp production) and five inputs (labor, pond area, machine, pond depth and activities cost). Cross section data of 64 samples of black tiger shrimp farming were investigated. The area of the technical efficiency ponds for Black Tiger Prawn (Penaeus monodon) aquaculture in Nha Trang is within the range of 0.08 - 2.5 ha and pond size was constructed to have positive effect on the technical and cost efficiency (Huy 2009).

Tung (2010) measured the technical efficiency of improved extensive shrimp farming in Ca Mau Province, Vietnam. Cross section data of 92 samples of shrimp farms from 2 districts (Cai Nuoc, Dam Doi) was used. DEA input-oriented variable return to scale were applied in the study and estimating technical super-efficiency was regressed to the pond area, farmer experiences, black tiger shrimp, mud crab stocking density and education of farmers. The results showed that the mean CRS (constant return to scale) technical efficiency of the total samples was 0.36. Moreover, pond area, experience and education of the owners of the shrimp farms were the mainly positive factors influencing efficiency of improved extensive shrimp farming in both districts. Nevertheless, only shrimp stocking density in Dam Doi district had a negative relationship with technical efficiency. The farms in Cai Nuoc district were more highly efficient than farms in Dam Doi District (Tung 2010).

In summary, regardless of estimation method, the average technical efficiency of aquaculture system in the above studies varied from more than 60 percent to 91 percent, except one case of Malaysia, one case of Arkansas, and 3 cases of Vietnam. The poly-culture system in China seemed to be more efficient than Vietnam. Those studies also revealed that farmer characteristics (age, education, experience, and extension contacts) influence technical efficiency and productivity. Moreover, some of the above studies used stocking density and regional variable as inputs in evaluating the efficiency or construction the production frontier.

4. Research methodology

4.1. Data collection

4.1.1. Primary data

Primary data of this research were based on farm level cross-sectional investigation of Black tiger shrimp and White leg shrimp crop year 2011. The data for this study are drawn from a field survey conducted by author and one author's friend in February and March 2012. Besides, these interviews were easier with the support from local authorities who often contacted with farmers and introduced interviewers to farmers. The randomly sampled cluster is the method used to collect each household for this paper.

4.1.1.1. Sampling method

Song Cau district has 12 aquaculture areas, in which Xuan Hai and Xuan Loc communes are large regions (occupied 81% total aquaculture area of district in 2011). A questionnaire was designed and pre-tested with 15 households in Xuan Loc commune in the first days of February 2012 to check how well it suited our purpose. Then the edited version of questionnaire was used for interviewing the Black tiger shrimp and White leg shrimp farms in February 2012.

The information was included in the questionnaire:

1) Household characteristics: age, education, experience, number of person in family, number of household members involved in farm, main occupation of household, income sources of household

2) Labor in shrimp culture: number of labor, total working days, and salary of regular labor

3) Basic information of farms: area, the number of ponds, the number of operating crops

4) Information related to fixed costs and variable costs in crop year 2011

5) The amount and unit price of outputs (Black tiger shrimp, White leg shrimp)

4.1.1.2. Sample size

The shrimp households are from nine communes of Song Cau district. The sample size was 150 shrimp farms (88 farms for Black tiger shrimp and 62 farms for White leg shrimp).

4.1.2. Secondary data

Secondary data for this study was collected from various sources such as books, journals, research reports, previous studies and available reports. Besides, some information was obtained from Department of Agriculture and Rural Development of Phu Yen province, Economic Department of Song Cau district and General Statistic Department of Song Cau district.

4.2. Data analysis

4.2.1. Descriptive statistic analysis

The study used simple descriptive statistic analysis, including: mean, standard deviation, maximum, minimum, percentage. This analysis was used to describe the characteristics of households. It also was employed for some main inputs and outputs which were used in estimating technical efficiency.

4.2.2. Variables for data envelopment analysis

Two groups of inputs and outputs were classified to use for technical efficiency analysis.

* *Outputs used in estimating the technical efficiency score:*

The quantity of two kinds of aquatic products including Black tiger shrimp *(Penaeus monodon)* and White leg shrimp (*Penaeus vannamei*) that was harvested during the first crop of 2011 production year, measured in kilogram.

* *Inputs used to measure technical efficiency score were labor, feed, chemical, and seed*

- *Labor* is expressed as number of hired persons and household's labors who might work full-time or part-time per crop. The cultured time is often 4-5 months and 3 months for Black tiger shrimp and White leg shrimp, respectively. The number of workers employed by the farms depends on farm size and number of ponds. Owner often hired workmen for aquaculture working during the crop time to monitor and maintain all activities such as feeding, water monitoring, shrimp disease control, etc. In addition, every farm has one to two family labors (depend on farm size) who worke on their farms to manage overall. If producers know how to use suitable labor source, it make save much cost for their farms. Therefore, labor is an important input in shrimp farm and is measured by the number of workers.

- *Feed* indicates the total feed quantity using for shrimp during time crop. All observed farms used commercial feed for shrimp. In theory, farmers should use special feed that is suitable for every shrimp development stage. However, in this case, all farms mostly use the same quality and priced feed during crop. The quantity of feed per crop depends on the stocking density, growth of shrimp, viability of shrimp and techniques of operators. Hence, employing the reasonable quantity of feed in shrimp culture is very essential. Feed in the study is measured in kg per crop.

- *Chemical*: Farmers often use antibiotic and chemical for improving shrimp's health and disease treatment. The use of medication in shrimp ponds is an important issue which determines the survival of shrimp. If users apply wrong dosage and specification, this will lead to unforeseen consequences. Therefore, chemical is also the considered input in shrimp farms. All the values of this input are measured in 1,000 VND.

- *Seed* used in shrimp culture was fingerling with various sources and different prices. However, most surveyed farms have the same shrimp source in this case. Every farm has different stocking density that depends on their finance and area. In data envelopment analysis, seed was measured in total number of fingerling per crop.

Table 4.1: Descriptive statistics of input and output variable for DEA analysis

	Black tiger shrimp				**White leg shrimp**			
	Mean	**S.D**	**Min**	**Max**	**Mean**	**S.D**	**Min**	**Max**
Output:								
Production (kg/crop)	483	458.59	50	2,000	2,527	1,198	130	8,000
Inputs:								
Labor (No. of person)	2.68	1.02	2	6	3.364	1.45	2	8
Feed (kg/crop)	764.27	770.59	30	3,400	2,918	2,391	90	10,000
Chemical cost (1000 VND)/crop	3,722	3,816	200	15,000	7,738	7,008	300	40,000
Seed (units/crop)	55,694	32,366	15,000	150,000	344,659	290,307	80,000	1,600,000

[Source: Own survey]

The table 4.1 summarizes the sample descriptive statistics of the variables used in the efficiency analysis at farm level of two groups. The White leg shrimp sample households on average produced 2,527 kilograms per crop, around 5 times compared to Black tiger shrimp. The stocking density of Black tiger shrimp was very low, which just was 10 fingerlings per m^2. On average, these farms used 55,694 fingerlings in crop year 2011. Because White leg shrimp can survive in high density environment, producers employed higher stocking of 58 fingerlings per m^2 to get higher present production. The table also revealed that average quantity of feed used per crop about 764 kg for Black tiger shrimp and 2,918 kg for White leg shrimp. The value of chemical used for White leg shrimp was 7,738,000 VND, which is nearly double compared to Black tiger shrimp farms. On average, the number of labor working for shrimp farming was nearly 3 people for the first group and more than 3 people for the second group.

Table 4.2: The Correlation between all inputs and output in technical efficiency analysis of Black tiger shrimp

	No. of labor (person)/crop	Quantity of feed (kg)/crop	Chemical (1,000 VND)/crop	No. of seed /crop	Production (kg/crop)
No. of labor (person)/crop	1				
Quantity of feed (kg)/crop	0.66	1			
Chemical (1,000VND)/crop	0.67	0.87	1		
No. of seed/crop	0.80	0.76	0.79	1	
Production (kg/crop)	0.68	0.99	0.87	0.78	1

Table 4.3: The Correlation between all inputs and output in technical efficiency analysis of White leg shrimp

	No. of labor (person)/crop	Quantity of feed/crop (kg)	Chemical (1,000 VND)/crop	No. of seed /crop	Production (kg/crop)
No. of labor (person)/crop	1				
Quantity of feed/crop (kg)	0.88	1			
Chemical (1,000 VND)/crop	0.81	0.92	1		
No. of seed/crop	0.84	0.86	0.82	1	
Production (kg/crop)	0.89	0.99	0.93	0.86	1

The table 4.2 and 4.3 give information about the correlation between every input and the output. We can see the coefficient of correlation is positive and high. It means that on average when operators increase more input (of every type) for their farms, the production might be increased more. Overall, there is a positive correlated between each input and the output.

Figure 4.1: Regression of production and number of labor

The figure 4.1 gives information about the relationship between number of labor and gross production. The regression line is estimated without constant, as zero input is not observed, and would not be logical when extrapolation the estimated line. The coefficient of determinant in Black tiger shrimp sample was R^2 = 0.4, which means that 40% variation of production is explained by number of labor. For White leg shrimp sample, coefficient of determinant R^2 = 0.69 implies that 69% variation of production is explained by number of labor.

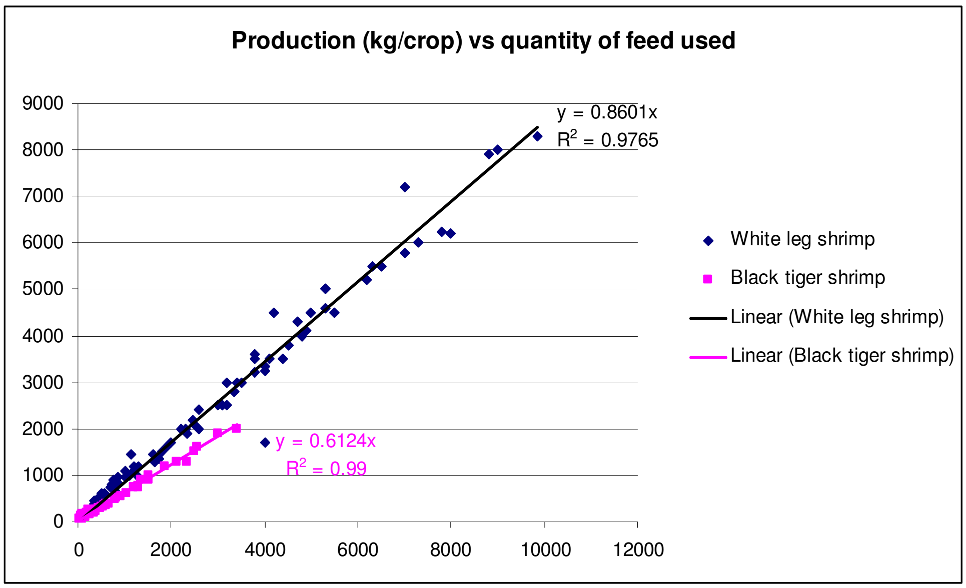

Figure 4.2: Regression of production and quantity of feed used

The relation between quantity of feed used and production was presented in the figure 4.2. These coefficients of determinant for two groups are very high (R^2 is 0.99 and 0.98 for Black tiger shrimp and White leg shrimp, respectively). This indicates that the relation between quantity of feed used and production is seriously close.

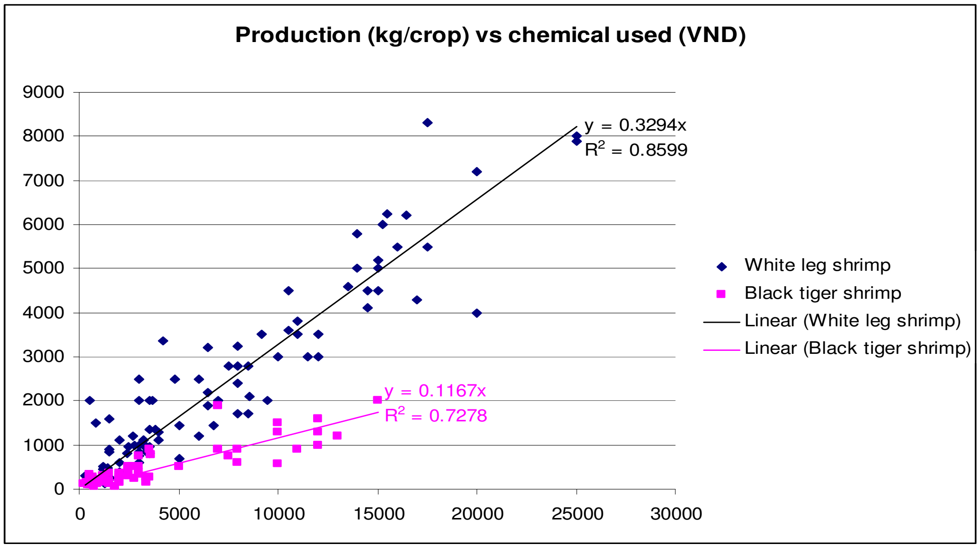

Figure 4.3: Regression of production and chemical used (1,000 VND)

The figure 4.3 reveals the relationship between chemical used (measured by 1,000 VND) and production and table 4.4 illustrates the relationship between seed used and production. Farmers must use chemical such as probiotics, vitamin C and drug for health improving and disease treatment of shrimp. As a result, the relationship between chemical used (measured by 1,000 VND) and production is somewhat close for two groups (R^2 is 0.73 for Black tiger shrimp and 0.86 for White leg shrimp). It is easy to see the production and seed used has quite close relationship from figure 4.4.

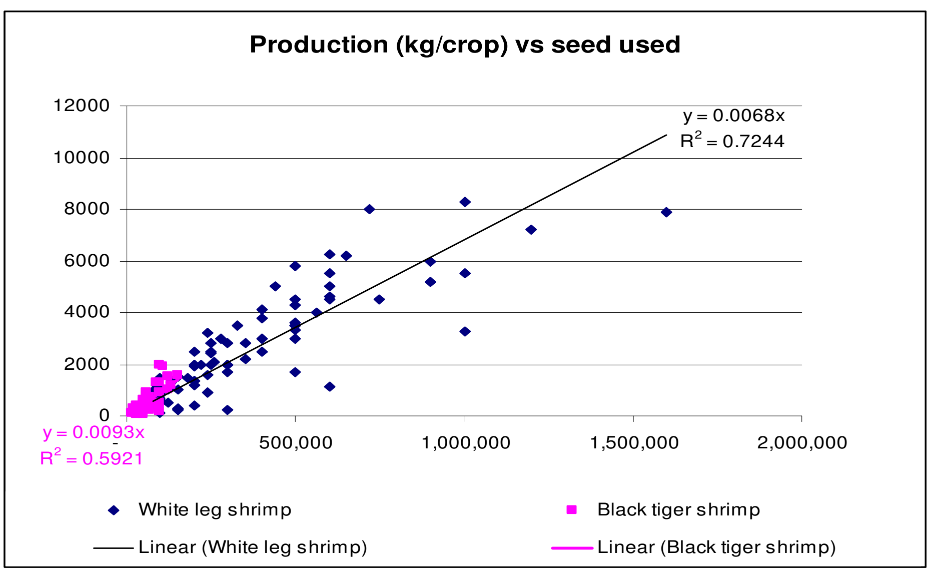

Figure 4.4: Regression of production and seed used

5. Results

This chapter consists of four sections. Firstly, the socio-economic of shrimp households are generalized with some main characteristics. Then, the comparing the profit of two groups are presented. Thirdly, technical efficiency score at farm level was presented. Final part is the correlation between profit and technical efficiency.

5.1. Socio-economic characteristics of shrimp farms

The table 5.1.1 and 5.1.2 presents socio-economic characteristics of shrimp farms surveyed and highlights the differences in farm structure between Black tiger shrimp farms and White leg shrimp farms. Operators used the first time in the year of 2011 for Black tiger shrimp cultivation (4 – 5 months) and the rest time for cultivation of crab, blue crab and rabbit-fish. Producers of Black tiger shrimp, on average, well educated, with over 50% having received some College education and having attended High school. Many did state that besides shrimp farms, they were engaged in other activities, some of these related to aquaculture (e.g., lobster culture, fish feed agent), and others not (e.g., fishing, trading, Government's officers, workers, stock raising, rice growing).

In contrast, the White leg shrimp farms are specialized in shrimp culture with no other substantial aquaculture activities. Because a large majority of the farm operators has original from Black tiger shrimp, the education level is the same in two groups. However, the percentage of attained College education is quite higher than in Black tiger shrimp farms. As measured by their time in the business, the interviewed shrimp farmers had same levels of experience (around 8 years) and the same age (42 years old).

Table 5.1.1: Socio-economic characteristics of the respondents on Black tiger shrimp farms

Parameters	Range/ Classification	Frequency	Percent (%)
Age of respondents (years)	26-40	33	53.2
	41-60	22	35.5
	61-65	7	11.3
	Total	**62**	**100**
	Mean ± SD **42** ± 10		
Experience (years)	2-5	18	29.1
	6-10	24	38.7
	11-17	20	32.2
	Total	**62**	**100**
	Mean ± SD **8.548** ± 4.108		
Job Status	Farmers	35	56.4
	Trader	16	25.8
	Government's officer	7	11.3
	Others	4	6.5
	Total	**62**	**100**
Education	Elementary	8	12.9
	Secondary school	22	35.5
	High school	21	33.9
	College	11	17.7
	Total	**62**	**100**
Household size (person)	1-4	43	69.4
	5-6	19	30.6
	Total	**62**	**100**
	Mean ± SD **3.88** ± 1.103		

[Source: Own survey]

As regards household size, both groups have around 4 people per family with the range from 1 to 6 people. With this medium size, farmers are easy to improve the quality of life. Furthermore, farmers approached the techniques of aquaculture from many valuable sources such as authorities, business, media and other sources. These make farmers always update and improve technology for their operation.

Table 5.1.2: Socio-economic characteristics of the respondents on White leg shrimp farms

Parameters	Range/ Classification	Frequency	Percent (%)
Age of respondents (years)	26-40	48	54.6
	41-60	34	38.6
	61-65	6	6.8
	Total	**88**	**100**
	Mean ± SD **41** ± 10		
Experience (years)	1-5	29	32.95
	6-10	33	37.5
	11-17	26	29.55
	Total	**88**	**100**
	Mean ± SD **7.965** ± 4.164		
Job Status	Farmers	52	59.1
	Trader	18	20.5
	Government's officer	12	13.6
	Others	6	6.8
	Total	**88**	**100**
Education	Elementary	13	14.8
	Secondary school	32	36.3
	High school	24	27.3
	College	19	21.6
	Total	**88**	**100**
Household size (person)	1-4	60	68.18
	5-6	28	31.82
	Total	**88**	**100**
	Mean ± SD **3.85** ± 1.140		

[Source: Own survey]

5.2. Results of profitability analysis

The profitability of shrimp farming production system depends on the underlying cost structure and the returns. The cost of shrimp culture can be divided into fixed costs and variable costs. Fixed costs are the costs that include pond lease, pond treatment, repair and maintenance, depreciation, non-depreciation assets (balance, bucket, basket and net). Variable costs are expenses that directly related to the scale of farm operations at any given time. Variable costs are the cost of seed, feed, chemical for disease treatment of shrimp, preparation pond, fuel and electricity, test kit for water checking, labor, harvesting, and telephone. The preparation cost includes the cost of mud removing, lime, chemical for parasite removing, and fertilizer. The fuel was consumed for machines and equipments such as water pumping motors, electric generator (used for power cutting conditions), and motors for oxygen creating equipments.

Some farmers must lease the pond for shrimp culture because they come from other regions. The cost for lease depends on the size of pond and geographic site. The depreciation cost is calculated based on the purchasing value and estimated using the straight-line method for guard houses, machineries and equipments. The pond treatment cost is the cost for pond cleaning after harvesting shrimp. The cost of balance, bucket, and net are included in non-depreciation cost. The cost structure and profitability for the 150 shrimp farms surveyed is presented in the table 5.2.1.

Table 5.2.1: Comparative costs and profitability per hectare in crop year 2011 of Black tiger shrimp farms and White leg shrimp farms

Item	Black tiger shrimp			White leg shrimp		
	Value (VND)	Value (USD)	(%)	Value (VND)	Value (USD)	(%)
Variable costs	**114,304,623**	**5,715.23**	**89.96**	**200,075,062**	**10,003.75**	**93.59**
Seed	2,101,528	1,05.08	1.65	33,803,681	1,690.18	15.81
Feed	36,048,558	1,802.43	28.37	96,614,210	4,830.71	45.19
Antibiotic, chemical	6,013,985	300.7	4.73	9,071,269	453.56	4.24
Preparation pond	3,852,776	192.64	3.03	4,595,922	229.79	2.15
Fuel, electricity	13,556,013	677.8	10.67	18,118,741	905.94	8.47
Test kit	285,275	14.26	0.23	286,247	14.31	0.14
Labor cost	51,470,344	2,573.52	40.51	36,367,321	1,818.37	17.02
Telephone	930,550	46.53	0.73	724,592	36.23	0.34
Harvesting cost	45,594	2.28	0.04	493,079	24.65	0.23
Fixed costs	**12,757,923**	**637.9**	**10.04**	**13,699,866**	**685**	**6.41**
Pond lease	1,333,333	66.67	1.05	2,587,558	129.38	1.2
Depreciation	2,465,644	123.28	1.94	2,590,334	129.52	1.2
Repair and maintenance	897,997	44.9	0.7	1,086,937	54.35	0.57
Pond treatment	7,531,076	376.55	5.93	6,516,973	325.85	3.03
Other assets	529,872	26.5	0.42	918,064	45.90	0.41
Total costs	**127,062,546**	**6,353.13**	**100**	**213,774,928**	**10,688.75**	**100**
Revenue	146,582,735	7,329.14		292,658,193	14,632.91	
Profit	**19,520,189**	**976**		**78,883,209**	**3,944.16**	
Cost/kg of shrimp	153,643	7.68		69,769	3.49	
Price/kg	166,742	8.34		89,447	4.47	
Return on investment (%)	15			37		
Profit margin (%)	13			27		

Exchange rate: 1 USD = 20,000 VND

[Source: Own survey]

On average, total production costs of Black tiger shrimp per hectare amounted to approximately 127,062,546 VND ($6,353.13), of which there are 89.96% represent variable costs while fixed costs account for only 10.04 percent. The observed cost structure of White leg shrimp is comparable to the cost structure observed of Black tiger shrimp showing higher variable costs of 200,075,062 VND or equivalently $10,003.75 (93.59%) and low fixed costs of 13,699,866 VND or equivalently $685 (6.41%). Approximately 80% of all variable costs in the study region were spent on seeds, production labor and feeds.

Black tiger shrimp farms produced approximately 827 kg per ha in one crop with the cost per kg of 153,643 VND ($7.68) and the current price level allows farmers to sell their output for 166,742 VND ($8.34/kg). The price of shrimp depends on the size, quality of shrimp and the market. The resulting average revenue per farm is equal to 146,582,735 VND ($7,329.14) per hectare. On average, the gross farm income of Black tiger shrimp farms is measured by profit per hectare of 19,520,189 VND ($976). The findings also show that these farms achieved a low profit margin (13%) and low return on investment (15%).

As regards the result of profitability analysis for White leg shrimp farms, the average production cost per kg was 69,769 VND ($3.49) with the present price level allows producers to sell their output for 89,447 VND ($4.47). The average production per hectare of these farms was 3,064 kg. This system is characterized by good level of profit compared to former system. As a result, these farms make an average profit of 78,883,209 VND ($3,944.16), which is approximately 4 times compared to Black tiger shrimp farms. This group also obtain higher profit margin (27%) and return on investment (37%) compared to previous group.

Test for Hypothesis 1: Profit of Black tiger shrimp farms is equal to White leg shrimp farms

To test the difference between means of profit of Black tiger shrimp farms and White leg shrimp farms, this study used Excel to solve this consideration. Let draw a sample of size n_1 from the Black tiger shrimp samples, and a sample of size n_2 from the White leg shrimp samples. Using the first sample the study obtains the sample mean $\overline{x_1}$ and sample variance

σ_1^2 ; from the second sample the study obtains the sample mean $\overline{x_2}$ and sample variance σ_2^2 .

The null hypothesis Ho: $\overline{x_1} = \overline{x_2}$

The two-sided alternative hypothesis: H1: $\overline{x_1}$ # $\overline{x_2}$

With the unequal sample variances, the study used the equation below for standard testing:

$$z = \frac{\overline{x_1} - \overline{x_2}}{\sqrt{\frac{\sigma_1^2}{n_1} + \frac{\sigma_2^2}{n_2}}}$$

The results from Excel were showed below:

Table 5.2.2: Descriptive statistic of profit per hectare between Black tiger shrimp farms and White leg shrimp farms

	Mean	S.D	Min	Max
Black tiger shrimp	19,520,188	55,019,793.83	-79,033,333	156,091,667
White leg shrimp	78,883,209	83,279,756.6	-90,576,667	271,435,417

[Source: Own survey]

Table 5.2.3: z-Test: Two Sample for Means

	Profit of Black tiger shrimp (VND)/ha	Profit of White leg shrimp (VND)/ha
Mean	19520188	78883209
Known Variance	3.02718E+15	6.93552E+15
Observations	62	88
Hypothesized Mean Difference	0	
z	-5.25	
P(Z<=z) one-tail	7.42412E-08	
z Critical one-tail	1.64	
P(Z<=z) two-tail	1.48482E-07	
z Critical two-tail	1.96	

[Source: Own survey]

As we can see from the table, |z| = 5.25 > z Critical two-tail = 1.96, so the study rejected Ho and accepted H1. It means that the profit per hectare of two groups is not equal with level of significance at 5%. Combining result from table 5.2.1 above, the study can conclude that the profit of White leg shrimp farms per hectare is higher than Black tiger shrimp farms per hectare.

Generally, with many advantages such as less disease, lower feed conservation ratio, higher culture density, and higher productivity, the culture of White leg shrimp is more popular. As regards the result from the profit analysis, the profit of White leg shrimp farms is higher 4 times than Black tiger shrimp farms. This suggests that White leg shrimp is a high economic value object, which can contribute to increase production and value of shrimp exports.

5.3. Technical efficiency results

This study measures the super-efficiency score under assumption of CRS to find outliers. Super-efficiency is a model that allows the efficient DEAs, one at the time, be compared the production frontier without the same DMU. The result is that in input efficiency some observations will have efficiency score larger than 100%. If the efficiency is much larger than 100 % (some use 150 % as cut-off criterion), these are considered outliers and are not analyzed more. In this research, the 3 outliers (B48 with super-efficiency score 1.59 from Black tiger shrimp group; W10 with super-efficiency score 1.6 and W28 with super-efficiency score 2.13 from White leg shrimp group) are removed with the super-efficiency score lager than 150%. The cut-off number of 1.5 is to some extent arbitrary. But 1.5 indicates that this DMU is 50 % more efficient than the DMUs formerly considered being 100 % efficient. After the outliers are removed, the study computes the efficiency score for 147 observations under CRS, VRS and scale efficiency without the DMUs removed. It may be also worth to see of the production of Black tiger shrimp and White leg shrimp is different technologies, and thus the study calculate efficiency for each group separately.

5.3.1. Efficiency scores of Black tiger shrimp farms

The technical efficiency measure corresponding to CRS assumption represents total efficiency (TE). The efficiency measure corresponding to VRS assumption represents pure technical efficiency (PTE). The SE = TE/PTE provides a measure of scale efficiency. Table 5.3.1 provides information on the mean technical efficiency scores of shrimp farm samples. Farm technical efficiency scores were measured under the assumptions of constant return to scale (CRS), variable return to scale (VRS) and scale efficiency (SE) using DEA input oriented model. As can be seen from the table, the mean total efficiency for all farms was 0.82. It means that, on average, farms produced shrimp at approximately 82% of the potential frontier production levels at the current status of technology and input levels. It also can be said that these operators could reduce their inputs by 18% and still obtain the same level of output. A quarter of whole sample (9 out of 61 farms) were technically efficient farms (i.e., farms operating on the production frontier). These farms together define the best practice or efficient frontier. This implies that the resource utilization process in these farms was functioning well. The remaining 52 farms have TE score less than 1 which means that they are technically inefficient. Hence, these inefficient farms could improve their efficiency by decrease inputs. There were just 3.28% of farms exhibited TE scores less than 0.6. The rest of farms revealed TE scores from 0.6 to less than 1.

Table 5.3.1: Distribution of farm technical and scale efficiency scores: DEA input orientation (Black tiger shrimp)

Distribution of farms	**TE scores under CRS (TE)**		**TE scores under VRS (PTE)**		**SE scores (SE)**	
	Number	Frequency (%)	Number	Frequency (%)	Number	Frequency (%)
0.2 to 0.4	1	1.64			1	1.64
0.4 to 0.6	1	1.64				
0.6 to 0.8	26	42.63	6	9.84	20	32.79
0.8 to 1	24	39.34	13	21.31	31	50.82
1	9	14.75	42	68.85	9	14.75
Mean	0.82		0.952		0.867	
S.D	0.132		0.091		0.138	
Min	0.291		0.616		0.291	
Max	1		1		1	

We can see that the average predicted technical efficiency under assumption of VRS was higher than TE under assumption of CRS. It was 0.952 with the significant transformation range (0.616 to 1). This indicates that producers could potentially increase output by 4.8% by making better use of existing technology. About 68.85% of whole sample (42 out of 61 farms) were on the production frontier (TE = 1). For these 33 farms that have been found to be inefficient under CRS assumption but became efficient under VRS case, we can interpret that the technical inefficiency in these farms is not caused by poor input use (i.e., managerial inefficiency) rather caused by the operations of the farms with inappropriate scale size.

The scale efficiency is equal to the ratio of the total efficiency to the pure technical efficiency. On average, the scale efficiency was about 0.867 with the range from 0.291 to 1. It indicates that observed farms could have further increased their output by about 13% if they had adopted an optimal scale. The findings above also illustrate that the estimated degree of scale efficiency is higher than the degree of technical efficiency. This means that the greater percentage of total technical inefficiency in the sample might depend on producing below the production frontier than on operating under an inefficient scale. In other words, it can be said that, to obtain the effective output, given their own structural conditions and input package, the priority of operators should be to improve their ability in utilizing their own technical inputs.

5.3.2. Efficiency scores of White leg shrimp farms

The average technical efficiency score under CRS was measured of 0.89. This specifies that farms produced shrimp at approximately 89% of the potential frontier production levels at the existing category of technology and input levels or these operators could reduce their inputs by 11% and still achieve the same level of output. 15 out of 86 farms were technically efficient farms (TE=1). It means that the production process of these farms is not characterizing any waste of inputs. It has been further recognized that in the rest 71 farms (having TE <1) managerial inefficiency occurs, albeit of different magnitude. The percentage of TE scores from 0.6 to less than 1 was measured of 82.4% and 17.4%, respectively. No farm had TE score less than 0.4.

Table 5.3.2: Distribution of farm technical and scale efficiency scores: DEA input orientation (White leg shrimp)

Distribution of farms	**TE scores under CRS (TE)**		**TE scores under VRS (PTE)**		**SE scores (SE)**	
	Number	Frequency (%)	Number	Frequency (%)	Number	Frequency (%)
0.4 to 0.6	1	1.16				
0.6 to 0.8	14	16.28	10	11.63	5	5.81
0.8 to 1	56	65.12	32	37.21	66	76.74
1	15	17.44	44	51.16	15	17.45
Mean	0.886		0.94		0.946	
S.D	0.094		0.086		0.075	
Min	0.49		0.67		0.67	
Max	1		1		1	

An improvement of the feasible region of the BCC model makes the number of the efficient farms under condition of VRS is hoped to be more than under CRS condition. As result, the number of efficient farms regarded assumption of VRS was 44 in comparison of 15 frontier farms under CRS condition. The predicted average PTE was 0.94. This means that producers could potentially increase output by 6% by making better use of existing technology. There was no farm had TE score less than 0.6.

The estimated mean scale efficiency was about 0.946 with the range from 0.67 to 1. The empirical results described above reveal that the estimated degree of technical efficiency is significantly lower than degree of scale efficiency. This denotes that the bigger proportion of total inefficiency in this case might depend on producing below the production frontier than on operating under an inefficient scale. In other words, it indicates that, the priority of producers should be to increase their ability in employing their own technical inputs to achieve the potential output with given their own structural conditions and input disposability.

5.4. The correlation between profit and technical efficiency score

This section was used to ascertain the relationship between total efficiency, pure technical efficiency, scale efficiency and profitability of Black tiger shrimp cultivation and White leg shrimp cultivation. The study applied Excel to solve this problem. The results were represented in the table 5.4.2 and 5.4.3.

Hypothesis 2: Profitability and total efficiency, pure technical efficiency, scale efficiency is positively correlated.

Table 5.4.1: Summary statistic of profit per crop of two groups

	Mean	S.D	Min	Max
Black tiger shrimp	15,545,547	38,721,385	-40,093,333	144,091,667
White leg shrimp	79,430,368	97,109,051	-48,955,000	366,823,333

Table 5.4.2: Correlation between profit and technical efficiency score (Black tiger shrimp)

	TE	**PTE**	**SE**
Profit	0.52	0.06	0.46

As can be seen from the table, the correlation coefficient between total efficiency and profit was 0.52, pure technical efficiency and profit was 0.06, scale efficiency and profit was 0.46. All these coefficients are positive. Therefore, when the technical efficiency is improved, profit of shrimp farms will be increased.

Table 5.4.3: Correlation between profit and technical efficiency score (White leg shrimp)

	TE	**PTE**	**SE**
Profit	0.35	0.11	0.33

As regards the White leg shrimp, the correlation coefficient between total efficiency and profit was 0.35, pure technical efficiency and profit was 0.11, scale efficiency and profit was

0.33. All these coefficients are positive. Therefore, when the technical efficiency is improved, profit of shrimp farms will be increased. From reported findings above, the study accepted the hypothesis 2 that is profitability and total efficiency, pure technical efficiency, scale efficiency is positively correlated.

6. Discussion and Conclusion

6.1. Discussion

The analysis of shrimp farm budgets shows that White leg shrimp farms obtain higher levels of profitability per hectare (78,883,209 VND = $3,944.16), which is about 4 times as much as Black tiger shrimp farms. Our estimations propose that although White leg shrimp farms generate a high level of profit per farms, this is largely due to the much larger production and lower production cost than in the Black tiger shrimp production system. In 2011, on average, Black tiger shrimp farms produced approximately 827 kg per ha in one crop. Many interviewed farms, who stocked Black tiger shrimp with low density (8-10 shrimps/m^2) and met difficulty in shrimp disease treatment. Therefore, the production was very low, which was still higher than the production of total district (0.69 tons/ha). For this shrimp disease spread and loss of farmers, local authorities in Song Cau district have banned farms operating the second crop for Black tiger shrimp and have encouraged farmers to culture other species such as crab, rabbit-fish.

About the return on investment, two groups have a positive ROI (13% and 15% for Black tiger shrimp and White leg shrimp, respectively) and then these investments could be undertaken. However, we can see investment on White leg shrimp farms has a higher ROI. A higher profit margin indicates a more profitable farmer that has better control over its costs compared to its competitors. As result, White leg shrimp also has a higher profit margin (37%). This means that these farms on average have a net profit of $0.37 for each dollar of sale. For these results, farmers could consider and choose the appropriate culture form for their operation.

The average technical efficiency under CRS, VSR and scale efficiency of Black tiger shrimp sample was estimated as 0.82, 0.95 and 0.87 as against 0.88, 0.94, and 0.95 for White leg shrimp sample. The estimates suggest that there are moderate degrees of technical efficiency among the shrimp farmers operating at household levels. Empirical results propose that the overall inefficiency should depend on producing below the production frontier and on operating under a rational scale. The former reason might be more important since technical inefficiency appears greater than scale inefficiency. The total efficiency score in this study is same with the findings of Huy (2008) and is higher than findings of Shamima (2009). In Khanh Hoa province, Huy (2008) reported a mean TE of Black tiger prawn farms was 82.6% while Shamima (2009) estimated the average TE of White leg shrimp farms was 67%. Although Phu Yen is located next to Khanh Hoa province, it is easy to see the difference in production environment between two places. Moreover, the findings of this study might only be the case for data collected in Song Cau district which is could not be representative of Vietnam aquaculture.

Shrimp farming is a high technically agricultural field, which requires rather higher investment, higher technical and financial management compared to other ones. Hence, it is very difficult to achieve high technique to obtain stable outcome. The small scale of producing will get higher production cost, which make producers have lower profit and higher risk, albeit high commercial price of shrimp. It is easy to recognize the profitability and technical efficiency has positive correlated. Therefore, developing the technical efficiency is one of the key to improve the profitability of shrimp farming.

6.2. Conclusion remarks

This research examined the profitability and technical efficiency of two groups: Black tiger shrimp farms (first group) and White leg shrimp farms (second group) in Song Cau district, Phu Yen province, Vietnam. The main results of this study are: (1) profit of the second group was 78,883,209 VND ($3,944.16), which was 4 times as much as the first group; (2) technical efficiencies of first group under assumption of constant returns to scale, variable returns to scale and scale efficiency were measured of 0.82, 0.952 and 0.87, respectively; (3) technical efficiencies of second group under assumption of constant returns to scale, variable returns to scale and scale efficiency were estimated of 0.88, 0.94 and 0.95, respectively.

Vietnam has favorable natural conditions to develop aquaculture. Shrimp is the main species which was cultured for a long time a go, especially in Mekong Delta and Central Coastal. Shrimp farming is continuing to play an important role in the economy of Vietnam, which contributes to create employment, increase farmers' income, and generate significant foreign currency sources. However, shrimp farming is facing many challenges such as epidemic disease, resource reduction, and increasing costs. The results of this research suggest that there were still many farms operating inefficiency. Therefore, the strategies are to be developed to reduce inefficiency in production of shrimp. More efficient utilizing of inputs, such as seed, feed, and chemicals as well as changing the scale of farms may be the main solution in the future for raise productivity and hence profitability of shrimp farming in Vietnam.

REFERENCES

Alam, M. F. and K. Murshed-e-Jahan., 2008, 'Resource allocaltion efficiency of the prawn carp farmers of Bangladesh', *Aquaculture Economics & Management,* 12 (3), pp.188- 206

Alam Md. Ferdous, Md. Akhtaruzzaman Khan, A. S. M. Anwarul Huq 2011, 'Technical efficiency in tilapia farming of Bangladesh: a stochastic frontier production approach', Springer Science and Business

Banker, R.D., A. Charnes, and W.W. Cooper 1984, 'Some Models for Estimating Technical and Scale Inefficiencies in Data Envelopment Analysis', Management Science 30(9): 1078-1092.

Battese, G.E. and T.J. Coelli 1993, 'A stochastic frontier production function incorporating a model for technical inefficiency effect', No. 69

Bozoglu, M. and Ceyhan, V. 2009, 'Cost and Profitability Analysis for Trout and Sea Bass Production in the Black Sea, Turkey', Animal and Veterinary Advances, vol. 8 (2), pp. 217-222.

Brummett, R. E., et al., 2008, 'Analysis of aquaculture investments in Periurban Yaoundé, Cameroon', Humid forest eco-regional centre, Yaoundé Cameroon

Cesaro, L., Sonia M., et al., 2009, 'Methodology for analyzing competitiveness, efficiency and economy of scale: Use and applications of DEA', FACEPA, No. D5.1.3.

Chiang, F.-S., C.-H. Sun, et al. 2004, 'Technical efficiency analysis of milkfish (*Chanos chanos*) production in Taiwan - an application of the stochastic frontier production function', Aquaculture, vol. 230 (1-4), pp.99-116

Cinemre, H. A., V. Ceyhan, et al. 2006, 'The cost efficiency of trout farms in the Black Sea Region, Turkey', Aquaculture, vol. 251(2-4): 324-332.

Coelli, T.J., 1996, 'A Guide to DEAP Version 2.1: A Data Envelopment Analysis (Computer) Program', CEPA Working Paper 96/08, Department of Econometrics, University of New England, Armidale

Coelli, T., Rao, D.S.P., O'Donnell, C.J., Battese, G.E., 2005, '*An Introduction to Efficiency and Productivity Analysis (Second Edition)'*, Springer Publishers, New York, USA

Cinemre H.A., Bozoğlu M., Demiryurek K. and Kılıc O., 2006, 'The cost efficiency of trout farms in the Black Sea Region, Turkey', *Aquaculture,* 25, pp.324-332

Dey, Madan M., Paraguas, Ferdinand J., Bimbao, Gaspar B. and Regaspi, Prescilla B., 2000, 'Technical efficiency of tilapia growout pond operations in the Philippine', *Aquaculture Economics & Management*, 4 (1), pp.33- 47

Dey, M. M., F. J. Paraguas, et al. 2005, 'Technical efficiency of freshwater pond poly-culture production in selected Asian countries: estimation and implication', Aquaculture Economics & Management, vol. 9(1-2): 39-63.

Den, D. T., T. Ancev, et al. 2007, 'Technical Efficiency of Prawn Farms in the Mekong Delta, Vietnam', Australian Agricultural and Resource Economics Society, New Zealand

Emokaro C.O., Ekunwe P.A. and Achille A., 2010, 'Profitability and Viability of Catfish Farming in Kogi State, Nigeria', Agriculture and Biological Sciences, 6 (3): 215-219.

Fare, R., Grosskopf, S. and Lovell, C.A.K. 1985, 'The Measurement of Efficiency of Production', Boston: Kluwer Academic Publishers

Farrell, M. J. 1957, 'The Measurement of Productive Efficiency', Royal Statistical Society, 120: 253-2990

Hanh, Bui Le Thai 2009, 'Impact of financial variables on the production efficiency of Pangasius farms in An Giang province,Vietnam', Msc. thesis, University of Tromsø, Norway & Nha Trang University, Vietnam.

Huy, Dang Hoang Xuan 2009, 'Technical efficiency analysis for commercial Black Tiger Prawn (*Penaeus monodon*) aquaculture farms in Nha Trang City, Vietnam', Msc. thesis, University of Tromsø, Norway & Nha Trang University, Vietnam.

Iinuma, M., K. R. Sharma, et al., 1999, 'Technical efficiency of carp pond culture in peninsula Malaysia: An application of stochastic production frontier and technical inefficiency model', Aquaculture, vol. 175 (3-4), pp.199-213.

Jolly, C.M. and H.A Clonts, 1993, *Economics of Aquaculture*, New York: Food Products Press, pp.100-101

Kaliba, A. R. and C. R. Engle 2006, 'Productive efficiency of catfish farms in Chicot county, Arkansas', Aquaculture Economics & Management, vol. 10(3): 223-243.

Lovell, CAK and APB Rouse 2003, 'Equivalent standard DEA models to provide super-efficiency scores', Operation Research Society, 54: 101-108

Luu, Nguyen 2009, ‘Phu Yen: Nuoi tom the chan trang o cua song Da Nong- Duoc mua, mat gia’, Nghe nuoi trong thuy san o huyen Song Cau.

Ministry of Fisheries 2006, ‘Bao cao danh gia ket qua thuc hien chuong trinh phat trien nuoi trong thuy san giai doan 2000-2005 va bien phap thuc hien den nam 2010’ Ministry of Fisheries 2006, ‘So ket chuong trinh phat trien NTTS giai doan 2000 2005 va ke hoach phat trien NTTS giai doan 2006 – 2010 nganh thuy san Phu Yen’

National Extension 2012, ‘Phu Yen: Tuan thu dung lich thoi vu nuoi tom nuoc lo, nuoc man’

Ogundari K., S.O. Ojo, 2009, ‘An Examination of Income Generation Potential of aquaculture Farms in Alleviating Household Poverty: Estimation and Policy Implications from Nigeria’, *Turkish Journal of Fisheries and Aquatic Sciences,* vol. 9, pp. 39-45

Okechi, J. K., 2004, ‘Profitability assessment: a case study of African catfish (Clarias gariepinus) farming in the Lake Victoria basin, Kenya’, Kenya Marine and Fisheries Research Institute (KMFRI), Kenya.

Sathiadhas, R and Najmudeen, T M and Prathap, K Sangeetha 2009, ‘Break-even Analysis and Profitability of Aquaculture Practices in India’, Asian Fisheries Science, vol. 22 (2), pp. 667-680.

Sharma, K.R., Leung, P., Chen, E., Peterson, A., 1999, ‘Economic efficiency and optimum stocking densities in fish poly-culture: An application of data envelopment analysis (DEA) to Chinese fish farms’, Aquaculture, 180, 207– 221

Sharma, K. R. and P. S. Leung 2000, ‘Technical efficiency of carp production in India: a stochastic frontier production function analysis’, Aquaculture Research, vol. 31(12): 937-947.

Son Vu Nam, Phuong Nguyen Thanh, Hai Tran Ngoc, Amararatne Yakupitiyage 2010, ‘Production and economic efficiencies of intensive black tiger prawn (Penaeus monodon) culture during different cropping seasons in the Mekong delta, Vietnam’, Springer Science and Business Media B.V.

Timothy J. Coelli, D.S. Prasada Rao, et al. 2005, ‘An introduction to Efficiency and Productivity Analysis’, Second Edition, Springer: 172.

Tung, Pham Ba Vu 2010, ‘Technical efficiency of improved extensive shrimp farming in

Ca mau province, Vietnam', Msc. thesis, University of Tromsø, Norway & Nha Trang University, Vietnam.

Zhu, J. 2001, 'Super-efficiency and DEA sensitivity analysis', European Journal of Operational Research, 129: 443-455

http://www.google.com.vn/books?hl=vi&lr=&id=V2Rpu8M6RhwC&oi=fnd&pg=PA1&ots=E0zilhp_1M&sig=9VktqIQyux0vPT00nsksGQ3oLi8&redir_esc=y#v=onepage&q&f=true

http://vi.wikipedia.org/wiki/Vi%E1%BB%87t_Nam

http://en.wikipedia.org/wiki/Return_on_investment

http://hcm.24h.com.vn/thi-truong-tieu-dung/o-at-nuoi-tom-the-chan-trang-c52a402742.html

Appendices

Appendix 1: List of inputs and output variables used for technical efficiency (TE) analysis and TE scores (Black tiger shrimp)

Name	No. of labor/crop	Quantity of feed/crop	Chemical used (1,000 VND)/crop	No. of seed used/crop	Production (kg)/crop	Super-efficiency (CRS)	TE CRS	TE VRS	SE
B1	2	270	2000	30,000	180	0.71	0.71	1	0.71
B2	3	1,050	8000	50,000	600	0.84	0.84	0.84	0.99
B3	2	1,500	7000	60,000	900	0.95	0.95	1	0.95
B4	2	300	2000	35,000	200	0.69	0.7	1	0.69
B5	4	450	3400	70,000	280	0.57	0.57	0.62	0.93
B6	2	350	1200	40,000	200	0.68	0.68	1	0.68
B7	3	390	700	20,000	260	1.006	1	1	1
B8	5	2,550	12000	150,000	1,600	0.9	0.9	0.98	0.93
B9	2	370	2000	40,000	220	0.67	0.67	1	0.67
B10	2	300	1200	28,000	180	0.71	0.71	1	0.71
B11	2	100	1800	50,000	50	0.29	0.29	1	0.29
B12	4	3,400	15000	100,000	2,000	1.16	1	1	1
B13	2	150	500	15,000	100	0.79	0.79	1	0.79
B14	2	270	1500	30,000	195	0.78	0.78	1	0.78
B15	3	180	500	70,000	200	0.91	0.92	1	0.92
B16	3	1,300	3000	60,000	750	0.87	0.87	0.87	0.99
B17	5	2,500	10000	120,000	1,500	0.88	0.88	0.93	0.95
B18	2	1,350	3500	60,000	900	1.04	1	1	1
B19	4	250	1200	30,000	150	0.64	0.67	0.69	0.92
B20	4	3,000	7000	110,000	1,900	1.13	1	1	1
B21	2	650	2500	30,000	390	0.89	0.89	1	0.89
B22	3	1,200	7500	70,000	750	0.86	0.86	0.89	0.97
B23	4	220	2000	100,000	265	0.79	0.79	1	0.79
B24	2	80	1500	30,000	160	1.28	1	1	1
B25	3	1,300	3600	60,000	780	0.89	0.89	0.89	0.99
B26	2	335	1300	35,000	210	0.73	0.73	1	0.73
B27	2	120	900	30,000	120	0.75	0.75	1	0.75
B28	3	800	2500	65,000	480	0.79	0.79	0.79	0.98
B29	2	600	3000	50,000	400	0.86	0.86	1	0.86
B30	2	450	3500	40,000	280	0.75	0.75	1	0.75

Name	No. of labor/crop	Quantity of feed/crop	Chemical used (1,000 VND)/crop	No. of seed used/crop	Production (kg)/crop	Super-efficiency (CRS)	TE CRS	TE VRS	SE
B31	2	170	600	15,000	105	0.75	0.75	1	0.75
B32	6	1,500	12000	120,000	1,000	0.82	0.82	0.98	0.84
B33	2	900	10000	70,000	560	0.88	0.88	1	0.88
B34	2	70	1500	30,000	120	0.86	0.86	1	0.86
B35	3	800	2500	50,000	500	0.85	0.85	0.86	0.99
B36	2	380	2800	40,000	240	0.72	0.72	1	0.72
B37	2	350	1000	30,000	210	0.76	0.76	1	0.76
B38	2	1,500	11000	100,000	900	0.95	0.95	1	0.95
B39	2	800	5000	75,000	500	0.86	0.86	1	0.86
B40	2	250	3420	30,000	150	0.62	0.62	1	0.62
B41	2	495	3000	40,000	320	0.79	0.8	1	0.79
B42	2	240	2000	35,000	160	0.63	0.63	1	0.63
B43	5	1,500	8000	100,000	900	0.79	0.79	0.87	0.9
B44	2	280	1000	25,000	180	0.78	0.78	1	0.78
B45	2	450	1200	30,000	300	0.91	0.9	1	0.9
B46	2	240	800	30,000	150	0.69	0.69	1	0.69
B47	3	120	2000	100,000	162	0.7	0.7	0.71	0.98
B48 (*)	**2**	**530**	**500**	**30,000**	**320**	**1.59**			
B49	2	450	1200	30,000	300	0.91	0.90	1	0.90
B50	5	1,850	13000	130,000	1,200	0.88	0.88	0.98	0.90
B51	2	100	200	25,000	120	1.31	1	1	1
B52	2	480	2500	50,000	300	0.76	0.76	1	0.76
B53	2	370	700	20,000	255	1.03	1	1	1
B54	2	30	750	30,000	60	1	1	1	1
B55	2	390	700	20,000	245	0.96	0.96	1	0.96
B56	4	2,350	10000	90,000	1,300	0.86	0.86	0.87	0.99
B57	3	575	2000	70,000	350	0.72	0.72	0.73	0.99
B58	2	100	400	50,000	150	1.17	1	1	1
B59	3	830	2700	100,000	520	0.81	0.81	0.84	0.97
B60	2	800	3000	50,000	510	0.88	0.88	1	0.88
B61	3	600	1500	60,000	360	0.77	0.77	0.78	0.99
B62	4	2,100	12000	100,000	1,300	0.91	0.91	0.95	0.96

Removed DMU: B48 (super efficiency score = 1.59 >1.5)

Appendix 2: List of inputs and output variables used for technical efficiency (TE) analysis and TE scores (White leg shrimp)

Name	No. of labor/crop	Quantity of feed/crop (kg)	Chemical used (1,000 VND)/crop	No. of seed /crop	Production (kg/crop)	Super-efficiency (CRS)	TE CRS	TE VRS	SE
W1	3	1750	3500	200,000	1350	0.74	0.76	0.76	0.99
W2	3	2200	3500	220,000	2000	0.92	0.94	0.98	0.97
W3	4	5500	15000	750,000	4500	0.88	0.9	0.92	0.98
W4	5	4000	8000	1,000,000	3250	0.81	0.82	0.85	0.97
W5	5	1000	2000	600,000	1100	0.93	0.93	0.97	0.95
W6	4	4000	4200	500,000	3350	0.97	0.97	1	0.97
W7	2	1900	1500	240,000	1600	0.99	0.99	1	0.99
W8	3	3100	3000	400,000	2500	0.91	0.97	0.99	0.98
W9	2	180	450	150,000	200	0.97	0.91	1	0.91
W10 (*)	**2**	**4800**	**20000**	**560,000**	**4000**	**1.6**			
W11	5	7300	15300	900,000	6000	1.008	1	1	1
W12	2	2300	3700	300,000	2000	1	1	1	1
W13	3	4000	8500	500,000	1700	0.49	0.48	0.67	0.73
W14	2	90	1250	100,000	130	1.15	1	1	1
W15	3	2600	3000	200,000	2000	0.87	0.89	0.90	0.98
W16	7	8800	25000	1,600,000	7900	0.91	0.92	0.99	0.92
W17	3	770	1500	100,000	850	1.04	1	1	1
W18	3	200	1300	300,000	200	0.76	0.76	0.79	0.97
W19	6	6200	15000	900,000	5200	0.84	0.84	0.86	0.98
W20	2	850	3000	100,000	850	0.83	0.83	1	0.83
W21	2	800	2400	100,000	820	0.88	0.89	1	0.89
W22	4	5000	10500	600,000	4500	1	1	1	1
W23	3	1200	6000	200,000	1200	0.79	0.79	0.79	0.99
W24	2	280	300	150,000	300	1.04	1	1	1
W25	4	2000	8000	300,000	1700	0.69	0.69	0.70	0.98
W26	3	3500	12000	400,000	3000	0.87	0.87	0.91	0.96
W27	2	800	5000	100,000	680	0.67	0.67	1	0.67
W28 (*)	**3**	**2300**	**500**	**200,000**	**2000**	**2.13**			
W29	2	1250	3200	100,000	1000	0.77	0.77	1	0.77
W30	5	6300	16000	1,000,000	5500	0.92	0.92	0.92	0.99
W31	4	4100	12000	500,000	3500	0.84	0.84	0.84	0.99

Name	No. of labor/crop	Quantity of feed/crop (kg)	Chemical used (1,000 VND)/crop	No. of seed /crop	Production (kg/crop)	Super-efficiency (CRS)	TE CRS	TE VRS	SE
W32	2	1800	800	150,000	1500	1.05	1	1	1
W33	6	7000	20000	1,200,000	7200	1.05	1	1	1
W34	5	5300	13500	600,000	4600	0.89	0.89	0.9	0.98
W35	3	2300	7000	300,000	2000	0.79	0.79	0.79	0.99
W36	4	3400	11500	500,000	3000	0.79	0.79	0.8	0.99
W37	2	720	3500	100,000	800	0.87	0.87	1	0.87
W38	3	3350	7500	350,000	2800	0.89	0.89	0.89	0.99
W39	3	360	2000	200,000	400	0.86	0.86	0.86	0.99
W40	2	220	1600	150,000	250	0.86	0.86	1	0.86
W41	6	4700	17000	500,000	4300	0.82	0.82	0.89	0.93
W42	3	3350	8500	300,000	2800	0.89	0.89	0.90	0.98
W43	2	580	3000	100,000	600	0.81	0.81	1	0.81
W44	4	3800	10500	500,000	3600	0.92	0.92	0.93	0.99
W45	2	450	1200	120,000	500	0.91	0.91	1	0.91
W46	4	5300	14000	600,000	5000	1.03	1	1	1
W47	4	4400	11000	500,000	3500	0.82	0.82	0.82	0.99
W48	2	700	3000	80,000	750	0.85	0.85	1	0.85
W49	2	1150	5000	100,000	1450	1.22	1	1	1
W50	2	800	3420	100,000	850	0.84	0.84	1	0.84
W51	2	1050	3500	100,000	970	0.79	0.79	1	0.79
W52	7	9000	25000	720,000	8000	1.01	1	1	1
W53	2	1200	3200	100,000	1100	0.85	0.86	1	0.86
W54	3	2330	6500	200,000	1900	0.78	0.78	0.78	0.99
W55	3	3200	6000	200,000	2500	0.93	0.93	0.93	0.99
W56	4	2450	6500	350,000	2200	0.81	0.83	0.85	0.97
W57	2	1200	4000	100,000	1100	0.8	0.81	1	0.81
W58	2	360	1200	80,000	450	1.01	1	1	1
W59	5	4200	14500	500,000	4500	0.97	0.98	1	0.98
W60	3	2200	9500	250,000	2000	0.79	0.79	0.79	0.99
W61	2	500	2000	80,000	600	0.95	0.95	1	0.95
W62	3	2600	8000	250,000	2400	0.88	0.88	0.88	0.99
W63	6	6500	17500	600,000	5500	0.88	0.88	0.90	0.97
W64	2	1650	4000	130,000	1300	0.79	0.79	1	0.79
W65	3	400	1200	80,000	440	0.9	0.9	1	0.90

Name	No. of labor/crop	Quantity of feed/crop (kg)	Chemical used (1,000 VND)/crop	No. of seed /crop	Production (kg/crop)	Super-efficiency (CRS)	TE CRS	TE VRS	SE
W66	3	3800	6500	240,000	3200	1.15	1	1	1
W67	2	850	2500	80,000	950	0.98	0.99	1	0.99
W68	3	1600	6800	180,000	1450	0.72	0.72	0.72	0.99
W69	4	4900	14500	400,000	4100	0.92	0.92	0.93	0.99
W70	6	8000	16500	650,000	6200	0.9	0.91	0.95	0.95
W71	3	2500	8600	260,000	2100	0.77	0.77	0.78	0.99
W72	4	4500	11000	400,000	3800	0.9	0.9	0.91	0.99
W73	4	3000	4800	250,000	2500	0.86	0.87	0.94	0.93
W74	2	1000	3420	100,000	950	0.8	0.81	1	0.81
W75	6	7800	15500	600,000	6250	0.93	0.93	0.99	0.93
W76	2	1700	3800	130,000	1350	0.81	0.81	1	0.81
W77	8	9850	17500	1,000,000	8300	0.98	0.98	1	0.98
W78	3	1100	2800	120,000	1000	0.8	0.8	0.82	0.99
W79	4	750	1500	240,000	900	1.06	1	1	1
W80	6	7000	14000	500,000	5800	0.94	0.94	1	0.94
W81	5	5300	15000	440,000	5000	0.99	0.9	1	0.99
W82	4	3800	9200	330,000	3500	0.95	0.95	0.98	0.97
W83	2	420	1400	80,000	490	0.94	0.94	1	0.94
W84	2	1300	2700	90,000	1200	1	1	1	1
W85	3	3350	8000	250,000	2800	0.92	0.92	0.92	0.99
W86	3	3200	10000	280,000	3000	0.97	0.97	0.9	0.99
W87	2	1100	3000	150,000	1000	0.81	0.83	1	0.83
W88	2	1200	3200	100,000	1100	0.85	0.86	1	0.86

Removed DMU: W18 (super efficiency score =1.6>1.5), W28 (super efficiency score =2.13 >1.5)