Effect of Financial and Environmental Variables on the Production Efficiency of White Leg Shrimp Farms in Khan Hoa Province, Vietnam

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Abstract

Since 1997, development of white leg shrimp farming in Vietnam has attracted considerable attention due to its high export potential. Therefore, it is now necessary to assess the annual efficiency performance of white leg shrimp farms in order to improve Vietnam's aquaculture policy. This paper based on a character sample of 61 white leg shrimp farmers in Khanh Hoa province, representing about 13.2% of such farmers in Khanh Hoa, Vietnam. Using an output-oriented VRS Data Envelopment Analysis, the standard efficiency was measured and then regressed to the farmer characteristics and production environment to identify the determinants of technical efficiency for those farms. The empirical results suggest that socio-economic factors such as education and experience are positively related and experience more significance than education, to the efficiency of white leg shrimp farmers. Some environmental factors, such as more distance from a channel, imply worse results for efficiency in white leg shrimp production. Financial factors, such as the proportion of total costs relative to total income, the proportion of variable costs relative to fixed costs, sales margin and return on asset have a positive effect on efficiency of the farmers. In addition, comparing the technical efficiency results of planned farms and unplanned farms, groups near to the channel and far from the channel, farmers who have a water keeping pond and those who do not have a water keeping pond, it was seen that the unplanned, far from the channel, and non-water keeping pond farms were less efficient than their counterparts. Therefore, this study suggests that there is a strong incentive for planned aquaculture. As it was seen that water sufficiency is necessary for efficient farming, additionally, it is better for a farm to be near the channel. If, however, it is far from the channel, a water keeping pond without culture is recommended. Moreover, having more experience in a cultured system was also suggested as a way to have the desired increase in productivity. Finally, further study about congestion problems, which have not been dealt with in this study, is recommended.

Dedication

This work is dedicated to my mother and my husband who have supported me greatly in my endeavors. The most important dedication is to my daughter, Nihan and my sons, Abir and Tamim who represent my future.

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Abbreviation

AE	Allocative Efficiency
AE_I	Allocative Efficiency of Input
AE_O	Allocative Efficiency of Output
BCC	Banker, Charnes and Cooper
CCR	Charnes, Cooper, and Rhodes
CE	Cost Efficiency
$CE_{\mathbf{I}}$	Cost Efficiency of Input
CRS	Constant Returns to Scale
CRSDEA	Data Envelopment Analysis with Constant Returns to Scale
DEA	Data Envelopment Analysis
DMU	Decision Making Unit
EA	Environmentally Adjusted
EE	Economic Efficiency
FCR	Feed Conversion Ratio
GO	Government Official
LP	Linear Programming
NGO	Non Government Official
OLS	Ordinary Least Square
PFPF	Probabilistic Frontier Production Function
RE	Revenue Efficiency
RE_O	Revenue Efficiency of Output
SE	Scale Efficiency
SPF	Stochastic Production Frontier
TC	Technological Change
TE	Technical Efficiency
$TE_{\mathbf{I}}$	Technical Efficiency of Input
TE_O	Technical Efficiency of Output
TFP	Total Factor Productivity
T	Traditional

VRS	Variable Returns to Scale
VRS DEA	Data Envelopment Analysis with Variable Returns to Scale
VND	Vietnam Nam Dong

1. Introduction

1.1 Problems Statement

Production of white leg shrimp (*Penaeus vannamei*), is a very important economic activity in the overall farming system of Vietnam. The practice of white leg shrimp culture is gaining popularity in most areas of Vietnam. Within the overall agro-fishery-based economy of the country, the contribution of white leg shrimp production has been considered promising for creating jobs, earning foreign exchange and supporting protein (Neilanda et al., 2001). Development of white leg shrimp farming has attracted considerable attention since 1997 due to its export potential. The shrimp sector is the largest export industry of Vietnamese aquatic products, generating US$1,625,707 thousand in 2008 and 36% of the total value of exports in 2009 (Tien D.,Griffiths D., 2010). In 2005, there were 3 million people employed in the fisheries sector in Vietnam with 300,000 working in aquaculture. In 2010, 2 million household members may be associated with the fisheries sector and 1,400,000 of those may be specifically associated with aquaculture (Thang N., 2005). Most of the white leg shrimp are exported to Japan (31%), USA (29%), and the EU (14%) by value in 2008. In this year, white leg shrimp contributed 20-30% to total shrimp exports (Tien D., Griffiths D., 2010). Vietnam's shrimp exports increased to 18.8% in volume and 7.7% in value out of total exports in the financial year 2007. At present, Vietnam is one of the largest shrimp producers in the world. The main reasons for the increasing popularity of white leg shrimp, include, firstly ease of breeding and domestication, secondly ease of high density culture, thirdly lower protein feed requirement than black tiger shrimp, fourthly tolerance of low water temperatures and fifthly tolerance of poorer water quality than black tiger shrimp. Therefore, in recent years, the production of white leg shrimp has increased rapidly in the Central, South Central and Northern provinces of Vietnam (Tien D., Griffiths D., 2010).

Khanh Hoa is one of the largest provinces of South Central Vietnam. Here, white leg shrimp culture is an important commercially feasible activity due to favorable climatic conditions. The waters of Khanh Hoa are highly productive and about 30,000 people are directly and indirectly involved in aquaculture activities in this province. White leg shrimp farming is the most dominant aquatic product and is the second highest culture after black tiger shrimp in 2008 (Khanh Hoa Agricultural office report, 2009).

The research area is presented in Figure 1.

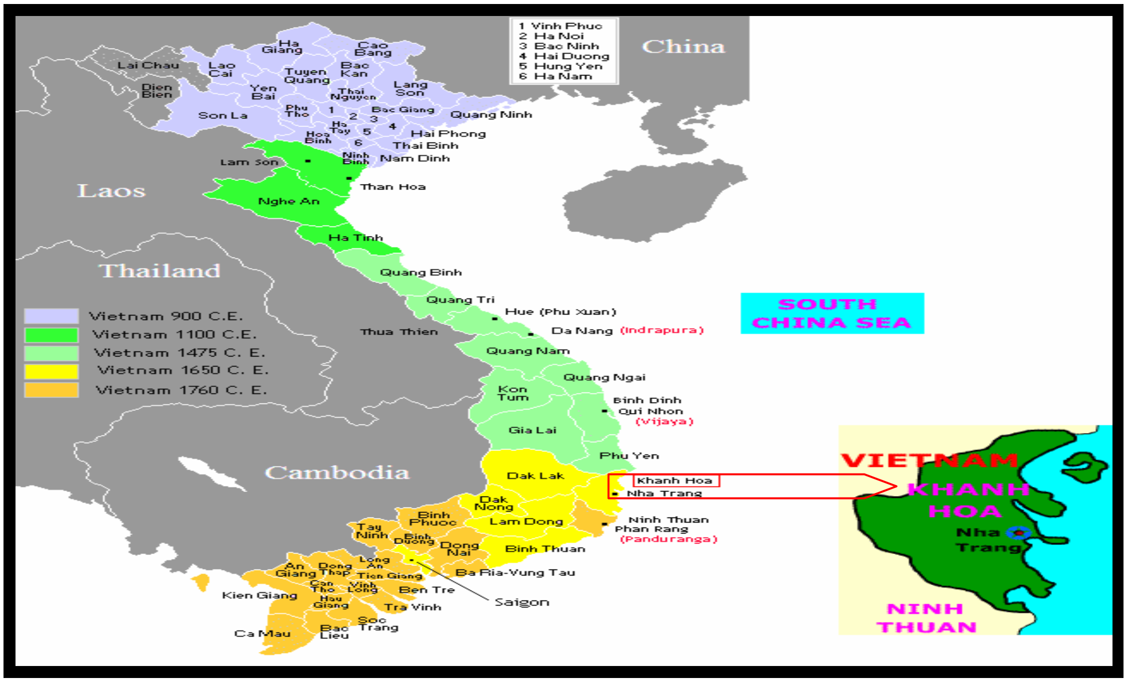

Figure 1 Map of Study Site

Source: http://upload.wikimedia.org/wikipedia/vi/5/56/Vietnam_Expand1.gif

White leg shrimp culture is labor intensive in Khanh Hoa and provides substantial employment, not only in production but also in transportation, processing and marketing. Together with medication, there has also been an intensive chemical input processing sector for white leg shrimp farming. Nowadays, white leg shrimp farming is said to expand the efficiency of aquaculture. The truth of this statement may depend firstly on a farmer's efficiency in production. Although white leg shrimp farming in Khanh Hoa needs managerial skills and up-to-date information, farmers have great constraints in understanding and adopting new technologies due to their low level of education, poor extension services, insufficient physical infrastructure and lack of credit and control (in terms of planning from the government at different levels), and vulnerable development of this industry relating to environmental impact. All of these things cause Vietnamese farmers to fail to fully utilize the potential of technology by making inefficient decisions. Many policy makers have, therefore, highlights on improving output and efficiency as an important source of possible growth in the white leg shrimp sector in Vietnam. However, farm level in turn on efficiency and output is unsatisfactory, especially on white leg shrimp farms. The expression of the commercial benefits of white leg shrimp, will eventually lead to reproduction in other provinces that can reach thousands of aquaculture farmers.

There are a few studies of shrimp production in other parts of Vietnam but, to my knowledge, no studies have been conducted to estimate technical efficiency using Data Envelopment Analysis (DEA) for white leg shrimp farming in Khanh Hoa. My thesis will focus on the following research question: Does white leg shrimp farming constitute an efficient use of resources? What are their technical efficiency levels? How many inputs were actually used and must be used, especially in the condition of limited assets such as pond range, existing man power, experienced staff and workers, seed and feed, infrastructure and so on? What are the output levels? Which factors should be restricted to improve technical efficiency? Are there any differences in level and determinants of technical efficiencies between efficient and non-efficient farms? Does the distance of the existing farms from the channels affect their efficiency? The answer to these questions will provide essential and useful information not only for the farmers themselves, but also for policy makers and the fisheries extension offices at both the local and central levels.

1.2 Objectives

a) To investigate what variables distinguish the efficient producers from the less efficient producers of white leg shrimp in Khanh Hoa province, Vietnam.

b) To do this, technical efficiency for a selection of white leg shrimp farms in Khanh Hoa province will be calculated using the DEA approach.

c) To identify whether there is a relationship between identifiable environmental factors and white leg shrimp production efficiency.

1.3 Research Hypotheses

a) Planned white leg shrimp farmers are more technically efficient than unplanned farmers.

b) The farmers who are near to the channel are more efficient than farmers who are far from the channel.

c) In the “far from channel farmers” category, the farmers who have a water keeping pond are more efficient than other farmers.

d) Individual characteristics of the farmers such as experience, education and distance of the existing farms from the channels are significant factors affecting the technical efficiency of white leg shrimp culture production.

1.4 Method and Methodology

The primary data used for conducting this research was cross-sectional data samples for the 2009 crop year. Primary data was collected through direct interviews with white leg shrimp farm operators in Khanh Hoa province from Dec-2009-January 2010. Secondary data was obtained from the Khanh Hoa Agricultural office. A DEA output-oriented model was employed to measure the pure technical efficiencies of each farm. Resulting estimates of farm technical efficiency scores were regressed by Ordinary Least Square (OLS) on environmental variable such as: distance from channel, some financial variables (the proportion of total costs relative to total income, the proportion of variable costs relative to fixed costs , sales margin, return on asset), in addition to other specific factors (experience in farming, age of household head, education level of household head) hypothesized to influence farm efficiency , in order to determine the importance of those different factors in explaining efficiency levels.

1.5 Organization of the thesis

The outline of the paper is as follows: Chapter 2 provides an overview of aquaculture in Khanh Hoa, chapter 3 explains the existing literature on production efficiency and measurement, the DEA method to measure the efficiency and applications of DEA in aquaculture. This chapter also presents the summary and results of recent studies relating to the relationship between financial experience and production efficiency. Chapter 4 describes the methods used to analyze the technical efficiency of the selected white leg shrimp farms in Khanh Hoa province and to estimate the effects of farm-specific factors, including the farm’s financial variables, on the production efficiency. The data used in the two steps of analysis are also described fully in this chapter. Chapter 5 presents the results and discussions of the thesis. Chapter 6 includes the summary, conclusions and implications of the thesis.

2. Overview of Aquaculture in Khanh Hoa

Aquaculture has been the most lucrative commercial activity in Khanh Hoa since it commenced in the mid-eighties using 5,197 km^2 land area. Khanh Hoa has a coastline of about 385 square kilometers and considerable climatic and geographic advantages for brackish water and marine aquaculture (Khanh Hoa Agricultural office report, 2009). Aquaculture is one of the major sources of income for poor rural households in the coastal areas of Khanh Hoa province, supporting more than 28050 people who were somehow engaged in backward and forward activities of aquaculture in 2006 (Dung V.,2008). The total area of brackish saline water farming 4,808 ha the area about 3,000 hectares of shrimp farming, intensive farming is now about 20% ha, 80% semi-intensive farming. The remaining 1808 ha area adopted an intercrop for shrimp, a fish or a service for weeds (Khanh Hoa Agricultural office report, 2009).

2.1 Contribution of Aquaculture

The aquaculture sector is a significant contributor to the economy of Khanh Hoa. The industry recorded its peak economic performance in the year 2006. Direct production value in 2006 was approximately 22.365 metric tonnes approaching a value of 1210.29 million Vietnam Nam Dong (VND). The relative contribution from aquaculture represented about 46% of the revenue generated from the fisheries sector in 2006. An export earnings from fish, shrimp and other seafood products totaled about $245 million in value and were 45.5tonnes by volume in 2006. Shrimp was the main product. Both the aquaculture and the marine fisheries sectors have expanded rapidly over the past decade. Aquaculture production has increased rapidly to around 7425.6 tonnes, while marine fisheries contributed in excess of 1469.64 tonnes. Inlands fisheries contribution was constant from 2002 to 2006 (Dung V., 2008).

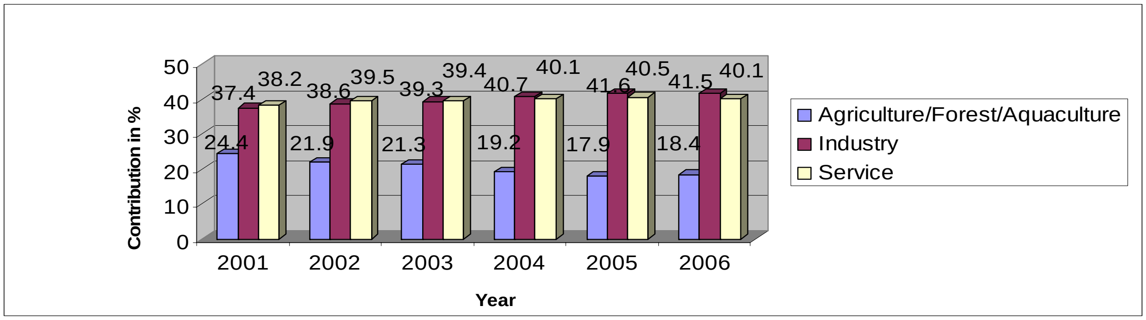

Figure 1 Different Sector's Contribution in Khanh Hoa from 2001-2006

Source: Dung V., 2008

From the Figure 1 we can see that the contribution of agriculture/forest /aquaculture is decreased from 2001 to 2006 in Khan Hoa.

The following figure 3 shows the contribution of agriculture, forest and aquaculture sector in Khanh Hoa between 2001 and 2006.

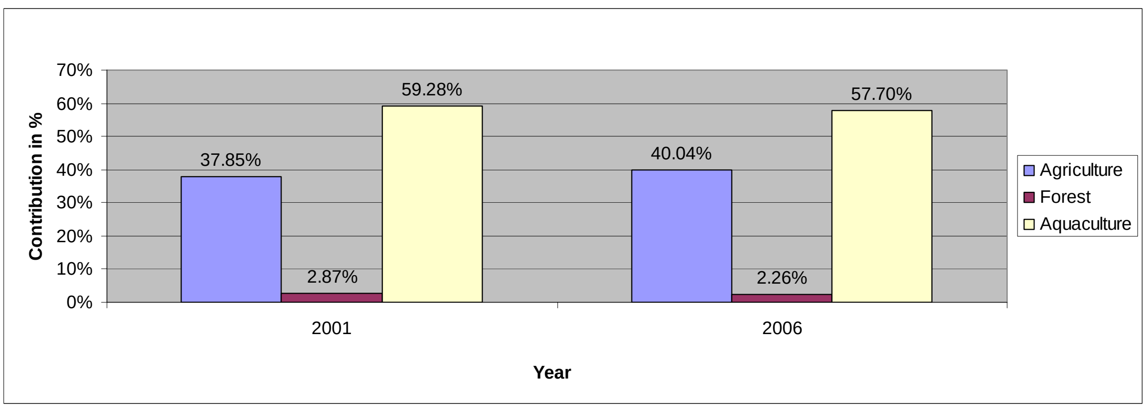

Figure 2 Agro-Fishery Sector's Contribution in Khan Hoa between 2001 and 2006

Source: Dung V,, 2008

When reviewing the bar chart we can see that the contribution of Aquaculture was decreasing from 2001 to 2006.

2.2 Kinds of Production

Khanh Hoa is one of the biggest producers in Vietnam in coastal aquaculture, especially in grouper, lobster and shrimp culture. Freshwater fish farming plays only a minor role. Marine mollusks are also of limited production, although pearls, mussels, abalone, scallops and Babylonia are cultured. There has been some foreign investment in marine fish cage culture and hatcheries in Khanh Hoa .The region is the largest lobster producer in Vietnam. Shrimp farming is also a dominant activity in aquaculture in Khanh Hoa (Khanh Hoa Agricultural office report, 2009).

The following table 1 shows financial source of investment to develop fishery industry in Khanh Hoa from 2001 to 2006

Table 1 Investment to Develop Fishery Industry in Khanh Hoa From 2001-6 (million VND)

Investment in fishery	Total	Govt.loan	local people loan	Others
Fishing	134.000	4.000		130.000
Processing	428.000	8.000	110.000	310.000
Fishing related services	50.993	46.207		4.786
Aquaculture	713.313	75.313	60.000	578.000
Marine	540.000		40.000	500.000
Fresh water	32.000	1.000	1.000	30.000
Another project	139.000	75.000	14.000	50.000
Other	30.213	0.213	5.000	25.000

Source: Dung V., 2008

2.3 Unplanned and Planned area

2.3.1 Unplanned area

Since the encouragement to develop aquaculture by the central and local government with land's law in 1993, the privatization of farm surface has become common. The fishers who located their fixed gears on farm area in the past could now replace them with their own permanent fish net enclosures. Moreover, other fishers and local landowners could also stake out private aquaculture areas in the farming area. Fishers and farmers were encouraged to convert water surface and land around farming areas into aquaculture areas. Therefore, some areas of cultured water territory were covered by aquaculture net-enclosures and another area of the water surface was occupied by shrimp ponds built out from flooded rice fields on the low-lying shore. With the privatization of farming surfaces, the fishers tried to get as great economic returns as possible without considering sustainability or the environment. That resulted in the decline of water quality and current flow. Water pollution led to widespread disease. Hence, lost and unstable aquaculture crops were common (Tyler, Phap and Thuan 2002; Tuyen 2005; Dung V., 2008).

2.3.2 Planned area

In order to solve the problems of unplanned area and ensure sustainable access to farming area resources, local people and governments together with many GO and NGOs programs have made enforcement to open water ways by removing parts of net-enclosure in some area around Khanh Hoa in the recent years. Some projects supported by some foreign donators applied participatory management in planning the farming resource governance in some area (Khanh Hoa Agricultural office report, 2009).

The government at district levels agreed with commune authorities to develop planning of farming area and then allocate aquaculture ponds to individual households or enterprises by land using contracts (Tuyen, 2005). Those planned areas might have less effects of disease or water pollution on productivity and open water ways. Sometimes the government would help in giving loans and taking leases on farm land (Dung V., 2008).

2.4 Shrimp Farming in Khanh Hoa:

Shrimp farming is dominant with a production of 15,500 tons in 2003, or 78% of total aquaculture production in the area. White leg shrimp culture is a profitable industry, involving approximately 500 farmers/households and creates many employment opportunities for local village people. There are 15 hatcheries and 21 breeding farms for white leg shrimp of which 5 hatcheries are in Nha Trang city, 5 in Ninh Hoa, 3 in Cam Ranh and 2 in Van Ninh (Khanh Hoa Agricultural office report, 2009).

2.5 Share of White Leg Shrimp in Export Market

Production of white leg shrimp in Khanh Hoa is reasonably efficient and lower cost than other provinces of Vietnam, particularly for export products. USA, Japan, EU are the main importers of white leg shrimp of Khanh Hoa in 2006.

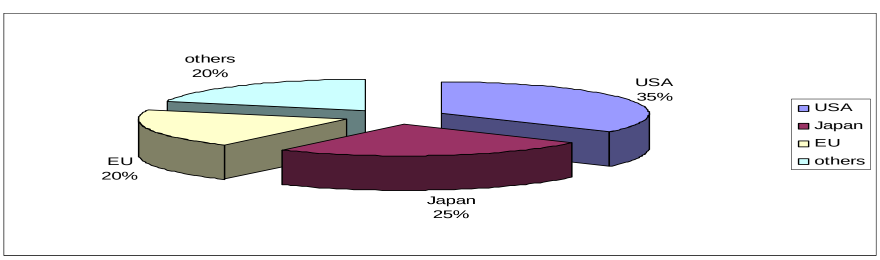

Figure 3 Share of Khan Hoa's White Shrimp Export Market in 2006

Source: Dung V., 2008

2.6 Development Programs for Aquaculture in Khanh Hoa

Khanh Hoa is implementing several projects for development programs in aquaculture, as follows:

a) Observing the production area and testing seed.

b) Observing irrigation of shrimp farming areas.

c) Helping farmers to borrow money from banks by especially with Bank for Agriculture and Rural Development.

d) Training human resource and applying extension work.

e) Establishing the Association of Shrimp in the districts, towns, cities to people involved in learning and exchanging experiences.

f) Reducing white leg shrimp quarantine fees to encourage farmers to quarantine animals before going commercial farming.

g) Currently the production of white leg shrimp facilities are agencies specialized supervision, thus quality is guaranteed (Khanh Hoa Agricultural office report, 2009).

3. Literature Review on Efficiency of Aquaculture

3.1 Definitions and Determination of Efficiency

Farrell (1957) proposed a provocative idea to define the output of the most efficient firm as the production frontier for all firms. Economic Efficiency (EE) is separated into two components: Technical Efficiency (TE) and Allocative Efficiency (AE). Technical efficiency (TE) is the ability of a firm to obtain maximum output from a given set of inputs. According to Farrell (1957) technical efficiency, is defined in relation to a given set of firms, in respect to a given set of factors measured in a specific way, and any change in these specifications will affect the measure. This is inevitable in any such measure. But with these qualifications it functions in a natural and satisfactory way as a measure of efficiency, whereas allocative efficiency is the ability of a firm to use the inputs in optimal firm to use the inputs in optimal proportions, given their respective prices proportions, given their respective prices (Lovell, 1993). Price efficiency (allocative efficiency) is very sensitive to the introduction of new observations and to errors in estimating factor prices (Farrell, 1957).

Efficiency can be measured in terms of input-orientation or output-orientation. In which, input-orientated efficiency finds time as a target point maximizing the proportion reduction in inputs or produces a given level of output from an optimal combination of inputs. Meanwhile output-orientated efficiency finds out at an angle that maximizes the proportional reinforcement in outputs or produces the optimal output from a given set of inputs.

Input-Orientation

Input-oriented technical efficiency says if we fix the output quantities produced, how much input quantities will be proportionally reduced. In a simple model we can measure 2 inputs and 1 output, under the assumption of constant returns to scale, input-oriented efficiency is illustrated in Figure 1.

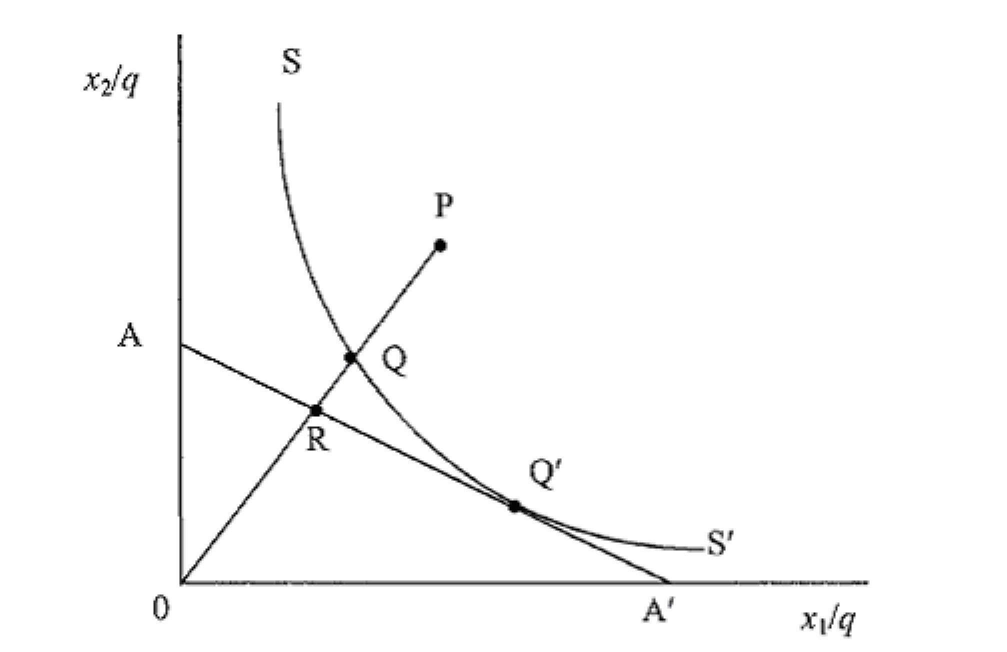

Figure 1 Technical Efficiencies and Allocative Efficiencies from Input Orientation

Source: Coelli et al., 2005

From this figure, the technically efficient firms are those that provide the curve SS'. Hence, Q and Q' are technically efficient points. Meanwhile, P shows technically inefficient point and the inefficiency of that firm could be explained by the distance OQ/OP when it is less than one. It means that the firm could diminish the use of both inputs from P to Q without the fall in output. In other words, with the purpose of attaining technically efficient production that firm would have to condense all inputs proportionally by QP/OP and the technical efficiency of a firm is usually measured by the ratio:

$$TE_I = OQ/OP$$

The technical efficiency term will be between zero and one. A firm is completely technically efficient if it's technical efficiency score is equal to one, and vice versa. If unit costs of inputs are existing, AA' represents an iso-cost line. Hence, R or Q' have the same total cost. However, the output at R point production is lower than at Q', which is the intersection between AA' iso-cost and SS' iso-quant (production frontier). Therefore,

Q' is said to be technically efficient as well as allocatively efficient. And the cost efficiency can be expected by the ratio:

$$CE_I = OR/OP$$

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

$$AE_I = OR/OQ$$

$$TE_I = OQ/OP$$

From those equations, the relation between technical, allocative, and cost efficiency can be explained by:

$$TE_I \times AE_I = (OR/OQ) \times (OQ/OP) = OR/OP = CE$$

Output-Orientation

Output-oriented technical efficiency says if we fixed the input quantities used, how much output quantities would be proportionally expanded. When we take the case of producing two outputs from a single input, output-oriented efficiency is explained in Figure 6. In this figure, the firms which are on the frontier curve ZZ' are technically efficient. A lies below the ZZ' curve. Hence, A is an inefficient point. And the distance AB shows technical inefficiency that outputs could be expanded without requiring extra inputs. Therefore, output-oriented technical efficiency is measured by the ratio of OA and OB

$$TE_O = OA/OB$$

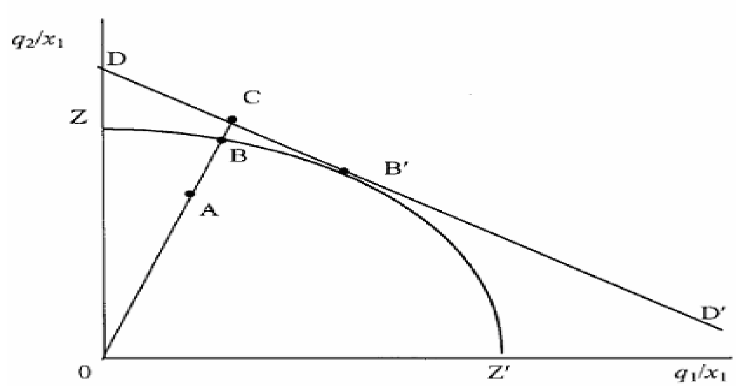

Figure 2 Technical and Allocative Efficiencies from Output-Orientation

Source: Coelli et al., 2005

Same to the input-oriented case, if the unit prices are obtainable, DD' shows the iso-revenue line. Hence, the intersection between the ZZ' technical efficient curve and DD' iso-revenue line, B' is said to be revenue efficient. And the revenue efficiency can be denoted by the ratio:

$$RE_O = OA/OC$$

Then allocative efficiency and technical efficiency can also be calculated by the ratio:

$$AE_O = OB/OC$$

$$TE_O = OA/OB$$

The relation between technical, allocative, and cost efficiency, can be denoted by:

$$TE_O \times AE_O = (OA/OB) \times (OB/OC) = OA/OC = RE$$

In review, the level of technical efficiency of a firm can be denoted by the relationship between observed production and the best practice production. A firm is technically efficient if its production point is on the boundary. In contrast, it is technically inefficient if the production point of that firm lies beneath the boundary.

3.2 Measurements of Efficiency

From the study of Farrell (1957) and the particular research on efficiency measurement for production units of Charnes, Copper, and Rhodes (1978) and Banker (1984), the two approaches of non-frontier and frontier have been developed to compute the technical efficiency in production. Wherein, non-frontier measures the technical efficiency by comparing the actual output and the standard frontier which is estimated from the trial data. As a result, while one can separate and consider the interaction between conventional and non-conventional inputs by the former, it is too costly to manage new study. Additionally, the valid condition in production might not be showed by trial conditions. The later approach explains the maximum output that can be produced from any given combination of inputs by an efficient firm. It has been classified into different methods. Data envelopment analysis and stochastic frontier analysis are the two most common techniques. Both techniques have advantages and disadvantages. A general decision making measurement frame work normally is based on the ranking and measurement of efficiency of non profit organizations by Data Envelopment Analysis and Stochastic Frontier Function. When we assume all firms are not necessarily technically efficient DEA and stochastic frontiers can be used to measure both technical change and efficiency change, if cross sectional, sometimes panel data are available.

DEA and stochastic frontiers are two alternative methods for estimating frontiers functions and DEA involves the use of linear programming whereas stochastic frontiers involve the use of econometric methods. Farrell (1957) suggested that the function be estimated from sample data using either a non-parametric piece-wise-linear technology, which results in the results development of the DEA approach, or a parametric function, which results in the or a parametric function, which results in the development of the stochastic frontier model.

3.2.1 Stochastic Production Frontier (SPF)

Aigner et al.(1977) and Meeusen and van den Broeck (1977) developed the Stochastic Production Frontier (SPF) function . SPF analysis is a parametric and econometric approach. This approach builds up a production function based on "average" values of the observed data. The advantage and novelty of this approach is taking into account the stochastic variation and variation due to inefficiency at the same time. This will be important if the output is affected by random noise. However, this method requires a specific functional form such as a Cobb-Douglas, translog or quadratic function to estimate the production function and it is necessary to have some distributional assumptions to divide the stochastic component from the inefficiency factor. Moreover, it is not useful in multiple output situations. Therefore, it will be a weakness for any production function with more than one output. Another approach to the solution of the "noise" problems is the stochastic frontier approach.

3.2.2 Data Envelopment Analysis (DEA)

Farrell (1957) firstly considered calculating efficiency based on the structure of hypothetical firms as a weighted average of some of observed firms. Since then, some literature has discussed the efficiency based on his ideas. Charnes et al. (1978) construct the efficient frontier as an envelopment of the data by using Linear programming methods. The consequential model is called Data Envelopment Analysis, DEA.

DEA measures the relative efficiency in the existence of not only single input-output but also multiple input and output factors at farm level or Decision Making Units (DMUs). When the weights are limited, efficiency of DMUs could be defined as the ratio of the weighted sum of outputs over the weighted sum of inputs

$$\text{Efficiency} = \frac{\text{Weighted sum of outputs}}{\text{Weighted sum of inputs}}$$

Consequently, even though missing taking into account the random error due to the deterministic nature, the major advantage of DEA approach is that DEA can be applied in multi input – multi output conditions. It is a non-parametric method and constructs the efficient frontier based on extreme values of the observed data. It uses linear programming techniques to measure efficiency. Thus, it is unnecessary to assume earlier any specific functional form or any assumption on distributions of error.

DEA can also identify sources and amounts of inefficiency in each input and each output for each farm, and identify the benchmark members of the efficient set. According to P. Smith (1990), when applying the principles of DEA to financial statements , a number of shortcomings have been identified. Such as:

a) Many inputs and outputs are not matched; that is, inputs, for example research and development expenditures, are often not recorded in the same accounting period as the benefits they give rise to.

b) There are considerable measurement difficulties, particularly with regard to the opportunity cost of capital inputs (the whole problem of inflation accounting is one example of this difficulty).

c) Even within a single industry, the entities being considered are not strictly comparable, perhaps operating in different markets, and being exposed to different risks.

d) Financial statements do not present much of the data in a sufficiently disaggregate form to undertake a full comparison of performance.

e) There are considerable variations in accounting practice, for example with regard to capitalization and depreciation and of course accounting periods vary.

In using DEA, we have to face some difficulties, such as :

a) There is the problem of determining which inputs and outputs should be selected for inclusion in the model. There is no device such as the selection procedure implicit in stepwise regression techniques to guide the analyst.

b) Arising from its treatment of stochastic variability. In contrast to statistically based methods, the technique relies on a search for outliers to identify the efficient frontier. In forcing the analyst to decide whether the outlier offers a genuine representation of feasible technology. Comprehensive sensitivity analysis is called for in the absence of any assumptions regarding the statistical distribution of variables.

If adequate data are available, the technique could be applied to the securities market it self, for example in identifying efficient portfolios. Such applications lie available financial statement data. One by-product of the analysis is a set of target performance indicators for inefficient firms, derived from the performance of the efficient comparison group. The success of data envelopment analysis in analyzing public sector service has to some extent been due to the wealth of data available, and the direct comparability of one entity with another. The problem with outliers to identify the efficient frontier in financial statement analysis has been to determine whether the inclusion of an outlier distorts the stochastic averaging procedure implicit in most statistical techniques.

Table 1 Comparison Between SRF and DEA

SRF	DEA
SRF has some advantages, such as 1. To allow for random shocks and measurement error. 2. It is possible to analyze the structure, and investigate the determinants of, producer performance. Therefore, it has a more solid grounding in economic theory. Weaknesses: (a) It is risky to impose strong a priori assumptions on the production technology by choosing a functional form (e.g. Cobb–Douglas, translog, etc.), given that most of the distributional characteristics of the production technology are a priori unknown. (b) The specification of the error structure is difficult to ascertain. In addition, such specification is likely to establish another potential source of error. (c) The continuity presumed in this approach may lead to approximation errors.	Some characteristics of DEA 1. A non-parametric method – using in pareto- efficiency of a Decision Making Unit (DMU). 2. Employs a piece wise linear frontier. 3. Solve n linear programs with one objective function for each DMU. 4. DEA principle applicable to determine observations. (Sengupta J.,1987) DEA has some advantages, such as : a) DEA could be applied neither a specific functional relationship between production output and input, nor any assumptions on the specific statistical distribution of the error terms. b) Minimal specification error. However, the DEA model does not allow for measurement error or random shocks. Instead, all these factors are attributed to (in) efficiency , a characteristic that certainly leads to potential estimation errors.

Source: Cullinane et al., 2005

In this study the DEA method to measure efficiency was chosen more than the stochastic frontier production approach for three main reasons. Firstly, data envelopment analysis is able to handle multi-outputs of white leg shrimp of the sample farms, which can not be handle stochastic production frontier. Secondly, it is unnecessary to communicate any functional form or any assumption on distribution of error, which is required in stochastic frontier production. Additionally, using data envelopment analysis a two-step approach can also identify the factors that effect technical efficiency results.

3.3 Empirical Studies on Technical Efficiency of Aquaculture

A great range of applications of DEA have been done in many studies to examine technical, allocative, cost and scale efficiency by applying input and output oriented models in many different activities in many different situations in many different countries. Areas where DEA is commonly used are hospitals, business firms, universities, cities, courts, banks and others, including the performance of countries, regions, etc. There are a number of efficiency studies applying DEA to agricultural sectors in many countries. But, using DEA on aquaculture has not been as common in comparison to these other areas.

The research of Bui Le Thai Hanh (2009) provides the analysis of the relationship between farm financial exposure and technical efficiency in the pangasius farming in An Giang province, in the Mekong Delta of Vietnam. A nonparametric DEA approach was applied to estimate technical and scale efficiency scores of 61 pangasius farms in An Giang province in the year 2008. Research results suggest that technical efficiency is influenced by investment level of farms as well as by farm operator's experience. The farms that have more investment will be more efficient (Bui Le Thai Hanh, 2009).

Kareem, Dipeolu et al. (2008) projected the economic efficiency of fish farming in Ogun, Nigeria using a stochastic frontiers production approach. Cross section data of 85 fish farms grouped into existing and mud pond type in this area were used. The analysis was derived from the Cobb Douglas production function involving fish production in kilograms and 6 inputs together with pond area, feed, lime, fingerlings, labor, and other materials. The technical inefficiency function involved experience, age and education of the operators and his/her household size. The empirical results revealed that the mean technical efficiency of concrete pond and earthen pond type were almost the same, about 0.88-0.89. And experience of the operators had a negative effect on the inefficiency of the existing pond. (Kareem, Dipeolu et al., 2008).

The study of Dang Hoang Xuan Huy (2009) used a minimizing input-oriented CRS DEA model with two output and five input variables which used the theory of technical efficiency. It mainly used Nha Trang‘s data (64 samples) to analyse, data from other areas in Khanh Hoa province. There are 25% performances of Black Tiger Prawn DMU is efficient and 75% performances of DMU are inefficient in Nha Trang city. He put to conduct for each of the inefficient factors. These were the units that management would focus on to improve input factors or resource reduction. (Dang Hoang Xuan Huy,2009)

Alam and Murshed-e-Jahan (2008) discussed the resource allocation efficiency of prawn-carp poly-culture systems in Bangladesh using DEA approach. Cross section data of 105 prawn-carp farms in this country were applied. The efficiency estimation was based on two outputs (prawn and carp) and four inputs (labor, fingerlings, inorganic fertilizers, organic fertilizers and feed) and the main results explained 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. Moreover, pond size was seen to have a positive effect on technical and cost efficiency. And there was a negative relationship between pond size and allocative efficiency, and between feed used and technical, allocative and cost efficiency (Alam and Murshed-e-Jahan ,2008).

Amos (2007) tested the productivity and technical efficiency of crustaceans in Nigeria using a SPF approach. Data from 100 crustacean farms in five villages in the Iaje Local Government Area of this country were used. The analysis was derived from Cobb-Douglas frontier production function with one output of the value of crustacean formed per hectare and five inputs: labor, cost of feed, equipment, foundation stock, and other costs. In which, feeds and equipment cost were seen to significantly affect technical efficiency. The empirical results explained that the mean technical efficiency of producers was 0.7. Moreover, it was seen that age of producers had a negative effect while family size had positive effect on technical efficiency (Amos, 2007).

Den et al. (2007) tested the technical efficiency of prawn farms in the Mekong Delta in Vietnam using SPF approach. Cross section data in 2004 of 193 prawn farms classified into extensive and intensive farms in this area were used for analyzing. The analysis was based on the Cobb Douglas production function in the first step involving one output of kilogram prawn per hectare per year and seven inputs: fingerlings, feed, chemical inputs, fuel, hired labor, type of prawn (dummy) and the farm definite technical inefficiency in the second step involving four inputs: farm area, and experience, age, education of the operators. The main results said that the mean technical efficiency was 46 percent. In which, extensive farms were technically more efficient than intensive farms with correspondingly 0.48 and 0.35. Additionally, there was a positive relationship between experience and technical efficiency. However, it was viewed that the younger the operators were, the more technically efficient the farms were (Den, Ancev et al., 2007).

The study of Hoang Van Cuong, 2009 was implemented with two main purposes, firstly reviewing the literature on efficiency and DEA methods, secondly applying certain DEA methods to examine the technical and scale efficiency of the intensive tiger shrimp farms in Binh Dai district, Ben Tre Province, Vietnam. In the thesis, therefore, after literature on efficiency and DEA methods were reviewed, a case study of measuring the performance of shrimp farms in Binh Dai district was implemented. In analyzing the case study, input oriented CRS and VRS DEA models were applied to measure the technical and scale efficiency of shrimp farms. Furthermore, super efficiency was also considered to have better ranking for the farms performance results from examining the intensive shrimp farming shows that at normal production process, the intensive tiger shrimp farms in Binh Dai district are quite efficient. Purely technical efficiency and scale efficiency level of the shrimp farms are rather high (on average above 90 percent). These results express that as risk factors are controlled, the intensive shrimp farming technology can control quite well the production process, so it could be encouraged to be applied (Hoang Van Cuong, 2009).

Cinemre et al., (2006) examined the cost efficiency of trout farms in the Black Sea Regionof Turkey using a two-stage DEA approach. Cross section data of 73 trout farms were applied. The analysis was derived from two inputs (feed and labor), a single output (trout) framework in the first stage, and Tobit model with 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) in the second stage. The results exposed that the mean technical, allocative and cost efficiencies were 0.82, 0.83 and 0.68, respectively. Beside this, pond tenure, farm ownership, experience as well as education level of the operators, contact with extension services, off-farm income and credit availability were shown to have positive effects on cost efficiency. There was, however, a negative relationship between cost efficiency and feeding intensity, pond size, and capital intensity (Cinemre, Ceyhan et al., 2006).

Kaliba and Engle (2006) considered the productive efficiency of catfish farms in Chicot, Arkansas using a weight-restricted DEA approach. Cross section data in 2001 of 32 catfish farms in this area were applied. The efficiency analysis was founded on one output of live catfish in kilogram per hectare and five inputs: labor, energy, quantity of fingerlings/stockers, quantity of feed, and other costs. Beside this, size of operation, experience of operator, extension services and land lessee were integrated in the two Tobit models in the second stage of the study. The results exposed that the mean technical efficiency under CRS and allocative, scale efficiency were 0.57, 0.67, and 0.77 respectively. Meanwhile, the technical and cost efficiency under VRS were correspondingly 0.73 and 0.49. In addition, operators' experience and extension contacts were viewed to have positive effects on the level of efficiency of those farms (Kaliba and Engle ,2006).

Mussa (2006) examined the technical efficiency of smallholder farmers in Southern Malawi applying SPF function. Cross section data in 2003 of 150 farms adopting and 150 farms non-adopting integrated aquaculture-agriculture. The analysis was derived from the Translog production function first. It was investigated against a Cobb Douglas functional form. Those production frontier implicated farming system output value in Malawi Kwacha and some inputs such as land, assets, labor, and others and the technical inefficiency function involving age and education of the farmers, extension services, availability of credit, number of plots ,membership of an association and recycling of materials. The results show that non-adopters were technically less efficient than adopters, with correspondingly 0.49 and 0.63. And there was a positive relationship between education, extension services, recycling of materials, number of plots and technical efficiency of adopting integrated aquaculture-agriculture farms (Mussa, 2006).

Dey et al., (2005) anticipated the technical efficiency and its determinants of freshwater pond poly-culture in selected Asian countries using SPF approach. The data of 300 samples from China, 409 samples from India, 180 samples from Thailand, and 120 samples from Vietnam collected by the World Fish centre and its partner institution were used. Those freshwater pond poly-culture farms were categorized into extensive, semi-intensive and intensive systems. The production frontiers were a Cobb Douglas function. The output included farm yield in kilogram per hectare. The inputs applied in those production frontiers were not only the common inputs, such as: stocking density, feed, labor, chemicals, but also the specific inputs, such as: energy, protein, phosphorus, nitrogen, fertilizer and its dummy variables. The farm-specific variables included age, education, experience of the farmer operator, the farm size, privately owned (dummy), distance from seed supplier/market and regional variable (dummy). The results showed that technical efficiencies of extensive and semi-intensive system were correspondingly 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. The technical efficiency of intensive systems in China had the highest score with 0.93. Moreover, a relationship was found between regional dummy, farm size, distance to seed supplier in China, education, farm size, pond owner dummy in India, farm area, pond owner dummy, distance to seed supplier/market in Thailand, age, education of operator, farm area, distance to nearest market in Vietnam and technical inefficiency (Dey, Paraguas et al. ,2005).

Chiang et al. (2004) explained the technical efficiency of milkfish in Taiwan using a SPF approach. Data of 433 aquaculture milkfish farms between 1997 and 1999 were used. Both Translog and Cobb Douglas frontier production models were estimated applying the maximum likelihood estimation method. The production frontier founded on the output of milkfish production quantity and five inputs: pond area, fry cost, feed cost, water and electricity cost and other costs. And inefficiency factors included the data collecting time (dummy), monoculture farm (dummy), fresh water (dummy), location (dummy), pond size (dummy), education (dummy), experience, labor. The empirical results viewed that the mean technical efficiency was 0.84 in the Translog model, and that milkfish farming in Taiwan diminished return to scale. Beside this, there was a positive relationship among fresh water, location variables, education, experience and labor and technical inefficiency. For the moment, data in 1998, monoculture farm, and reading ability of the farmer had negative effects on technical inefficiency (Chiang, Sun et al. ,2004).

Pantzios et al. (2004) implemented the input-oriented Malmquist productivity index to aquaculture farms in Greece using a stochastic frontier approach and translog input distance function. Panel data sets of 14 sea-bass and sea-bream farms between 1995 and 1999 were applied for analysis. Its translog input-distance function was derived from two outputs: the total annual production of sea-bass and sea-bream measured in tons, and four inputs: labor, stocking rate, fish feed and cages area. The empirical results viewed that the mean technical efficiency of sea-bass and sea-bream farms showed to be unchanged at approximately 0.7 over the time (Pantzios, Tzouvelekas et al., 2004).

Sharma and Leung (2000) measured the technical efficiency of carp production in India using a SPF approach. Since then its levels and determinants in carp pond in this country were tested. Cross section data of 906 carp farms in India classified into semi-intensive/intensive and extensive were used. The analysis was founded 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 and 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 main findings were 0.805 and 0.658 of technical efficiency score for semi-intensive/intensive and extensive respectively. Additionally, the former was found technically more efficient than the later. In addition, fish, water and feed management practices had positive effects on technical efficiency. In particular, there was a negative relationship between technical efficiency of extensive system and aquaculture as primary activity, semi/intensive farms’ technical efficiency and farmers’ experience (Sharma and Leung, 2000).

Iinuma, Sharma and Leung (1999) explained the technical efficiency of carp pond culture in Peninsula Malaysia by using a SPF approach. The technical efficiency was anticipated to give some policy implications for promoting carp production in this area. 94 carp pond farms classified into intensive/semi-intensive and extensive cultures were used for analysis. The analysis was derived from the production frontier, which was in Cobb Douglas functional form, relating output of total quantity of fish harvested in 1994 production year considered in kilograms per hectare and six input variables including seed, seed ratio, feed, feed ration, labor and other inputs and technical efficiency model that includes five farm-specific variables such as: culture intensive, ownership, carp farming as a primary activity, pond area, and pond age. The main results exposed that the mean technical efficiency was 42%. In which, an intensive/ semi-intensive system was more technically efficient than an extensive one with correspondingly 0.565 and 0.236 on average. Moreover, age and ownership were found to have positive effects on technical inefficiency. In the intervening time, there was a negative relationship between intensive culture and technical inefficiency (Iinuma, Sharma et al., 1999).

Sharma et al. (1999) considered the economic efficiency of fish poly-culture in China using output-based DEA approach. Then the optimum stocking densities for those farms were recommended. Cross-section data of 115 fish poly-culture farms from eight provinces in China were applied. The analysis was founded 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 main results viewed that the sample average technical, allocative, and economic efficiencies were 0.83, 0.87, and 0.74, respectively. Additionally, technical and economic efficiency had a negative relationship with farm size. The large farms (> 10 ha) and those from the underdeveloped provinces were technically less efficient than the small ones (< 0.5 ha) and those from the developed provinces (Sharma, Leung et al. ,1999).

Jayaraman (1997) explained the economics analysis of carp culture in Thanjavur district, Tamil Nadu state, India, and identified the reasons for yield variations by using a PFPF. Cross section data of 40 carp farms were applied for the analysis. The analysis was derived from the average production function estimated by the Ordinary Least Square method and PFPF involving the mean yield of carp and five inputs: pond size, stocking ration, labor, feed cost, and the average price of fish. The results reveal that 23 out of 40 farms had a technical efficiency of less than 0.5; only one farm was technically efficient (Jayaraman ,1997).

3.4 Empirical Studies of Environmental Factors on Aquaculture

Kebede Tewodros Aragie (2001) attempted to measure the technical efficiency of rice farmers in the mid hills of Nepal, identify its determinants, and establish its relation to farmers environmental orientation in his study," Farm Household Technical Efficiency: A Stochastic Frontier Analysis". There are various methodological matters to consider in estimating technical efficiency. This study has a specific objective of assessing various distributional assumptions made on the estimation of stochastic frontier models and compare estimation results for technical efficiency (Kebede Tewodros Aragie ,2001).

The paper of Ton Nu Hai Au (2009) measured the mean technical efficiency of 91 percent in prawn poly-culture (prawn (*Peneaus monodon*)-rabbitfish (*Siganus oramin*)-others pattern) farms in Tam Giang lagoon, Vietnam, using an input-oriented VRS data envelopment analysis. The estimated technical super-efficiency was then regressed to the farmer characteristics, extension contacts, stocking density, and production environment to identify the determinants of technical efficiency of those farms. Experience of the operator's and their attendance to aquaculture training courses were the factors positively influencing farm level efficiency, while prawn stocking density had a negative relationship with their technical efficiency (Ton Nu Hai Au,2009)

In "Sustainable aquaculture and producer performance: measurement of environmentally adjusted productivity and efficiency of a sample of shrimp farms in Mexico", Francisco J. et al. (2004), have examined The competition among shrimp producing countries, the rapid advances in technology and the increase in market demand suggest that the shrimp industry at a global level and in Mexico in particular needs to take appropriate measures to maintain its viability and be able to compete successfully. This can be achieved by making better use of the available scarce resources and appropriate technology without further deteriorating the environment. Based on an unbalanced panel of semi-intensive shrimp farms containing primary-source information at pond level for the period 1994, 1996–1998 in northwest Mexico, this paper assesses farm performance indicators adjusted to incorporate environmental impacts. This 4-year time series coincides with a switch in the species reared in commercial shrimp farms from white leg shrimp (first 2 years) to blue shrimp, as a consequence of viral disease outbreaks in the former species which impacted operations in Mexico in 1995 and 1996. Therefore, efficiency and productivity can be measured and the results can be analyzed in correspondence with three events: use of white or blue shrimp in operations; the effect of experience of working with one species after many years (white shrimp) and to initiate a learning curve with a new species (blue shrimp) after 1996; and the effect of the viral outbreak on production performance. Using an input distance function approach, TFP and TE using both T and EA indicators were examined. TFP was reduced in 1996–1998 compared to 1994, due to a technological regression as reflected by increased input-intensive production technology resulting in an increase in undesirable outputs. The learning curve resulting from a shift from white leg shrimp to blue shrimp production species resulted in higher FCRs, water exchange and pollution emissions, despite increasing shrimp yields. In all years except 1994, EA TE and EA TFP were lower than the traditional TE and TFP scores. TE and TFP had an opposite behavior than yields in this period of time. In order to improve the TC component of TFP in light of stable TE scores, increased government assistance in disseminating technological know-how is necessary to improve TFP at a faster rate during the transition period (Francisco J. et al., 2004).

In summary, Data Envelopment Analysis and Stochastic Frontier Analysis have been applied in most of the above studies. In which, the Stochastic Production Frontier method dealt with efficiency by using econometric techniques. Consequently, the studies using this method had their specific production functional forms such as linear function, Cobb Douglas function, translog function, and quadratic function. Likewise, they forced the specific assumption on the error term. While data envelopment analysis dealt with efficiency by using linear programming techniques. It consequently requires specific orientation and returns to scale assumptions of the analysis instead of functional form and error term assumption.

4. Methodology

4.1 The Research Area

This study was conducted in Khanh Hoa province located on the South Central Coast of Vietnam. The research area included, Nha Trang , a coastal city and capital of Khanh Hoa, Cam Ranh, a smaller town directly to the south of Nha Trang, and Cam Lân District, another town in the south of Khanh Hoa. These are the first, second and third largest parts of Khan Hoa province. The sea water area studied included Nha Trang Bay and Cam Ranh Bay, which is regarded as the best natural condition in the world. The potential for development in Khanh Hoa is great because it contains over 300 km of coastline and an additional 135 km of coastline along the offshore islands. It has many advantages for developing marine farming (Khanh Hoa Agricultural office report, 2009).

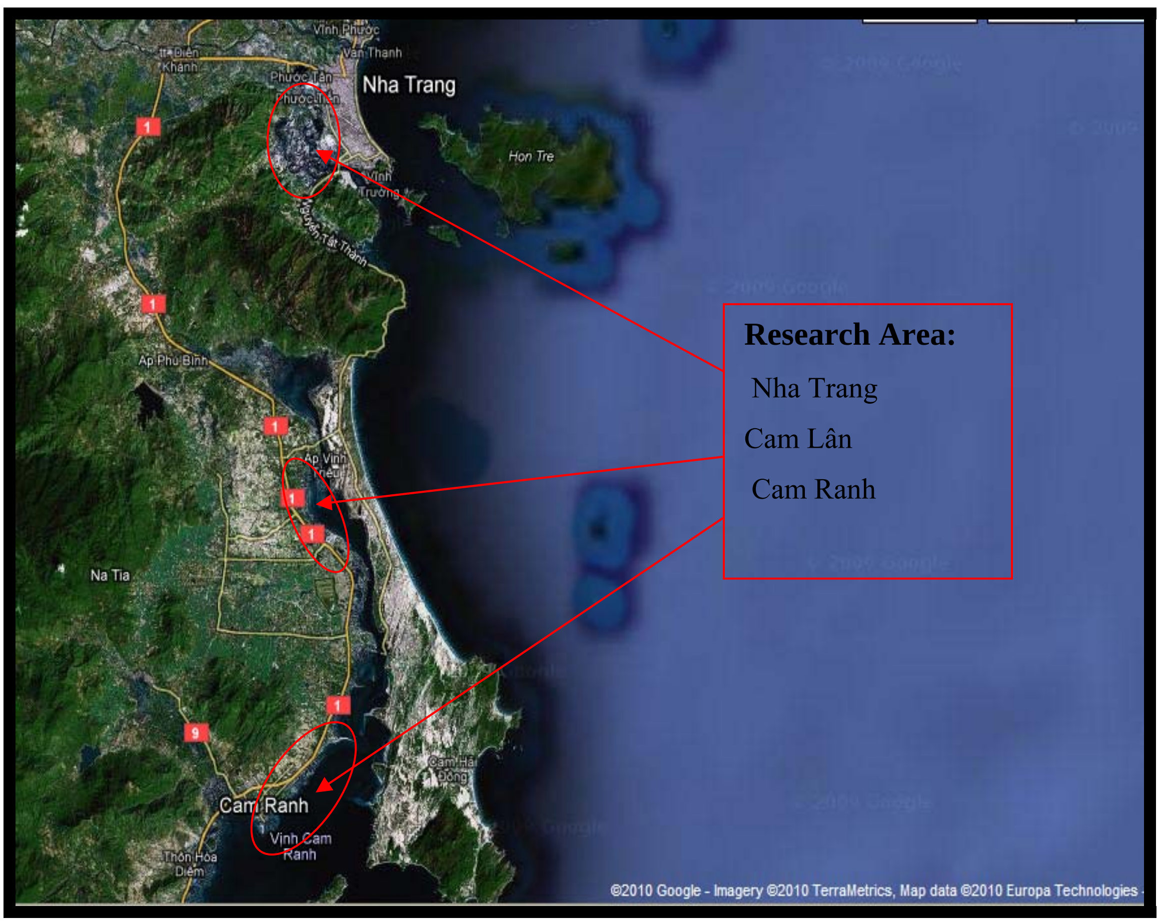

Figure 1 Conducted Research Area of Khanh Hoa

Source: Google-Imagery, 2010

4.2 Data Collection

4.2.1 Primary Data

The bulk of data used in this study was collected from farmers growing only white leg shrimp. Thirty-six percent of the data came from Cam Ranh, Fifty-six percent from Nha Trang, and eight perecent from Cam Lân. Sixty-one samples of white leg shrimp farm data was collected through a questionnaire for the 2009 crop year from 462 white leg shrimp farms in Khanh Hoa.

4.2.2 Secondary Data

Secondary data for this study was collected from various sources such as books, journals, research reports, and the 2009 statistical yearbook of Khanh Hoa, Agricultural Statistics Office with relevant information on efficiency analysis and production of aquaculture.

4.3. Sampling Method

In order to develop the questionnaire, several pilot surveys were conducted for correcting the mistakes, evaluating and selecting relevant questions and information and eliminating unnecessary ones. Farms were selected randomly. We went to the sites selected beforehand according to the accessibility by road and approached the farmers and asked if their household heads were willing to co-operate. If they said "yes", we started conducting the questionnaire. The interviewer was a student of the Nha Trang University Aquaculture Department. He had experience with collecting data and knowledge of white leg shrimp farming operations. The first questionnaire was translated into Vietnamese for asking and explaining the questionnaire easily to the farmers. The survey experienced several problems common to some agricultural sectors experiences. It took times to approach directly the household head who could supply the correct information we needed in the questionnaire. Although the questionnaire was prepared carefully, the data collected could have been affected by some perception bias of the respondents. Farmers usually do not keep standard accounting books. Therefore, when asked for some detailed information about past activities they had to recall what had already happened. However, we feel confident that the answers of the respondents do reflect the characteristics of white leg shrimp farming in a sufficient way that warrants us to do empirical analyses because quality-checking the data during and after the survey did not reveal any extremely incorrect or impossible answers.

The following lists of information were included in the structured questionnaire:

1) Household characteristics:

- Age
- Education
- Experience
- Production system

2) Financial variables:

i) The amount and cost used in white leg shrimp culture:

Variable operating cost information:

- Hired labour (Permanent)
- Hired labour (Temporary)
- Own self operation
- Total working days
- Medicine (lime and chemical)
- Feed, Feed Conversion Ratio (FCR) value
- Seed
- Energy
- Transportation

Fixed operating cost information:

- Equipment
- Capital construction cost
- Maintenance cost

ii) The source, kinds, timing and cost of all lease information about pond

iii) The source, kinds, timing and interest of all funds information

iv) The amount and unit price of outputs

v) Farmers' ability to access credit in buying and selling and extension services

vi) Equipment information: Uses, Number /size, cost

- Initial Aerators
- Basket
- Mattock
- Nets
- Pumps
- Shovels
- Vehicles
- Wheel barrow
- Boat
- House
- Others

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

4) Related information: fish sold place after harvest, formation, insurance information, partnership with another farm, government planning, survival rate.

5) Environmental variables: how far from the channel, farm water depth

4.4 Data Analysis

The primary data was the main information used for this analysis. In this study, there was descriptive analysis based on observations, and then, technical efficiency at farm level of those observations was measured using a data envelopment analysis (DEA) approach. I used an output oriented DEA approach for measuring the TE of the farms. Finally, Shazam (Version 10.0) for statistical analysis was used to investigate the factors affecting the technical efficiency of white leg shrimp culture.

4.4.1 Technical Efficiency Analysis:

4.4.1.1 *The 1st Stage: Data Envelopment Analysis (DEA)*

As mentioned above, Farrell was the first one who considered about the efficiency measurement by using the simple model of two inputs - single output under constant return to scale. Based on that, Charnes, Cooper, and Rhodes (CCR) (1978) developed the Data Envelopment Analysis. DEA is used to measure the relative efficiency or performance at the firm level. It constructs a non-parametric piece-wise frontier over the data by using linear programming methods. Its calculation is based on the comparison output and input used for the production frontier. The efficiency score is 1 (one) when the production point of a decision making unit (DMU) is on the frontier. This is the interpreted that the producer is 100 % efficient. A DMU having an efficiency score smaller than 1 is less than 100 % efficient. Efficiency can be calculated in either an input-orientation or output-orientation direction. In input-orientation, technical efficiency will address the question: "By how much can inputs be proportionally reduced without changing the output quantities produced?" Likewise, an output-oriented technical efficiency focuses on maximizing the output quantities and addressing the question: "By how much can outputs be proportionally increased without changing the inputs quantities used?" (Farrell 1957).

DEA concepts have developed into many models, depending on the type of questions that are asked. Regarding returns to scale CCR (Charnes, Cooper, and Rhodes) presented a Constant Returns to Scale (CRS) model, whereas BCC (Banker, Charnes and Cooper) presented the variable returns to scale model. Also the actual mathematical formulation, as a DEA formulation is basically a LP-model, may have a primal or a dual formulation. The multiplier form is similar to the primal LP formulations, and its dual formulation is in DEA parlance called the envelopment model. It is important to realize that the multiplier model and the envelopment model always will give the same results regarding efficiency, but will in some other aspects present the results in different ways. For practical purposes, mostly related to interpretation, the envelopment model is usually the one used for numerical calculations.

Charnes et al., (1978) proposed the CCR model to find out radial reduction in input or radial expansion in output based on the restrictions of CRS, strong disposability of inputs and outputs, and convexity of feasible input-output combinations. But as Coelli et al., (2005, p. 172) mentioned "CRS assumption is only appropriate when all firms are operating at an optimal scale". Meanwhile "imperfect competition, government regulations, constraints of finance, etc. may cause a firm to be not operating at optimal scale". Then Banker, Charnes and Cooper in 1984 sustained to extend the model by turning to the problem of returns to scale (Banker, Charnes et al. 1984; Timothy J. Coelli, D.S. Prasada Rao et al. 2005; Alam and Murshed-e-Jahan 2008; Kiatpathomchai 2008).

The standard BCC-DEA model under input-oriented approach was familiar with measuring technical efficiency where a more clear distinction between fixed and variable input factors is a better model. We can estimate the extent to which the controllable or discretionary outputs can be maximised by the DMU manager while keeping the exogenously fixed outputs at their current level by extending the CCR and BCC models.

Another method for dealing with the censoring of DMU efficiency scores is to use super efficiency scores. This method was originally planned by Andersen and Petersen in 1993. This is the term of efficiency score larger than one. That is because each firm is not allowed to use itself as a peer. Although one of its drawbacks is infeasible results of some samples, it is normally used for sensitivity testing, identifying the outliers, and OLS regressing in the second stage instead of Tobit regression (Timothy J. Coelli, D.S. Prasada Rao et al. 2005).

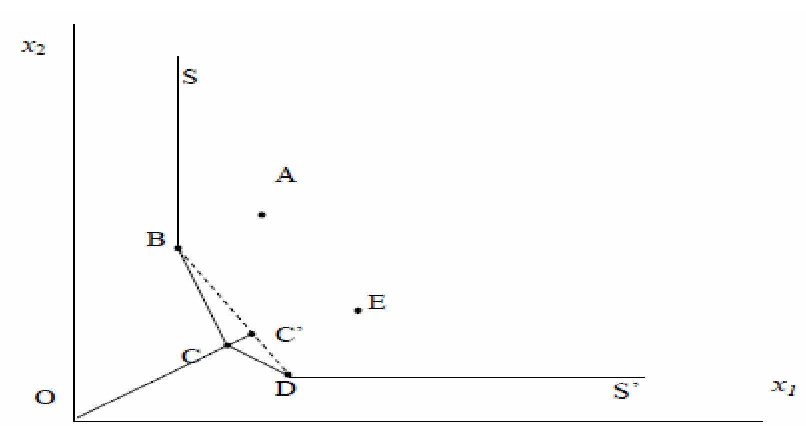

Figure 2 Super Efficiency

Source: Coelli, 2005

Consider the case of using two inputs to produce a particular output, if the standard DEA is applied, firms B, C and D are on the frontier and have a technical efficiency score of one.

However, considering the case of firm C, if super efficiency DEA is applied, C itself will no longer form a part of the frontier. B and D are two firms forming the new frontier and the projected point of C is C'. The super-efficiency score of C is the ratio of OC' and OC. A and E are inefficient firms. Their original technical efficiency scores do not change when the super efficiency method is used (Timothy J. Coelli, D.S. Prasada Rao et al. 2005). Adler et al. (2002) showed three problems such as : benchmarking, multivariate statistical techniques, combining multiple criteria decision methodology with this approach. Thrall (1986) noted that the super-efficiency CCR model may be infeasible. Zhu (2004) prove under which conditions various super-efficiency models are infeasible. Chen (2005) proposed a modified super-efficiency DEA model to overcome the infeasibility problem and to correctly capture the possible super-efficiency existing in forms of the input saving or output surplus (Banker, R.D. and R.M. Thrall. 1992).

In making efficiency measurements and comparisons, one must separate the effects of the environment (the exogenous factors) and the effects of the productive efficiency. Different methods have been utilized for adjusting efficiency scores to control for environmental factors (Coelli et al. 2005). Environmental influences can be controlled for by regressing the initial scores on the environmental variables, and then adjusting the initial scores by dividing them by the expected scores.

Tobit regression is often encountered in second stage data envelopment analysis (DEA), i.e. when the relationship between exogenous factors (non-physical inputs) and DEA efficiency scores is assessed. i.e. Tobit regression is used to explain the variation in the efficiency scores related to farm-specific factors and to explore the correlates of efficiency because of the bounded nature of the DEA efficiency scores. It is possible that there may be variations in efficiency that are not controlled for the time varying covariates, therefore to include dummies and exploring the determinants of efficiency from a set of explanatory variables ,Tobit models is preferred to be used. It is however not obvious that Tobit is the only, or optimal, approach to modeling DEA scores. Tobit or some similar methods (logit) are optimal methods used for doing regressions when dependent variable is truncated. Here, restricted to one as upper level. OLS may be a workable substitute, though not optimal. OLS may actually in many cases replace Tobit as a sufficient second stage DEA model. The Tobit method is the method where the dependent variable is censored, that is limited to a maximum value of one. We can use the Tobit method when we use DEA efficiency as a dependent variable (Coelli et al. 2005)

This paper uses the two-stage Data Envelopment Analysis (DEA), to measure the technical efficiency of 61 white leg shrimp farms in Khanh Hoa. In the second stage, this paper uses OLS and Tobit regression models to examine the factors that significantly influence the farm's efficiency of a set of explanatory variables.

For white leg shrimp farmers in Khanh Hoa, due to the limitation of resources, such as infrastructure, channel systems, seeds and environmental factors for aquaculture areas, capital, availability of man power, skilled staff and workers for investment and the restriction of expanding pond size, an output-oriented Data Envelopment Analysis (DEA) approach is suitable to describe the production possibility situation and is used to estimate technical efficiency scores. The output-oriented measure is used to answer the question what are the most efficient combinations of fixed input among white leg shrimp farmer patterns to maximize output. Hence, the maximizing of outputs use can be used for fixed inputs cost prove farm technical efficiency, maximize the producing output or increase the gross margin from white leg shrimp farmer. Moreover, due to the existence of imperfect competition, limited finance and socioeconomic limitations of farmers in this study area, most farms are not operating at optimal scale. Hence, VRS DEA model seems to be more appropriate for analyzing technical efficiency than CRS in this study.

4.4.1.2 Model Specification of Technical Efficiency

In a DEA analysis, it is generally assumed that there are n DMUs using amounts of m different inputs to produce s outputs. The notation is as follows.

x_{ij} = input i (i = 1, . . . ,m; DMU_j (j = 1; . . . ; n)

y_{rj} =output r (r = 1; . . . ; s)

I used an output orientation in this paper. The production of white leg shrimp farms has led to a shortage of medicine, feed and energy in Vietnam. This is especially the case in Khanh Hoa where our sample firms are located. Under these circumstances, it is important for farmers to know how much output can be produced if a firm is to improve its technical efficiency, given a fixed amount of inputs. Hence, an output orientation is the preferred option. I used $F_{0(xj\ ,yj)} = \phi$ maximum to represent the output-oriented Farrell efficiency score that shows the maximum possible expansion of output for DMU_j.

We assume VRS in this paper. The envelopment form of the output-oriented VRS DEA model is specified:

$$\text{Max } W_0 = \phi_0$$

Subject to:

$$x_{i0} \geq \sum_{j=1}^{n} \lambda_j \cdot x_{ij} \qquad (\text{ i=1, … , m})$$

$$\sum_{j=1}^{n} \lambda_j \cdot y_{rj} \geq \phi_0 \cdot y_{r0} \quad (\text{r=1, …, s})$$

$$\sum_{j=1}^{n} \lambda_j = 1$$

$$w_{0} \gtrless 0, \lambda_j \geq 0 \text{ V } j$$

Let y_{r0}, $0 \subseteq \{1,2,\ldots..s\}$ represents the sets of specific output of interest .We can obtain a measure of specific models where only the outputs associated with O are optimized.

Here $1 \leq \phi \leq \infty$ and ϕ -1 is the proportional increase in outputs that could be achieved by the i- th firm, with input quantities held constant. $1/\phi$ defines a TE score that varies between zero and one.

The efficiency measure is compiled as the inverse of the maximum proportional output that can be achieved with input quantities held constant. The efficiency measure obtained in this way defines a technical efficiency score that varies between zero and one.

Variables

Since DEA two-stage method was used in this study, two groups of output and inputs were categorized. To estimate farm technical efficiency, data of farm households and the enterprises were aggregated to obtain five inputs and one output. The output is white leg shrimp production. Observing the sample , the main inputs used to calculate the technical efficiency score were Labor, Medication and Feed, Seed, Energy and Fixed cost**.**

All white leg shrimp produced on the sample farms were output value in (value of annual production. Mill Dong), which was the only output variable. Five inputs were used:

1.Hired labour plus value of own labour
2. Medication and feed
3. Seed
4. Energy
5. Fixed costs

Output

The Output used in estimating the technical efficiency score was the value of annual production of white leg shrimp farmers harvested during the 2009 production year measured in millions of dong.

Labor

In this study, labor is expressed as total working hours including both members of the farm's household and hired labor who might work full-time or part-time. The type and number of workers employed by the farms were up to each stage of crop cultivation and farm size. Own and hired labor is measured by monetary value in VND. In the beginning and at the end of the crop, it is necessary to work full-time to improve and maintain the ponds and to harvest. Hence, in those stages, the farms often employed from 1 to 5 workers, depending on the farm size, including both hired and household farm labors. The larger farms tended to hire labor and work full-time rather than part-time. Therefore, labor is also an important input in white leg shrimp farming.

Medication and Feed

Feed

Feeds are dependent on fishmeal. Poor feed quality may reduce growth, depress health and survival, reduce water and pond soil quality, and increase pollution. In this study, the feed was measured by FCR. Then it was transferred into VND. Extensive systems have the advantage of maximizing the use of natural food. Highly intensive closed systems may offer the shrimp a wide variety of natural elements and that may present a further opportunity for reducing the protein content of feeds.

Medications

The supply of medications is likely to remain relatively reliable and will probably increase. Better site selection, and water supply reduce dependency on and cost of medications. All the values of medication and feed cost were measured in VND**.**

Seed

In many places seed is still caught in the wild. The supply of such seed cannot be guaranteed; its availability is generally seasonal; and it may carry disease. The quality may be poor as a result of excessive use of chemicals, the practice of multiple spawning, and poor feeding which results in a shortage or high cost for the farmers. Moreover, defining the seed for white leg shrimp farmers might increase the number of constraints and lead to the frontier become tighter. Therefore, seed in this analysis was expressed as total seed cost of white leg shrimp measured in mill VND.

Energy

Energy, in this analysis was expressed as the total fuel costs of white leg shrimp farmers; they sometimes used petrol or motor electricity, which is measured in mill VND.

Fixed cost

Equipment and maintenance costs, in this analysis were expressed as the total fixed cost of white leg shrimp farmers, which is measured in mill VND.

4.4.1.3 The 2nd Stage: Ordinary Least Square Regression (OLS)

DEA has some deficiencies such as: The DEA approach does not account for the measurement error and statistical noise that may influence the shape and position of the frontier and it does not allow for conventional tests of hypotheses, which are typical of the econometric approach. So, in order to identify factors affecting technical efficiency scores which were measured in the first stage, a second stage OLS model was used. It regressed the first stage index on some discretionary and non-discretionary factors in this stage. However, because the upper limit on the efficiency index from the first stage is 1, OLS regression can produce biased estimates and this stage requires a priori specification of functional form, though for simplicity these are not measured in this analysis. Measures of farm technical efficiency calculated from the previous stage are used in regression analysis to estimate the relationship between the efficiency and different farm characteristics, including farm's age of the household head , schoolings of the household head , experience of the household head, environmental variables such as farm is how far from the channel , farm's financial variable such as the proportion of total costs relative to total income , the proportion of variable costs relative to fixed costs , sales margin , return on asset .

4.4.2 Descriptive Statistic Analysis

This section deals at first with some descriptions of collecting data then simple descriptive statistic analysis, including: mean, variance, standard deviation, maximum, minimum, percentage and descriptive analysis was done in both stages of the study. First, some main inputs and outputs which were used in estimating technical efficiency were described. Then, the summary of significant characteristics of the white leg shrimp farmers which were used in the OLS stage was included. In the later part, because the differences in some characteristics between

1) Planned (15 observations) and unplanned groups (46 observations)
2) The farmers who are near the channel (25 observations) and far from channel (36 observations).
3) In the "far from channel farmers category", The farmers who have water keeping ponds (6 observations) and those that do not have water keeping ponds (30 observations) [Insufficient number of observations of water keeping ponds make statistical tests difficult ,but the few data points illustrates rather than prove this statement].

A t-test for unbalanced groups was done to test whether these characteristics were different from zero or not. The t – value to test for significance of difference is estimated by the following formula:

$$t = \frac{(\overline{Y_1} - \overline{Y_2}) - (\mu_1 - \mu_2)}{\sqrt{\left[\frac{(n_1 - 1)s_1^2 + (n_2 - 1)s_2^2}{n_1 + n_2 - 2}\right] \cdot \left(\frac{n_1 + n_2}{n_1 \cdot n_2}\right)}}$$

Degrees of freedom is df = $(n_1 + n_2 - 2)$

Where,

$\bar{y}_1$ = mean value in planned group /near the channel / have water keeping pond

$\bar{y}_2$ = mean value in unplanned group / far from channel / not have water keeping pond

μ_1 = expected value in planned group / near the channel / have water keeping pond

μ_2 = expected value in unplanned group / far from channel / not have water keeping pond,

s_1^2 = Variance in planned group / near the channel / have water keeping pond

s_2^2 = Variance in unplanned group / far from channel / not have water keeping pond, and

n_1= Observations in planned group / near the channel / have water keeping pond

n_2= Observations in unplanned group / far from channel / not have water keeping pond

The test statistic includes:

1. The null hypothesis is Ho: $\mu_1 - \mu_2 = 0$ :: There is no difference in mean value of the white leg shrimp farmers in Khanh Hoa who are in planned group / near the channel / have water keeping pond and unplanned group / far from channel / not have water keeping pond farmers.

The alternative hypothesis is H_1: $\mu_1 - \mu_2 \neq 0$: The mean value of the white leg shrimp farmers in Khanh Hoa who are in planned group / near the channel / have water keeping pond and the mean value of the unplanned group / far from channel / not have water keeping pond farmers have differences.

2. The test statistic $t \sim t(n_1 + n_2 - 2)$ if the null hypothesis is true

3. Let select the level of significance α=0.05. In a two tail test $\alpha/2$ =0 .025 of probability is allocated to each tail of the distribution.

For (1) and (2) test, The critical value is $t_{(0.975,59)} = 1.960$ with $n_1 + n_2 - 2 = 59$ degrees of freedom. Thus we will reject the null hypothesis in favor of the alternative if $t \geq t_{(0.975,59)}$ or if $t \leq -t_{(0.975,59)}$

For (3) test, The critical value is $t_{(0.975,34)} = 2.032$ with $n_1 + n_2 - 2 = 34$ degrees of freedom. Thus we will reject the null hypothesis in favor of the alternative if $t \geq t_{(0.975,34)}$ or if $t \leq -t_{(0.975,34)}$

4.5 Description about Data

In the study, 75% of farmers operate under the semi-intensive system, 9% in extensive 3% in intensive 10 % combined with semi-intensive and extensive and 3 % combined with semi-intensive and intensive management were reported. Shrimp aquaculture production consists mainly of white leg shrimp (*Penaeus vannamei*) and it takes place almost exclusively in earthen ponds. Post graduate respondents were 7% and primary school level respondents were 26% whereas most experience, ≥ 18 years were 16% and less experience, ≤ 5 years 10%. Cam Ranh's farmers naturally have more benefits than others because they have sufficient water all year round.

About 31% of respondents took extra days for harvesting (≥ 100 days) as sometimes they were waiting for an increased price which varied from 38,000 VND to 55,000 VND or sometimes for their disease free shrimps, but if they observed that their shrimps were affected by disease they tried to finish the harvesting quickly to ignore the losses and start the new season quickly, such as 51% respondents were doing for 3 seasons in the cropping year 2009.

Only 20% of respondents showed that they are farming under Govt. planning, but this group gets some benefits from the government, such as they can easily get a bank loan at a lower rate(5%) where as others taking money from different sources, have to bear 10-12% interest. Under government planning farmers can more easily lease land and they do not have to bear any of the costs of making channels or some other construction projects. So they are more cost effectives farmers.

Temporary labor was mainly used at the beginning of the season for making ponds and during the ending period of harvesting. Most of the farmers who work by themselves ,are small but 26% of big farms were using their own labour as they combined their farms as extensive or intensive with semi-intensive .The feed conversion ratio (FCR) varied depending on the season and the management; it is $\leq$ 1.1 for 30% respondent. Survival rate was $\geq$ 85% for 41% data, for 1 data 45% and for 1 data 100% which means all shrimp were in fully treatments for that farm. Energy use (EU) throughout the life cycle for 1 data which using petrol and 1 data, using motor electricity.

Table 1 Equipment Users

Name of Equipment	User Percentage (%)
Initial Aerators	28
Basket	84
Mattock	87
Nets	79
Pumps	84
Shovels	69
Vehicles	84
Wheel barrow	77
Boat	79
House	64
House keeper house	2

Source :Own data

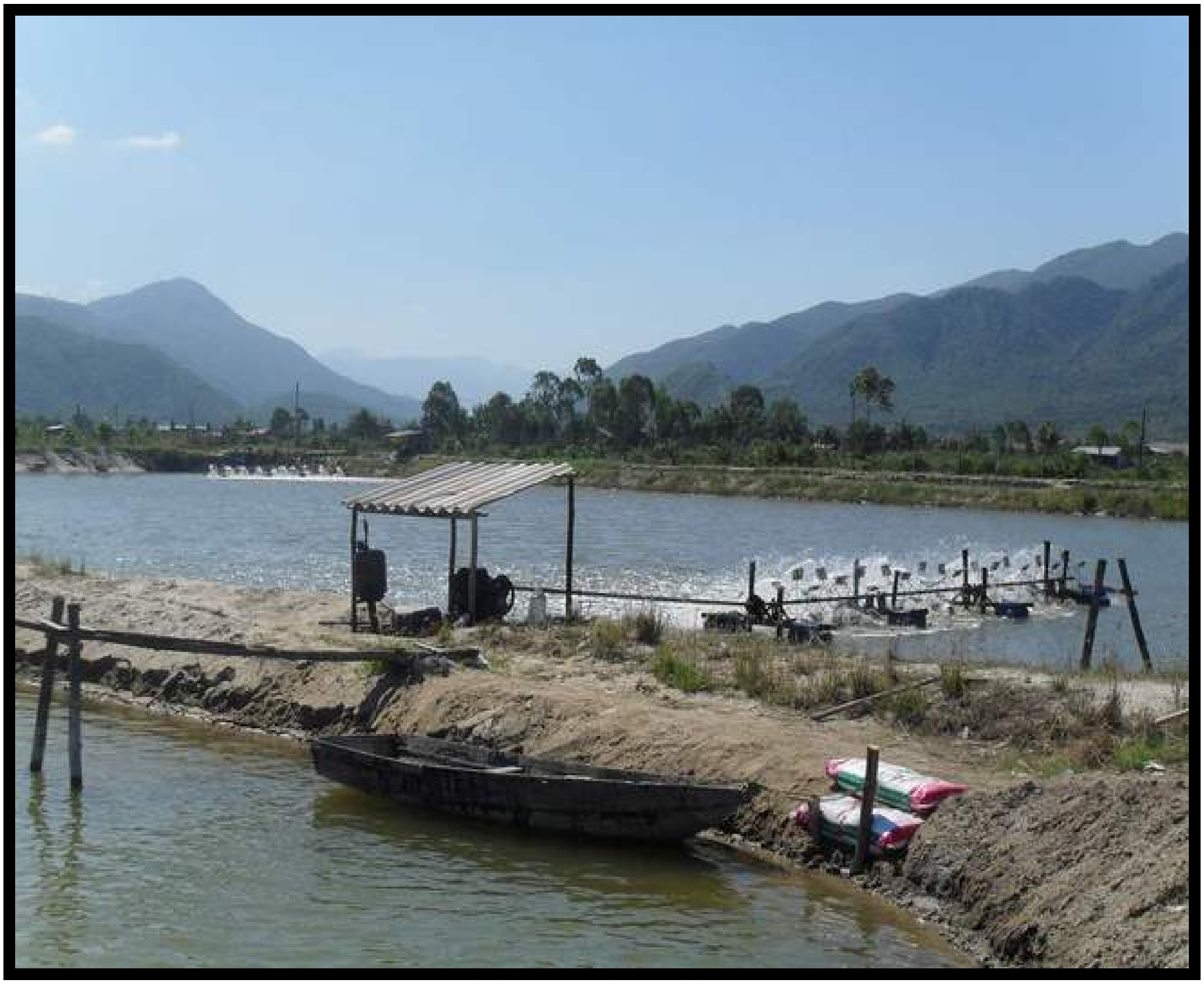

Figure 3 Equipment (Boat) in Cam Ranh White Leg Shrimp Pond
Source : Field survey

About 66% farmers sold their fish in the local market, and 8% exported , 3% sold to other cities, others combined local, other city and exporting where 100% respondents sold as live, only 5% combined with fresh.38% respondents answered retailers as their price determinators,7% recognized the market and 49% denoted a combination of the retailer and the market. 34% respondents sold that in credit as 40% per season and 15% bought input by credit as 10% in 30 days. 8% of respondents had a partnership with another farm or another species in another pond to avoid the risk of white leg shrimp.

Figure 4 Using Equipment (Aerator) in Cam Ranh White Leg Shrimp Pond
Source: Field survey

In this study, all the explanatory variables were obtained from the sample farms by questionnaire. This study introduced two new explanatory variables namely environmental factors (farm existence far from channel, depth of pond), As far as I know, these factors have not been used in previous studies. 41% respondent were near the channel ($\leq$500 m) and 59% respondent were far from channel(> 500m) ,in which 13% of respondents were very far from the channel (> 5000 m), and 34% of respondent's pond depth was $\leq$ 1.1 m. The water sufficiency and water quality during the harvesting supported the production rate performance. The ponds which were near the channel had no deficit of water and the water quality was also good, so most of them have low/medium water depth whereas ponds which were far from the channel, sometimes had water deficits, so some farmers kept 1or 2 ponds for water storage, only 17% of respondents were the same types, who have water storage ponds and most of them have a deep water depth.

5. Results and Discussion

5.1 Results

Data Envelopment Analysis Program (Saitech Professional Version 1.0) was used to calculate the technical efficiencies of the white leg shrimp firms in our sample. In this chapter, I will first describe about the statistics of input and output Variables. Then the distribution of farm technical efficiency scores from the DEA results are measured and after computing the technical efficiencies, comparing the distribution of farm technical efficiency scores and characteristics of efficiency scores by variables in different criteria and by factors are presented systematically in different tables.

In section 5.1.2.1, I proceeded to test the hypotheses I, II and III on : whether planned white leg shrimp farmers are more technically efficient than unplanned farmers, whether the farmers who are near the canal are more efficient than farmers who are far from the canal, and to take a reflection of water storage farmers in far from canal farmers category, I proceeded to test whether the farmers who have water keeping ponds, are more efficient than other farmers with enhancing technical efficiency and to test the hypothesis IV on whether individual characteristics of the farmer such as experience, education and how far from canal are significant factors affecting the technical efficiency of white leg shrimp culture production enhances technical efficiency using the OLS method. The results of the two stage processes are reported in the following tables and graphs in this chapter.

5.1.1 Description about Statistics of Input and Output Variables

In 2009, there were about 432 White leg shrimp farmers in Khanh Hoa province. Table 4 presents a summary of descriptive statistics of used inputs and output for 61 surveyed data of white leg shrimp farmers. To estimate farm's technical efficiency, data of farm households were aggregate to obtain five inputs and one output. Output is value of annual production.

Table 4: Descriptive Statistics of Inputs and Output Variables for 61 White Leg Shrimp Farms in Khanh Hoa Province, 2009

Variables	Mean	St.Dev	Min	Max
Value of annual Production (million VND)	625.71	470.43	280.00	2968.0
Hired Labor + Value of own (million VND)	50.95	38.22	12.0	210.00
Medication and Feed (million VND)	224.99	219.10	45.0	1311.0
Seed (million VND)	27.06	17.32	7.0	111.0
Energy (million VND)	49.45	40.65	10.0	300.0
Fixed cost (million VND)	11.55	11.59	3.0	85.0

Source: own data

Note: All economic values are in million VND; they are measured on an annual basis Labor includes both full time family and hired labor. 18,950.00 VND equals 1.0 USD, using online Universal Currency Converter, browsing date 9 May 2010.

Table 4 shows that the sample farms are quite heterogeneous in terms of technical characteristics such as Labor, Medication and Feed, Seed, Energy, and Fixed cost. Regarding the value of labour used for the sample, labour values ranged from 12 to 210 million VND, with an average amount of about 50.951 million VND. Medication and Feed costs varied from 45.000 to 1311 million VND, with a mean of 224.99 million VND. The average Seed cost was 27.064 million VND, with a range from 7.0000 to 111.00 million VND. The average Energy cost was 49.449 million VND, with a range from 10.000 to 300 million VND. The number of fixed costs of white leg shrimp farmers also varied from 3.0000 to 85 million VND, with an average of about 11.549 in the year 2009. The effect of output prices on the annual gross production of the white leg shrimp farmers will therefore be aggregated into the seasonal effect.

5.1.2 Efficiency Scores

Farm Technical Efficiency (TE) scores under the assumptions of CRS and VRS were estimated using a DEA output oriented model. The difference between VRS and CRS TE indicates the existence of scale inefficiency in the sample farms. The distributions of standard Technical Efficiency and Scale Efficiency(SE) scores of white leg shrimp farms are reported in Table 5.

Table 5 : Standard Technical Efficiency and Scale Efficiency Scores of White Leg Shrimp Farms

Table 7 part a				Table 7 part b			
DMU's	CRS TE	VRS TE	SE	DMU's	CRS TE	VRS TE	SE
1	0.40746	0.42871	0.95044	32	0.89153	0.91850	0.97063
2	0.47084	0.48189	0.97707	33	0.58547	0.58929	0.99351
3	0.64980	0.65260	0.99570	34	0.55330	0.57434	0.96337
4	0.47822	0.49579	0.96456	35	0.40868	0.40869	0.99998
5	0.79696	0.79802	0.99866	36	0.47787	0.48144	0.99258
6	0.80072	0.83372	0.96042	37	1.00000	1.00000	1.00000
7	0.90019	0.97839	0.92007	38	0.37653	0.37983	0.99132
8	0.51941	0.57434	0.90436	39	0.72538	0.98251	0.73828
9	0.42377	0.45665	0.92800	40	0.55926	0.56629	0.98758
10	0.37358	0.37380	0.99941	41	0.92680	1.00000	0.92680
11	0.43319	0.43360	0.99905	42	0.93798	0.97903	0.95807
12	0.32234	0.32383	0.99539	43	0.74737	0.76652	0.97502
13	0.88211	0.96719	0.91203	44	0.52763	0.53234	0.99115
14	0.93065	1.00000	0.93065	45	0.85872	1.00000	0.85872
15	0.93580	0.93737	0.99832	46	0.90483	1.00000	0.90483
16	0.84555	0.85705	0.98658	47	0.52884	0.54077	0.97793
17	0.49574	0.50575	0.98020	48	0.38360	0.40044	0.95793
18	0.41559	0.41624	0.99842	49	1.00000	1.00000	1.00000
19	0.39243	0.39550	0.99224	50	0.50007	0.50355	0.99308
20	0.49084	0.49167	0.99830	51	0.90371	1.00000	0.90371
21	1.00000	1.00000	1.00000	52	0.35850	0.35889	0.99890
22	0.79249	0.81047	0.97781	53	0.45158	0.45321	0.99640
23	1.00000	1.00000	1.00000	54	0.51365	0.52067	0.98651
24	0.94208	1.00000	0.94208	55	0.38138	0.40400	0.94400
25	0.85937	0.97826	0.87847	56	0.34877	0.41502	0.84037
26	0.87847	1.00000	0.87847	57	0.71113	1.00000	0.71113
27	0.95984	0.98872	0.97079	58	1.00000	1.00000	1.00000
28	0.70826	1.00000	0.70826	59	0.83331	0.87480	0.95257
29	0.76740	1.00000	0.76740	60	1.00000	1.00000	1.00000
30	1.00000	1.00000	1.00000	61	0.83258	1.00000	0.83258
31	0.62804	1.00000	0.62804				

Source : Field survey

Table 5 gives information on the range of technical efficiency scores of samples which shows that the average efficient farmer of the sample firms was 11.48% under technical efficiency with Constant Returns to Scale and Scale Efficiency, whereas 31.15% under technical efficiency with Variable Returns to Scale. The technical efficiency under VRS ranged from 0.323838 to 1, with the mean measure of 0.73492 and the technical efficiency under CRS ranged from 0.322346to 1, with the mean measure of 0.684097.

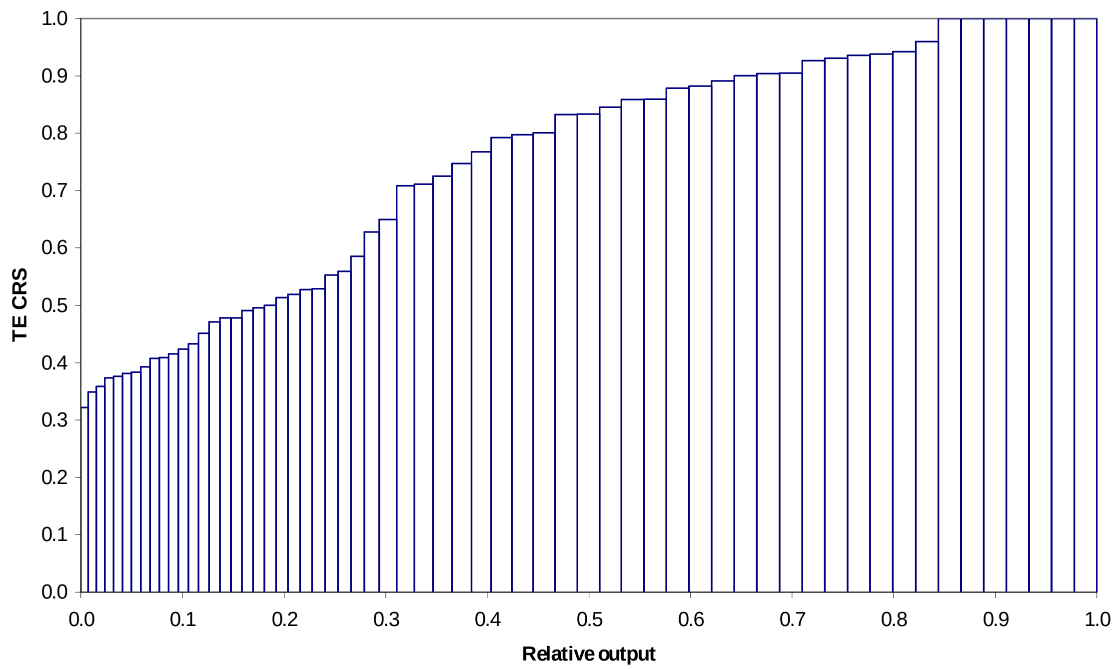

Figure 11: Relative CRS Efficiency with Output of All Farms

Source : Field survey

The difference between The technical efficiency under VRS and CRS is indicating the presence of SE. Scale efficiency refers to the optimal size that a certain percentage increase in output would lead to the same proportion expand in inputs. The scale efficiency ranged from 0.827888 to 1,with the mean measure of 0.939771.

If we review the salter diagrams in figure 11 and 12 ,the relative CRS and VRS efficiency with output ,we can see that technical efficiency for all farms is higher under VRS than CRS.

It can be said that, on average, white leg shrimp farmers in Khanh Hoa province are producing white shrimp at about 73.49% under VRS of the potential frontier production levels at the present state of technology and input levels. It also means that farms can increase their outputs by 26.51% under VRS and still produce the same level of input.

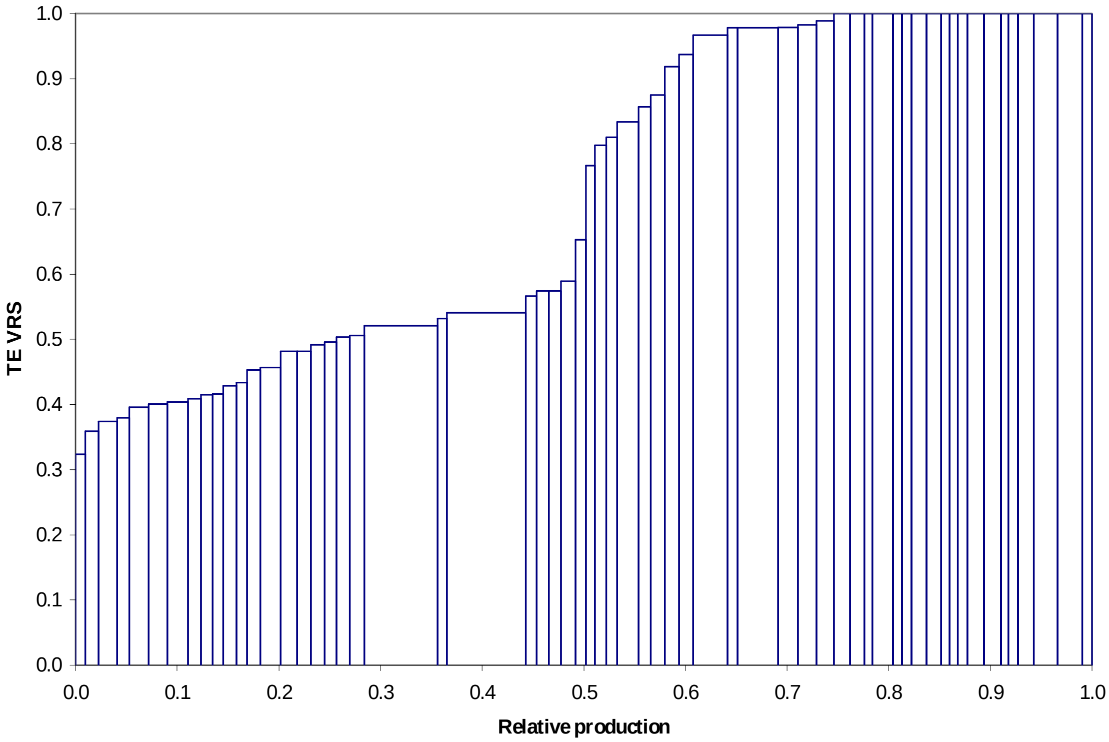

Figure 12 : Relative VRS Efficiency with Output of All Farms

Source : Own data

From the RTS report in figure 13, we can say that the number of technically efficient farms (i.e., farms operating on the production frontier) were 11% constant returns to scale, 73% increasing returns to scale, 16% Decreasing returns to scale.

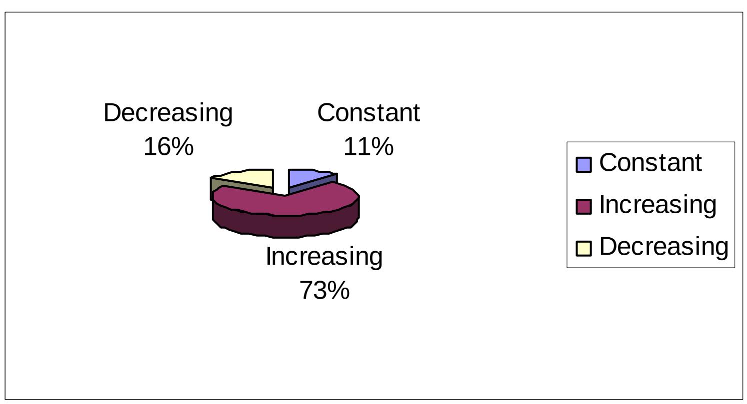

Figure 13 : RTS Report

Source : Field survey

The efficiency analysis of all farms are presented in table 6.we can observe that the average SE is the highest, near to efficiency. The average VRS TE scores of all farms was 0.73492 which means average farmers were technically inefficient but they were close to efficiency in production but the average CRS TE scores shows the lowest rank in efficiency.

Table 6 : The Efficiency Analysis of All Farms

Efficiency	Mean	St.Dev	Min	Max
CRS TE scores	0.684097	0.228807	0.322346	1.0000
VRS TE scores	0.73492	0.25693	0.32384	1.0000
SE scores	0.939771	0.05212	0.827888	1.0000

Source : Own Data

The average CRS TE scores of all farms was 0.684097 which means average farmers were technically inefficient but they were not so near to efficiency in production under CRS and the average SE scores of all farms was 0.939771 which means average farmers were very close to scale efficiency in production.

5.1.2.1 Comparing Farm's Technical Efficiency Scores

Testing Hypothesis I: Planned white leg shrimp farmers are more technically efficient than unplanned farmers

The distributions of mean, standard deviation, minimum, and maximum levels of CRS TE ,VRS TE and SE scores for planned and unplanned farms are reported in Table 7.In general, averagely a planned farm produced more output per mill VND of white leg shrimp than an unplanned one.

Table 7: The Efficiency Analysis of Planned and Unplanned Farms of White Leg Shrimp in 2009

	Planned white leg shrimp farmers (15 Observations)				Unplanned white leg shrimp farmers (46 Observations)			
	Mean	St.Dev	Min	Max	Mean	St.Dev	Min	Max
Total output	950.000	850.760	280.000	2968.00	519.9630	152.983	304.000	930.000
VRS TE scores	0.76918	0.27097	0.39550	1.0000	0.72374	0.25428	0.32384	1.000
CRS TE scores	0.71941	0.25151	0.34877	1.0000	0.672581	0.22264	0.32234	1.000
SE scores	0.94106	0.07606	0.73828	1.0000	0.942881	0.08567	0.62804	1.000

Source: Own data

If we compare between planned and unplanned farmers we see that the mean value of VRS and CRS TE scores is higher of planned farms than unplanned farms and the SE scores are almost similar between these categories.

In the 2009 crop year, The planned farms tended to more mean value of annual production of white leg shrimp than unplanned ones.

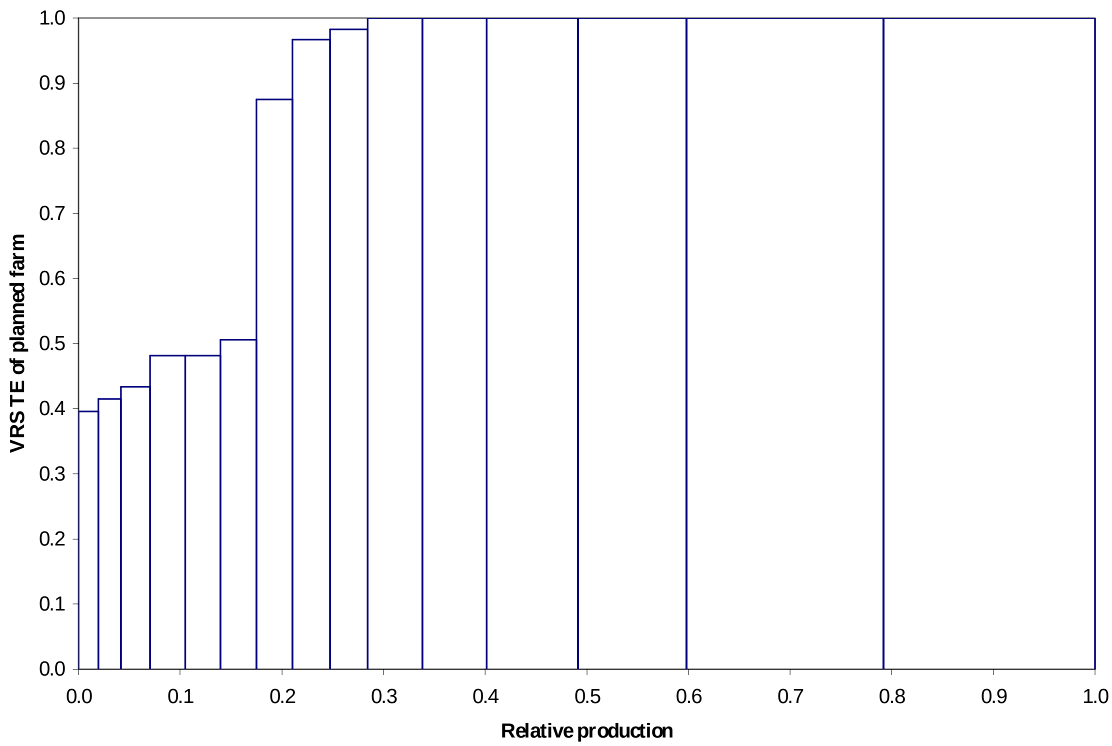

Figure 14: Relative Production and VRS Efficiency of Planned Farms

Source: Own data

If we compare the salter figures 14 and 15, the relative production of planned and unplanned groups with VRS TE , it is seen that the efficiency of planned farms is higher than unplanned farms.

When reviewing the table 8, the summary statistics of the variables used at farm level of planned and unplanned farms ,we see that on average, a farm spent about 61.067 million VND for labor costs per year in a govt. planning area. The range of this input variable was from 15.000 to 180.00 million VND. In which, an unplanned farm spent almost 47.652 million VND of labor cost on average, where the range was 12.000 to 210.00 mill VND.

Table 8: Summary Statistics of The Variables Used at Farm level of Planned and Unplanned in 2009.

Planned white leg shrimp farmers :					**Unplanned white leg shrimp farmers**			
Variables	Mean	St.Dev	Min	Max	Mean	St.Dev	Min	Max
Labour	61.067	41.781	15.000	180.00	47.652	36.870	12.000	210.00
Medica-tion and Feed	348.15	389.83	50.000	1311.0	184.83	100.11	45.000	429.00
Seed	37.140	24.719	7.5000	111.00	23.778	12.843	7.0000	60.000
Energy	55.120	37.354	15.000	180.00	47.600	41.897	10.000	300.00
Fixed cost	16.633	21.609	3.0000	85.000	9.8913	4.7375	4.0000	28.000

Source: Own data

On average, a farm spent about 348.15 million VND on medication and feed per year in govt. planning areas. The range of this input variable was from 50.000 to 1311.0 million VND. In which, an unplanned farm spent almost 184.83 million VND for medication and feed on average, where the range was from 45.000 to 429.00 mill VND.

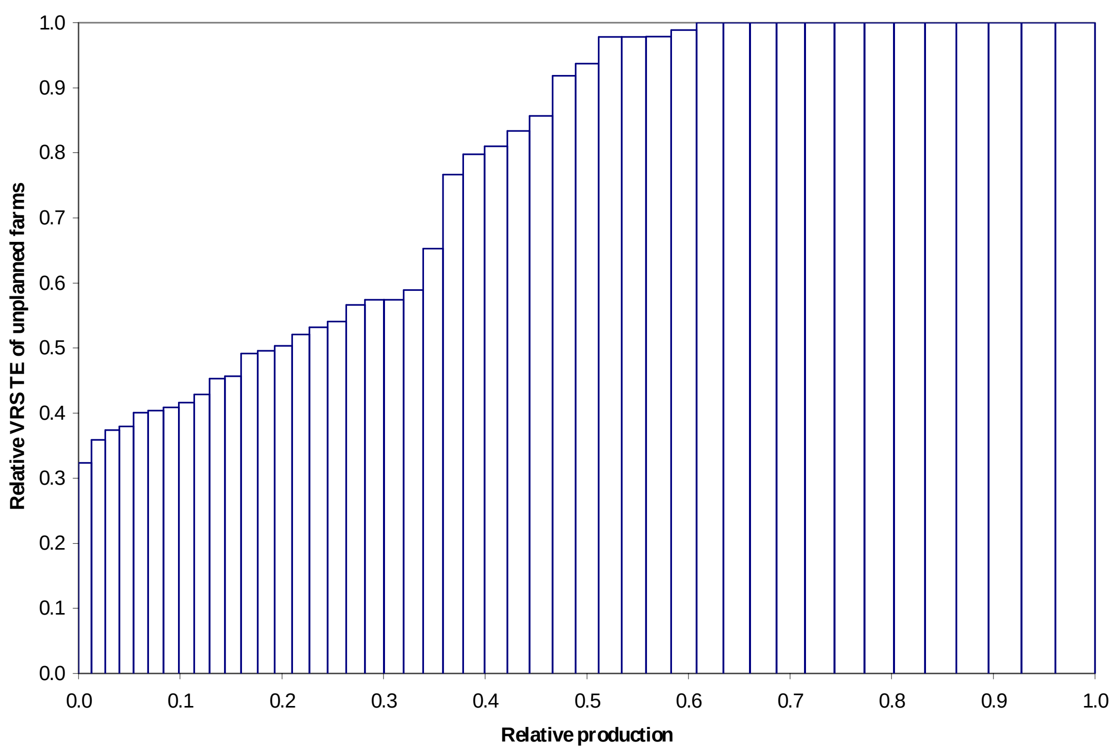

Figure 15: Relative Production and VRS Efficiency of Unplanned Farms
Source: Own data

The results also show that Seed cost, per farmer averaged approximately 37.140 mill VND in total for planned farms. The minimum was only 7.5 Mill VND, while the maximum was near 15 times higher in planned ponds, whereas in unplanned ponds, seed cost, per farmer averaged approximately 23.778 mill VND in total. The minimum was only 7.0000, while the maximum was only near 9 times higher in the year 2009.

The average energy costs of all planned farms were 55.120 mill VND but 47.600 mill VND in all unplanned farms . The minimum quantity of energy cost of all planned farms were 15.000 mill VND and 10.000 mill VND in all unplanned farms , while the maximum were 180.00 mill VND and 300.00 mill VND respectively.
The results also show that fixed cost, used per farmer averaged approximately 16.633 mill VND in total for planned farms. The minimum was only 3.0000, while the maximum was 85.000 mill VND in planned ponds, whereas in unplanned ponds, fixed cost, used per farmer averaged approximately 9.8913 mill VND in total. The minimum was only 4.0000 , while the maximum was 28.000 mill VND.

Figure 16: Comparisons Efficiency Between Planned and Unplanned Farms
Source: Own data

All of the sample farm's average efficiency score of the firms was 11.48% under Constant Returns to Scale and 31.15% under variable returns to Scale. The figure no 16 shows that 40% efficient farms in planned area whereas only 28% efficient farms under unplanned area, while inefficient farms under unplanned area is higher than planned area.

The distributions of mean, standard deviation, minimum, and maximum levels of some main factors with these two categories are compared in table 9. Some main factors are: the age of the household head, schooling of the household head, experience of the household head , the farm is how far from the channel, the proportion of total costs relative to total income, the proportion of variable costs relative to fixed costs, sales margin and return on asset. The mean values of these variables are shown in table 9.

In general, the mean values of independent variables of planned-pond groups were higher than that of unplanned-pond groups, except the schoolings of the household head, the proportion of variable costs relative to fixed costs and return on asset of unplanned farms was larger than planned.

Table 9 : Comparing the Mean Value and Standard Deviation of Factors in Planned and Unplanned Farms in 2009

Planned farmers(n_1=15)			Unplanned farmers(n_2=46)		Differences
Variables	Mean	S.D.	Mean	S.D.	t-test
VRS TE	0.78245	0.22716	0.71942	0.26640	0.286324
The age of the household head	46.200	12.353	44.435	8.8460	0.3072
Schooling of the household	9.4000	3.6016	9.8696	2.9560	0.326158
Experience	11.800	6.6783	12.065	5.2383	0.444888
How far from the channel	2426.7	3699.1	1508.5	1698.9	0.183116
Proportion of total costs relative to total income	2.0638	0.59577	1.6978	0.60673	0.025303
Proportion of variable costs relative to fixed costs	32.421	18.669	39.211	19.777	0.119652
Sales margin	0.47902	0.14134	0.24647	0.80134	0.005285
Return on asset	11.73	14.44713	32.13	71.2362	0.044102

Source : Own data

On average, the age of the household head of the farms was 46.2 years and had near 10 years of schooling and more than 11 years of experience in planned areas. In which, unplanned farmers were about 44.435 years of age and had 9.8696 years of schooling and more than 12 years of experience on average.. However, the t-test results, which tested whether the differences in mean values of all variables between two groups was different from zero or not, shows that the value of test statistic was not less than the critical value if a 5 percent level of significance was selected Critical value: : $t_{\alpha} = t_{0.05} =$ 1.645 (at 59 d.f.) and the test statistic *t* lies in the accepted region: All variable's critical values $< t_{\alpha} = 1.645$.

It means that the null hypothesis that there is no difference in mean of all variables such as age of the household head ; schoolings of the household head, experience of the household head ; distance of the farm from the channel, the proportion of total costs relative to total income , the proportion of variable costs relative to fixed costs , sales margin, return on asset between planned and unplanned farmers was accepted.

To test the hypothesis II : The farmers who are near the channel are more efficient than far from channel farmers.

The distributions of mean, standard deviation, minimum, and maximum levels of TE scores are reported in the Tables 10. It also presents the efficiency analysis at farm level of near the channel and far from channel farmers, in 2009. The average VRS and CRS TE scores of all farms who are near the channel ($\leq$ 500 m) were 0.77676 and 0.724477 which were higher than those who are far from the channel(>500 m) which were 0.70816 and 0.656055 and the average SE scores of both categories were almost same, but in both groups the average farmers were technically inefficient but they were close to efficiency in production.

Table 10: The Efficiency Analysis of Near From Channel and Far From Channel Farms of White leg Shrimp in 2009

	Near from channel farmers:				Far from channel farmer			
	Mean	St.Dev	Min	Max	Mean	St.Dev	Min	Max
Total output	547.24	239.9796	304	1280	680.2028	576.5696	280	576.5696
VRS TE scores	0.77676	0.27172	0.35890	1.0000	0.70816	0.24298	0.32384	1.0000
CRS TE scores	0.724477	0.250667	0.358504	1.0000	0.656055	0.211394	0.322346	1.0000
SE scores	0.938397	0.066344	0.767405	1.0000	0.940199	0.095221	0.628049	1.0000

Source : Own data

If we compare the figures 17 and 18 ,we see that the VRS efficiency is higher for near the channel farmers are more efficient than far from channel farmers.

When reviewing the table 11, the summary statistics of the variables used at farm level of near the channel farmers and far from channel farmers ,we see that on average, a farm spent about 50.840 million VND in labor costs per year in near the channel area. The range of this input variable was from 12.000 to 108.00 million VND. In which, the far from the channel farms spent almost 50.861 million VND of labor costs on average, where the range was 12.000 to 210.00 mill VND .

On average, a farm spent about 190.92 million VND for medication and feed per year in the near the channel area. The range of this input variable was from 45.000 to 507.00 million VND. In which, a far from the channel farm spent almost 248.08 million VND on Medication and Feed on average, where the range was 45.000 to 1311.0 mill VND .

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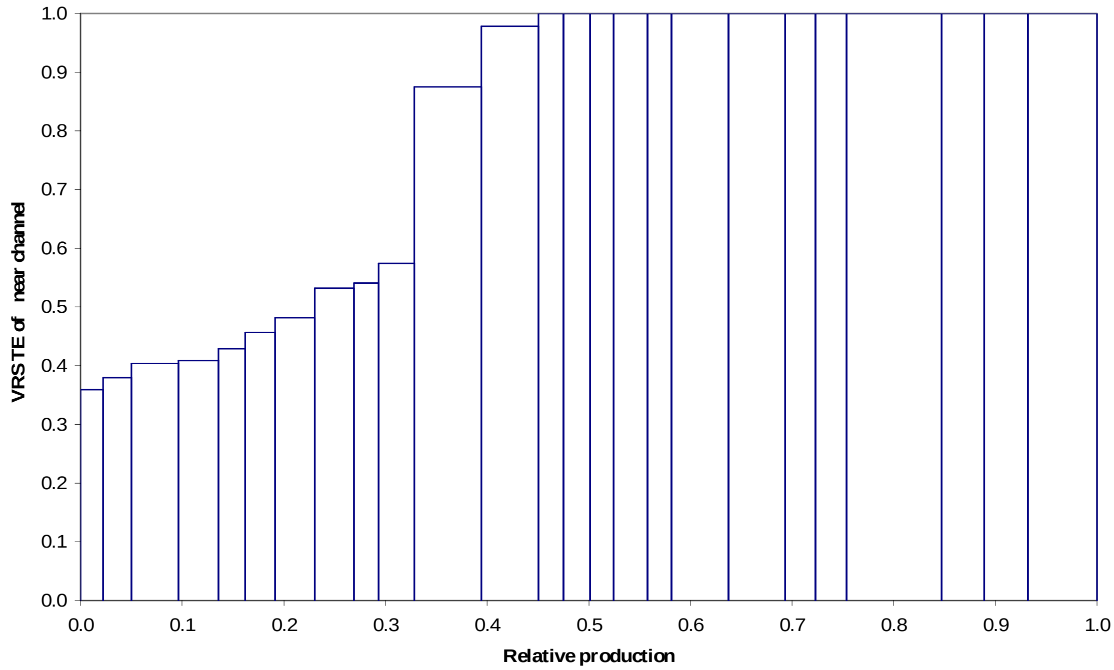

Figure 17 : Relative Production and VRS Efficiency of Near Channel Farms
Source : Own data

The results also show that Seed cost, used per farmer averaged approximately 26.920 mill VND in total for planned farms. The minimum was only 7.5000 , while the maximum was 8 times higher in near the channel ponds, whereas in far from the channel ponds ,seed cost, used per farmer averaged approximately 26.830 mill VND in total. The minimum was only 7.0000 mill VND , while the maximum was only near 16 times higher in the year 2009 .

The average energy costs of all near the channel farms was 38.720 mill VND and 57.233 mill VND in all far from the channel farms . The minimum quantity of energy costs of all planned farms were 10.000 mill VND and 18.000 mill VND in all far from the channel farms , while the maximums were 60.000 mill VND and 300.00 mill VND respectively.

Table 11: Summary Statistics of The Variables Used at Farm Level of Near From Channel Farmers and Far From Channel Farmers in 2009.

	Near the channel farmers				Far from channel farmers			
Variables	Mean	St.Dev	Min	Max	Mean	St.Dev	Min	Max
Labour	50.840	25.750	12.000	108.00	50.861	45.408	12.000	210.00
Medication and Feed	190.92	127.49	45.000	507.00	248.08	264.35	45.000	1311.0
Seed	26.920	16.059	7.5000	60.000	26.830	18.084	7.0000	111.00
Energy	38.720	16.557	10.000	60.000	57.233	49.957	18.000	300.00
Fixed cost	9.0600	4.8095	3.0000	25.500	13.125	14.413	4.0000	85.000

Source : Own data

The results also show that fixed costs, used per farmer averaged approximately 9.0600 mill VND in total for near the channel farms. The minimum was only 3.0000, while the maximum was 25.500 mill VND in planned ponds, whereas in far from the channel ponds , fixed cost, used per farmer averaged approximately 13.125 mill VND in total. The minimum was only 4.0000 , while the maximum was 85.000 mill VND .

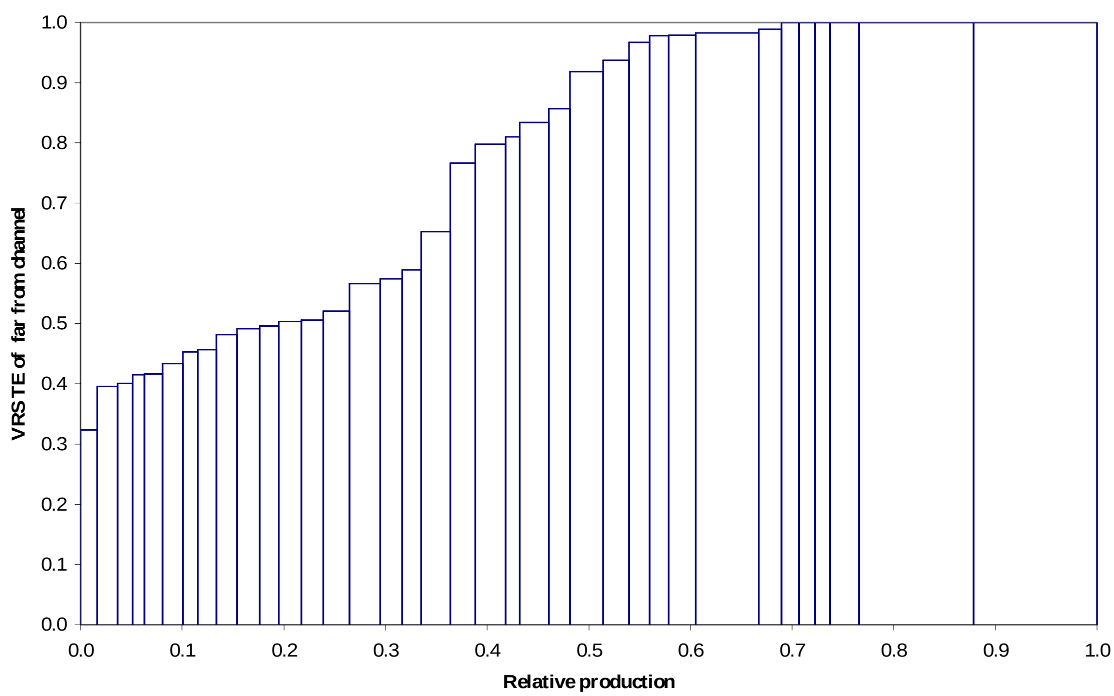

Figure 18 : Relative Production and VRS Efficiency of Far From Channel Farms
Source : Own data

The figure no.19 shows that 52% of farms in near the channel area were efficient whereas only 17% of farms were efficient in the far from the channel category, while inefficient farms in the far from the channel category are higher than in the near the channel category.

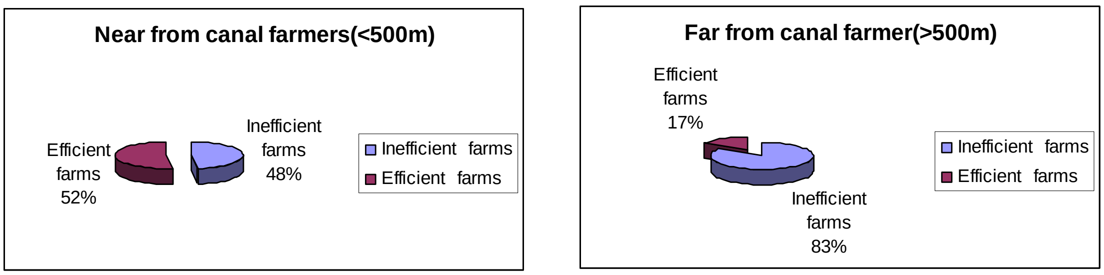

Figure 19 : Comparisons Efficiency Between Near the Channel and Far From the Channel Farms
Source : Own data

The distributions of mean, standard deviation, minimum, and maximum levels of some main factors with these two categories are compared in table 12. Some main factors are: the age of the household head, schooling of the household head, experience of the household head , the farm is how far from the channel, the proportion of total costs relative to total income, the proportion of variable costs relative to fixed costs, sales margin , return on asset .

The mean values of these factors are shown in table no.12. In general, the mean values of independent variables of far from the channel pond groups were higher than that of near the channel -pond groups, except the proportion of total costs relative to total income , The proportion of variable costs relative to fixed costs, sales margin though the technical efficiency of near the channel farms was larger than far from the channel farms.

On average, the age of the household head of the farms was 42.64 years and had near10 years of schooling and more than 10 years of experience in the near the channel area . In which, far from the channel farmers had 46.41667 years of age and 9.861111 years of schooling and more than 13 years experience on average .

Table 12: Mean Value and Standard Deviation of Factors in Near Channel and Far From Channel Farmers

Near from channel farmers (n_1=25) :			Far from channel farmers(n_2=36) :		Differences
Variables	Mean	S.D.	Mean	S.D.	t-test
VRS TE	0.773442	0.276252	0.708162	0.242982	0.172726
The age of the household head	42.64	8.260751	46.41667	10.48094	0.060841
Schooling of the household	9.6	2.753785	9.861111	3.356467	0.370321
Experience	10.52	3.25474	13.02778	6.574783	0.027122
How far from the channel	179.64	173.3899	2813.889	2551.655	0.000000216
Proportion of total costs relative to total income	1.839383	0.758821	1.751988	0.510404	0.309137
Proportion of variable costs relative to fixed costs	40.27321	24.2666	35.64448	15.63267	0.203022
Sales margin	0.389243	0.187838	0.379529	0.198714	0.423471
Return on asset	16.33	24.50034	33.09	79.60848	0.242412

Source : Own data

However, the *t*-test results, which test whether the differences in mean values of all variables between the two groups is different from zero or not, shows that the value of test statistics was less than the critical value if a 5 percent level of significance was selected. Critical value: : $t_\alpha = t_{0.05}$ = 1.645 (at 59 d.f.) and The test statistic t lies in the accepted region: All variable's critical values < t_α = 1.645 . It means that the null hypothesis that there is no difference in mean of all variables such as age of the household head ; schoolings of the household head , experience of the household head ; the farm is how far from the channel , the proportion of total costs relative to total income, the proportion of variable costs relative to fixed costs , sales margin between near the channel and far from the channel farmers was accepted.

Hypothesis III: "In far from channel farmers category", The farmers who have water keeping ponds, are more efficient than other farmers.

The distributions of mean, standard deviation, minimum, and maximum levels of TE scores are reported in Table 13. It also presents the efficiency analysis at the farm level of far from channel farmers category, the farmers who have water keeping ponds, and no water keeping pond farmers in 2009.

Table 13: The Efficiency Analysis of Farmers Who Have Water Keeping Pond and Non Water Keeping Pond of White Leg Shrimp in 2009

	Have water keeping pond 6 OBSERVATIONS				Non water keeping pond 30 OBSERVATIONS			
	Mean	St.Dev	Min	Max	Mean	St.Dev	Min	Max
Total output	599.1667	221.3652	360.00	930	680.6559	592.964	280	2968
VRS TE scores	0.8051	0.2738	0.4086	1.000	0.7079	0.2449	0.3238	1.0000
CRS TE scores	0.7721	0.2560	0.4086	1.000	0.6537	0.2120	0.3223	1.0000
SE scores	0.9660	0.0663	0.8325	1.000	0.9377	0.0974	0.6280	1.0000

Source : Own data

The average VRS and CRS TE and SE scores of all farms who have water keeping ponds were respectively 0.80513, 0.772146 , 0.966047 which were higher than those who have no water keeping ponds which were 0.70799 , 0.653716 and 0.937748 but in both groups, on average, farmers were technically inefficient but they were close to efficiency in production .

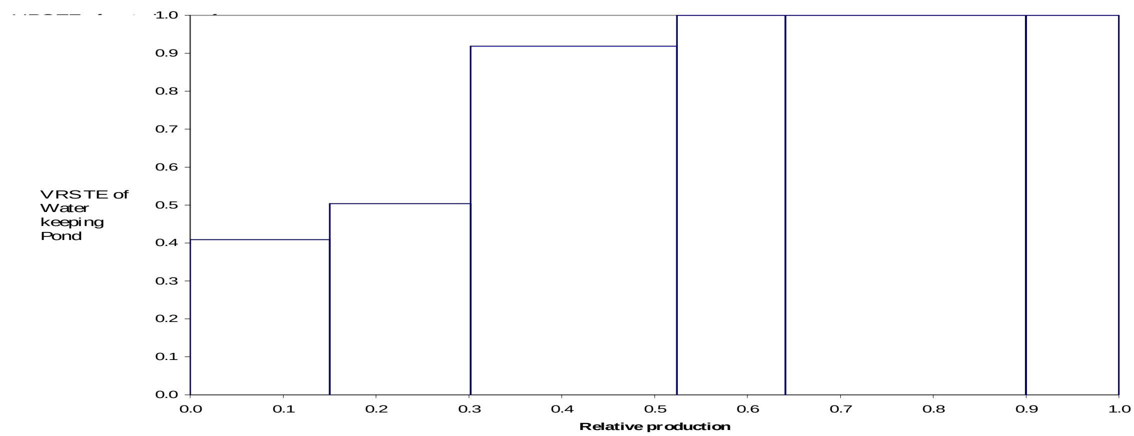

Figure 20: Relative Production and VRS Efficiency of Water Keeping Farms
Source : Own data

If we compare the salter diagrams in the figures 20 and 21 ,we see that the VRS efficiency is higher for water keeping ponds and they are more efficient than no water keeping pond farmers.

When reviewing the table 14, the summary statistics of the variables used at farm level of water keeping ponds and no water keeping pond farmers ,we see that on average, a farm spent about 60.000 million VND on labor costs per year who have water keeping ponds. The range of this input variable was from 30.000 to 108.00 million VND. In which, a no water keeping pond farm spent almost 50.324 million VND of labor costs on average, where the range was 12.000 to 210.00 mill VND.

Table 14: Summary Statistics Of The Variables Used In The Efficiency Analysis At Farm Level Of The Farmers Who Have Water Keeping Pond, And No Water Keeping Pond Farmers In 2009.

	Have water keeping pond				No water keeping pond			
	Mean	St.Dev	Min	Max	Mean	St.Dev	Min	Max
Labor	60.000	30.120	30.000	108.00	50.324	46.331	12.000	210.00
Medication and Feed	217.50	143.63	45.000	429.00	245.91	271.85	45.000	1311.0
Seed	26.417	13.865	9.0000	40.000	26.570	18.465	7.0000	111.00
Energy	40.167	24.895	11.000	75.000	56.982	51.330	18.000	300.00
Fixed cost	8.3333	3.3862	6.0000	15.000	13.456	14.774	4.0000	85.000

Source : Own data

On average, a farm spent about 217.50 million VND on Medication and Feed per year who have a water keeping pond. The range of this input variable was from 45.000 to 429.00 million VND and the farmers who have no water keeping pond spent almost 245.91 million VND of Medication and Feed cost on average, where the range was 45.000 to 1311.0 mill VND .

The results also show that Seed cost, used per farmer averaged approximately 26.417 mill VND in total for those who have water keeping pond farms. The minimum was only 9.0000 , while the maximum was 4.44 times higher who have water keeping ponds, whereas farmers who have no water keeping ponds ,seed cost, used per farmer averaged approximately 26.570 mill VND in total. The minimum was only 7.0000 mill VND , while the maximum was only near 16 times higher in the year 2009 .

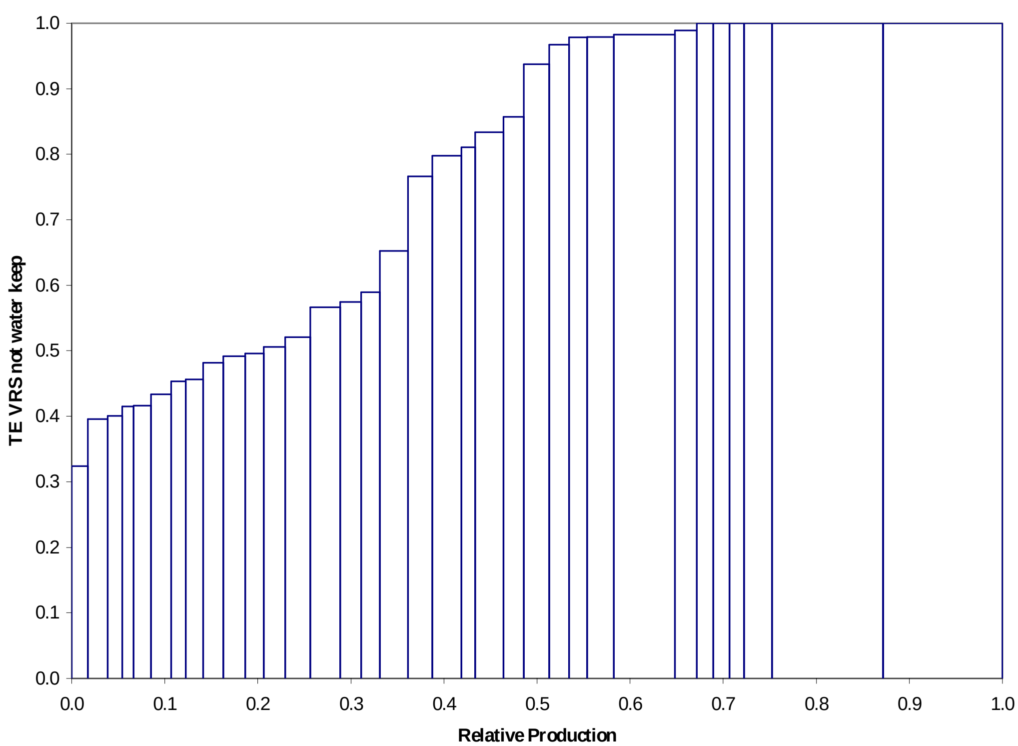

Figure 21: Relative Production and VRS Efficiency of Non Water Keeping Farms

Source : Own data

The average energy cost of farmers who have water keeping pond farms were 40.167 mill VND whereas 56.982 mill VND in farmers who have no water keeping pond farms . The minimum quantity of energy cost of all farmers who have water keeping pond farms were 11.000 mill VND and 18.000 mill VND in all farmers who have no water keeping pond farms, while the maximum were 75.000 mill VND and 300.00 mill VND respectively.
The results also show that fixed cost, used per farmer averaged approximately 8.3333 mill VND in total for farmers who have water keeping pond farms. The minimum was only 6.0000 , while the maximum was 15.000 mill VND in farmers who have water keeping ponds, whereas in farmers who have no water keeping ponds, fixed cost, used per farmer averaged approximately 13.456 mill VND in total. The minimum was only 4.0000 , while the maximum was 85.000 mill VND.

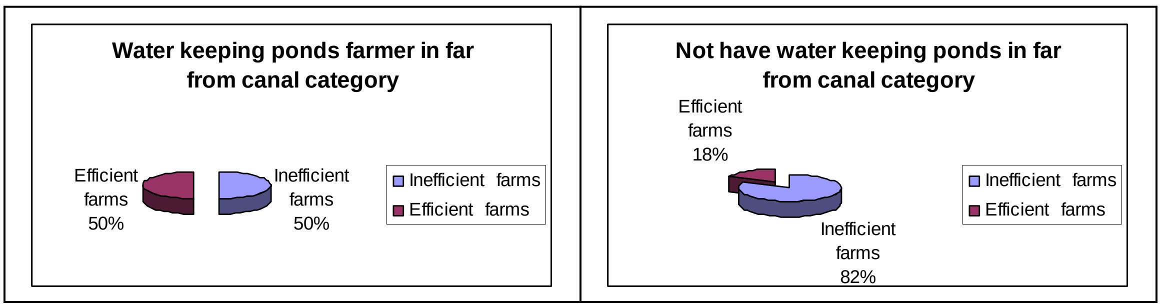

Figure 22:: Comparisons Efficiency Between Farmers Who Have Water Keeping Pond and Non Water Keeping Pond Farms
Source: Field survey

The figure no 22 shows that 50% of farms who have a water keeping pond are efficient whereas only 18% of farms who have no water keeping pond are efficient farms , while there are more inefficient farms under the no water keeping pond category.

The distributions of mean, standard deviation, minimum, and maximum levels of some main factors with these two categories are compared in table 15. Some main factors are: the age of the household head , schooling of the household head, experience of the household head , the farm is how far from the channel, the proportion of total costs relative to total income, the proportion of variable costs relative to fixed costs, sales margin , return on asset.

The mean values of these factors are shown in Table 15 In general, the mean values of independent variables of those who have no water keeping pond farms were higher than that who have water keeping pond farms, except schoolings of the household head, The proportion of variable costs relative to fixed costs, sales margin though the technical efficiency of near the channel farms was larger than far from the channel farms.

On average, the age of the household head of the farms in the near the channel farmers was from 38.33333 years and they had more than 10 years of schooling and more than 10 years of experience . In which, far from the channel farmers had about 47 years of age of the household head of farms and 9.764706 years of schooling and more than 13 years of experience on average .

Table 15: Mean Value And Standard Deviation Of Factors In Water Keeping And Non-Water Keeping Ponds

Have water keeping pond(n_1=6)			No water keeping pond(n_2=30):		Differences
Variables	Mean	S.D.	Mean	S.D.	t-test
VRS TE	0.805126	0.27382	0.707993	0.244968	0.222402
The age of the household head	38.33333	5.887841	47	10.49675	0.007037
Schooling of the household	10.16667	2.639444	9.764706	3.429452	0.375718
Experience	10.66667	3.204164	13.35294	6.623568	0.071531
How far from the channel	1266.667	1974.504	2773.529	2595.954	0.069306
Proportion of total costs relative to total income	1.734568	0.185037	1.766554	0.521809	0.393636
Proportion of variable costs relative to fixed costs	46.58135	26.58835	34.25382	14.55361	0.157051
Sales margin	0.417619	0.066113	0.382156	0.204295	0.21507
Return on asset	26.13	41.93919	34.53	81.755	0.710464

Source: Field survey

However, the t-test results, which test whether the differences in mean values of all variables between two groups different from zero or not, show that the value of test statistic was not less than the critical value if a 5 percent level of significance was selected Critical value: : $t_\alpha = t_{0.05}$ = 1.691 (at 34 d.f.) The test statistic *t* lies in the accepted region: All variable's critical values < t_α = 1.691.

It means that the null hypothesis that there is no difference in mean of all variables such as age of the household head ; schoolings of the household head , experience of the household head ; The farm is how far from the channel , the proportion of total costs relative to total income , The proportion of variable costs relative to fixed costs , sales margin ,return on asset between who have water keeping pond farms and who have no water keeping pond farms was not refused.

Hypothesis IV: Individual characteristics of the farmer such as experience, education and the ponds existence- how far from channel are significant factors affecting the technical efficiency of white leg shrimp culture production

Ordinary least squares (OLS) estimates of the parameters of the model are presented in Table 16 With the R^2 value of 0.4399 , the independent variables used in the model were able to explain 44% of the variation in the technical efficiency scores under VRS for the study area. t- statistics are calculated, with the null hypothesis that a parameter is zero, which means that the estimated variable has no effect on the dependent variable given that the other variables are in the model.

Table 16: Descriptive Statistics Of Factor Affecting Variables For 61 White Leg Shrimp Farms In Khan Hoa Province,2009

Variables	Mean	St.Dev	Min	Max	Estimated coefficient	t-value 52 df	P –value
VRS TE	0.73492	0.25693	0.32384	1.0000			
The age of the household head	44.869	9.7408	30.000	68.000	-0.01048	-1.392*	0.169
Schooling of the household	9.7541	3.1019	5.0000	15.000	0.00989	0.218	0.829
Experience	12.000	5.5678	2.0000	30.000	0.01119	1.588**	0.118
How far from the channel	1734.3	2348.7	0.0000	15000	-0.00002	-0.961	0.341

Proportion of total costs relative to total income	1.7878	0.61981	0.68627	4.2953	0.26539	4.810 *	0.000*
Proportion of variable costs relative to fixed costs	37.542	19.580	6.7059	109.17	0.0059079	3.115 *	0.003*
Sales margin	0.30365	0.70460	-4.9206	0.76719	0.0050757	0.09671	0.923
Return on asset	26.220	63.293	-42.667	455.32	**0.0005988**	1.146 **	0.257
Constant					0.765	4.120*	0.*
R2	0.4399						
F	5.105**						

*Statistically significant at the level of 5%.

**Statistically significant at the level of 10%.

Source: Field survey

Result indicates that the effect of socio-economic factor such as Age of households for white leg shrimp farming is significant at the 5% level. Age negatively related to efficiency The efficiency decreases with longer age of household.

Another socio-economic factors education and experience positively related, not low significance. Though, experience more significant than education for efficiency of white leg shrimp farmers.

Variable Education level has an expected sign, but it is not statistically significant. These contradictory results might be explain due to the fact that although higher educated farmers might have not more experience , they may not be more careful and conservative in adopting new technology, than experience farmers therefore, lead to less efficiency. It is believed that farming experience with higher level of educational achievement may lead to a better assessment in using output efficiently and making complex and important decisions in farm investment or farm operating.

As expected Distance from channel negatively related to efficiency. More distance from channel implies worse result for efficiency in white leg shrimp production. More distance farmer get less water which affects the production efficiency .

Financial factor such as the proportion of total costs relative to total income has high significant on technical efficiency. That means if the total income increases the total cost must be increased.

The proportion of variable costs relative to fixed costs has also high significant on technical efficiency. That means if the fixed cost increases the variable cost must be increased.

Sales margin is not significant on technical efficiency but positively related with efficiency .Return on asset is also positively related and significant with efficiency .

All of the financial variables effect means if the total income increases the total cost will increase. , they are motivated to improve their efficiency. In practical, this result suggests that proportion of total costs relative to total income and proportion of variable costs relative to fixed costs motivate managers to become more efficient because farmers who have income or fixed costs can generate enough financial resources to cover their operating expenses. It is appropriate in the case of white leg shrimp farming which need the high cost for operating.

In short, the results indicate that financial exposure (as measured by the proportion of total costs relative to total income and proportion of variable costs) is a source of efficiency for all white leg shrimp farms in the sample, the increase in sales margin is positively related to the technical efficiency scores for those farms.
Overall, the effect of all factors are significance on standard technical efficiency of white leg shrimp farmers.

5.2 Discussion

Findings of the research showed that, on average, White leg shrimp farms under the analysis were 11.48% under Constant Returns to Scale and 31.15% under Variable Returns to Scale technically efficient under the assumption of constant returns-to-scale (CRS) with TE CRS ranged from a minimum of 0.322346 to a maximum 1.000 and technically efficient under the assumption of variable returns-to-scale (VRS) with TE VRS .Minimum 0.323838 and maximum values 1.000 of efficiency score show considerable variability among farms. Mean technical efficiency under CRS suggests that the outputs used by White leg shrimp farms can be increased by their outputs by 31.59% under CRS and still produce the same level of input 26.51% and produce the same level of input if each farm in the sample was producing on the the efficient frontier at variable returns to scale.

The results of this study may only be the case for data collected in Khanh Hoa province. It can not be representative of Vietnam aquaculture. The individual analysis reveals that the unplanned group and far from channel and not have water keeping pond group used the combination of output more inefficiently than planned group and near the channel and have water keeping pond group . They could potentially maximize their output under VRS than under CRS without changing the input quantities used.

Doing aquaculture in planned group and near the channel and have water keeping pond environment would lead to higher level of technical efficiency than in unplanned group and far from channel and not have water keeping pond in far from channel category . It means that the first, second and third hypothesis that planned group and near the channel and have water keeping pond farm had higher technical efficiency than unplanned group and far from channel and not have water keeping pond farms were true. This result might imply that production environment was really an important factor in doing aquaculture and in order to improve productivity aquaculture area should be planned and near the channel and have water keeping pond if their existence are far from channel to get better water quality (table 7, 10 and 13)

However, most farms were from unplanned group and far from channel and not have water keeping pond farms group, such as 75 % of total farms were unplanned, 41 % of total farms were near the channel ,17% have water keeping pond only 25 percent were planned, 59% were far from channel , 83% have not water keeping pond in far from channel category. That might be due to small planned group and near the channel and have water keeping pond farm samples collected. If considering the efficient proportion in each type of ecosystem, from 40 percent of total planned , 52 percent of near the channel and 50% of have water keeping pond farms were operating efficiently, while only 28 percent of total unplanned group , 17 percent of far from channel and 18 percent of not have water keeping pond farms were on the frontier (figure 16,19 and22).

Furthermore, the individual analysis reveals that except 11 percent of CRS farms which were at optimal scales, about 73 percent of IRS farms should expand their operating scale to improve their productivities. Because if any farm in IRS farms increased by one percent of input levels, he/she could expand by more than one percent of outputs produced. Any k percent increase in input levels used by those 11% CRS farms would lead to k percent increase in outputs produced. Only 16 percent of total farms should not increase their scale because their outputs would only be expanded less than 1 percent when they used one more percent of inputs (figure 13).

Farm technical efficiency was found to be influenced by farm the proportion of total costs relative to total income. . The results indicate that financial exposure is a source of efficiency for all white leg shrimp farms in the sample. In other words, the increase in the proportion of total costs relative to total income positively influences the technical efficiency of those farms.

There has a significant positive relationships were found between technical efficiency and proportion of variable costs relative to fixed costs. Increased fixed cost for applying modern machines and equipment in operating as well as improvement of ponds and increase variable costs in cropping season , lead to better performance of technical efficiency .

The experience of household head measured by the years of white leg shrimp farming has positive effects on technical efficiency indicates that the more experiences the farmers have had in previous time of farming, the more efficiency those farms will have.

In addition, although experience could not be increased simply by attempts of human being, sharing experience should be done to improve the knowledge of aquaculture farmers. This should especially be implemented in unplanned group and far from channel and not have water keeping pond farms , because a one percentage increase in experience and the proportion of total costs relative to total income would result in almost 0.26 percentage change in technical efficiency of this group (table 16).
Due to the limitation of time and ability, this study could not presently show how much slack of the output congestion is. This might be an interesting topic for further study in the future.

6. Conclusion and Implications

6.1 Thesis Summary

White shrimp was first cultured in South America. Due to uncontrolled farming activities in those countries the entire industry was devastated. The industry has not recovered fully from the earlier onslaught in most South American countries, such as Ecuador (Francisco J. et al.,2004).This study provides an important rationale for cooperation between several interested parties in utilizing the high production capacities of white leg shrimp. The rationale is that an increase in the cooperation level leads to an increase, not only in the stocking densities, but also in several other related factors of white leg shrimp production. Moreover, the possibilities for cooperation in utilizing government planning, a farm's existence near the channel and keeping water in a special pond are examined. Some measures are also proposed to improve the aquaculture area. Suggestions are made for planning the aquaculture area, locating farms near the channel and keeping a water holding pond without culture if the farm is far from channel. Cooperation between unplanned farms and governmental offices would also improve technical efficiency. Moreover, for farmers, being experienced with a cultured system was also suggested in order to increase productivity. An empirical investigation of the profitability and efficiency of a white leg shrimp farmer was demonstrated. Finally, the study will propose some aquaculture strategies for Vietnam.

6.2 Conclusion

This research uses the DEA method to estimate the technical efficiency of selected white leg shrimp farms in Khanh Hoa province. Cross-sectional data of direct interviews from 61 farms from three regions were used in this study. To estimate the technical efficiency, the data for each farm in the sample was aggregated into five inputs (labor, medication and feed , seed ,energy, fixed cost) and one output (value of white leg shrimp production). Farm individual technical efficiency scores were used in a regression model to reveal the relationship between the technical efficiency under assumption of variable returns to scale and different farm-specific characteristics including the farm's financial variables. Variables hypothesized to influence technical efficiency included age of household head ,education of household head, experience ,distance from channel ,the proportion of total costs relative to total income, the proportion of variable costs relative to fixed costs, and sales margin .The empirical results suggest that socio-economic factors such as education and experience positively related, with experience being more significant than education, to the efficiency of white leg shrimp farmers. Environmental factor such as a greater distance from the channel implied worse result for efficiency in white leg shrimp production. Financial factors, such as the proportion of total costs relative to total income, the proportion of variable costs relative to fixed costs, sales margin and return on asset had a positive effect on efficiency of the farmers. In addition, comparing between the technical efficiency results of planned farms and unplanned farms, farms near to the channel and far from the channel , farmers who have a water keeping pond and who do not have a water keeping pond, it was seen that the unplanned farms and far from the channel and non-water keeping pond farms were less efficient than their counterparts . Insufficient number of observations of water keeping ponds make statistical tests difficult ,but the few data points illustrates rather than prove this statement ..

6.3 Implication

The economic performance indicators presented in this paper, based on a 2009 survey of costs and production data of a sample of 61 white leg shrimp farms in Khanh Hoa, Vietnam, demonstrate that experience has a significant effect on the technical efficiency of white leg shrimp farms. As discussed above, socio-economic factors of a white leg shrimp farmer; such as : age of household head, education period, and experience may be among the reasons for the difference in the number of white leg shrimp production per year. For more detailed policy recommendations, more data about socio-economic factors of farmers needs to be collected. Support that does not contribute to capacity and effort expansion, however, such as training farmers, providing information about how to prevent disease, how to keep sufficient water, and how to maintain a farming process with good management, may be good for this type of farming. Finally, convincing other farming related investor countries to establish a Regional Farming Management Organization for white leg shrimp may be an important policy recommendation for long-term development in aquaculture. Based on data collected from a sample of 61 white leg shrimp farmers in Khanh Hoa, this paper has provided new knowledge about the annual production of this expanding type of farming in a rapidly developing country. Future work may consist of the gathering of socio-economic information about farmers and include more farmers to create time series. Further discussion on policy implications of the economic and statistical analyses confirmed above will be a challenging task. From the experience of many farming nations around the world, we know that there is a limit to farming production in any area and generate some environmental effect to deplete natural resources and harm the economy of the farming industry. We are, however, convinced that cost and production studies, including analyses of data, are necessary for good farming policy development in Vietnam and other farming interested developing countries.

References

Aigner, D.J., Lovell, C.A.K., Schmidt, P.J. (1977). Formulation and Estimation of Stochastic Frontier Production Function Models. Journal of Econometrics, 6: 21–37

Alam, M. F. and K. Murshed-e-Jahan (2008). "Resource Allocaltion Efficiency Of The Prawn-Carp Farmers Of Bangladesh." Aquaculture Economics & Management.

Amos, T. T. (2007). "Production and Productivity of Crustacean in Nigeria." J. Soc. Sci 15 (3): 229-233.

Andersen, P. and Petersen. N.C. (1993) A Procedure for Ranking Efficient Units in Data Envelopment Analysis. Management Science 39 (10): 1261-1264.

Arthur E. Neilanda, Neill Soleya, Joan Baron Varleyb, David J. Whitmarsh,2001: Shrimp Aquaculture: Economic Perspectives For Policy Development

Banker, R. D., A. Charnes, et al. (1984). "Some Models For Estimating Technical And Scale Inefficiencies In Data Envelopment Analysis." Management Science 30.

Banker, R.D. and R.M. Thrall. 1992. "Estimation of Returns to Scale Using Data Envelopment Analysis." European Journal of Operational Research 62(1): 35-44.

Charnes, A., W.W. Cooper, and E. Rhodes. 1978. Measuring the Efficiency of Decision Making Units. European Journal of Operational Research 2(6): 429-444. 46

Charnes, A., Cooper, W.W. and Rhodes, E. (1981). Evaluating Program and Managerial Efficiency: An Application of Data Envelopment Analysis to Program Follow Through. Management Science, 27(6): 668–697.

Chen, Y., Measuring super-efficiency in DEA in the presence of infeasibility", European Journal of Operational Research, Vol. 161, (2005) pp. 545–551.

Chiang, F.-S., C.-H. Sun, et al. (2004). "Technical Efficiency Analysis Of Milkfish (*Chanos Chanos*) Production In Taiwan - An Applicantion Of The Stochastic Frontier Production Function." Aquaculture.

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

Cooper, W.W., Seiford, L.M., Zhu, J. (2004) Data Envelopment Analysis History, Models and Interpretations, in Hand book of Data Envelopment Analysis .

.

Cuong Hoang Van ,2009 ,Technical and Scale Efficiency of the Intensive Tiger Shrimp Cultivation Farms in Binh Dai district, Ben Tre Province, Vietnam - An Application of DEA

Department Of Agriculture, " Khanh Hoa Aquaculture Report On The Results Produced For 2009"

Den, D. T., T. Ancev, et al. (2007). "Technical Efficiency Of Prawn Farms In The Mekong Delta, Vietnam."

Dey, M. M., F. J. Paraguas, et al. (2005). "Technical Efficiency Of Freshwater Pond Polyculture Production In Selected Asian Countries: Estimation And Implication." Aquaculture Economics & Management 9(1): 39-63.

Dzung Tien and Mr. Don Griffiths,2010: Shrimp GAP and BMP in Vietnam: Policy, Current Status And Future Direction

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

Francisco J. Martinez-Corderoa, PingSun Leungb,2004, Sustainable Aquaculture And Producer Performance: Measurement Of Environmentally Adjusted Productivity And Efficiency Of A Sample Of Shrimp Farms In Mexico

Hanh Bui Le Thai (2009):Impact Of Financial Variables On The Production Efficiency Of Pangasius Farms In An Giang Province,Vietnam

Huy Dang Hoang Xuan (2009) Technical Efficiency Analysis For Commercial Black Tiger Prawn (*Penaeus monodon*) Aquaculture Farms In Nha Trang City, 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 175(3-4): 199- 213.

Jati k. sengupta ,1987:Production Frontier Estimation To Measure Efficiency :A Critical Evaluation In Light Of Data Envelopement Analysis

Jayaraman, R. (1997). "Carp Culture in Thanjavur District, Tamil Nadu,

Kaliba, A. R. and C. R. Engle (2006). "Productive Efficiency Of Catfish Farms In Chicot County, Arkansas." Aquaculture Economics & Management 10(3): 223-243.

Kareem, R. O., A. O. Dipeolu, et al. (2008). "Economic Efficiency In Fish Farming: Hope For Agro-Allied Industries In Niagara." Chinese Journal of Oceanology and Limnology 26(1): 104-115.

Kebede Tewodros Aragie(2001),"Farm household Technical Efficiency :A Stochastic Frontier Analysis, A Study Of Rice Producer In Mardi Watershed In The Western Development Region Of Nepal."

Kevin Cullinane a, Teng-Fei Wang b, Dong-Wook Song c, Ping Ji .2005 ,The Technical Efficiency Of Container Ports: Comparing Data Envelopment Analysis And Stochastic Frontier Analysis

Kiatpathomchai, S. (2008). "Assessing Economic and Environmental Efficiency of Rice Production Systems in Southern Thailand: An Application of Data Envelopment Analysis." Agricultural Sciences, Nutritional Sciences and Environmental Management.

Lovell, C.A.K. (1993). Production Frontiers and Productive Efficiency, in H.O. Fried, C. A.K

Meeusen, W., Van den Broeck, J. (1977) Efficiency Estimation from Cobb- Douglas production functions with composed error. International Economic Review, 18: 435–444

Mussa, R. (2006). "Technical Efficiency of Smallholder Farmers in Southern Malawi: A Study of Adopters and Non-adopters of Integrated Aquaculture." University of Malawi Chancellor College.

Nguyen Viet Thang,2005: Viet Nam Country Report On Policies For Sustainable Shrimp Culture

Pantzios, C., V. Tzouvelekas, et al.(2004) "Parametric Decomposition Of The Input-Oriented Malmquist Productivity Index: With An Application To Greek Aquaculture."

P Smith ,1990 , Data Envelopment Analysis Applied to Financial Statements

Sharma, K. R., P. S. Leung, et al. (1999). "Economic Efficiency And Optimum Stocking Densities In Fish Polyculture: An Application Of Data Envelopment Analysis (DEA) To Chinese Fish Farms." Aquaculture 180(3-4): 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 31(12): 937-947.

Thompson, R.G., Singleton, F., Thrall, R. and Smith, B. (1986). Comparative Site Evaluations for Locating a High-energy Physics Labs in Texas. Interfaces, 16(6): 35–49.

Timothy J. Coelli, D.S. Prasada Rao, et al. (2005). An Introduction to Efficiency and Productivity Analysis, Second Edition, Springer: 172.

Ton Nu Hai Au,2009, Technical Efficiency Of Prawn Poly-Culture In Tam Giang Lagoon, Vietnam

Tuyen, T. V. (2005) "Scale Up Of Participatory Planning For Resource Governance: A Case In Sam Chuon Lagoon, Vietnam."

Tyler, S. R. (2002) "Learning from the Field: Applying Commons Theory in Practice." President, Adaptive Resource Management Ltd, Victoria B.C. Canada.

Vo Van Dung (2008). "LưỢng Giá Giá TrỊ Kinh TẾ ChỦ YẾu CỦa ĐẦm Phá Khanh Hoa." KỶ YẾu HỘi NghỊ Khoa HỌc LẦn ThỨ II: 72-110.; Vo Van Dung (2008), "Economic Valuation of The Khanh Hoa ."

Appendix 1

DMU No.	DMU Name	Output-Oriented VRS Efficiency	Output-Oriented CRS Efficiency	$\Sigma\lambda$	Output-Oriented RTS
1	46	2.33256	2.45419	0.88119	Increasing
2	15	2.07515	2.12384	0.91460	Increasing
3	12	1.53231	1.53892	0.92165	Increasing
4	18	2.01695	2.09105	0.87300	Increasing
5	12	1.25309	1.25476	1.01316	Decreasing
6	18	1.19944	1.24886	0.71384	Increasing
7	20	1.02208	1.11087	0.57972	Increasing
8	75	1.74112	1.92524	0.76942	Increasing
9	12	2.18985	2.35973	0.83526	Increasing
10	18	2.67522	2.67679	1.00467	Decreasing
11	18	2.30625	2.30844	0.97642	Increasing
12	90	3.08796	3.10226	1.04798	Decreasing
13	54	1.03392	1.13364	0.54193	Increasing
14	102	1.00000	1.07451	0.73333	Increasing
15	210	1.06681	1.06860	0.98010	Increasing
16	115	1.16679	1.18265	0.91748	Increasing
17	62	1.97723	2.01716	0.90138	Increasing
18	30	2.40242	2.40622	0.98248	Increasing
19	18	2.52844	2.54821	1.10577	Decreasing
20	66	2.03387	2.03731	0.95942	Increasing
21	81	1.00000	1.00000	1.00000	Constant
22	12	1.23385	1.26184	0.91975	Increasing
23	36	1.00000	1.00000	1.00000	Constant
24	70	1.00000	1.06148	0.41049	Increasing
25	20	1.02222	1.16364	0.40909	Increasing
26	12	1.00000	1.13834	0.40909	Increasing
27	78	1.01141	1.04183	0.86296	Increasing
28	48	1.00000	1.41189	0.43636	Increasing
29	80	1.00000	1.30309	0.44243	Increasing
30	108	1.00000	1.00000	1.00000	Constant
31	30	1.00000	1.59223	0.64974	Increasing
32	84	1.08872	1.12166	1.26422	Decreasing
33	24	1.69695	1.70802	0.94138	Increasing
34	48	1.74111	1.80731	0.87611	Increasing
35	54	2.44683	2.44688	0.99939	Increasing
36	46	2.07707	2.09259	1.02039	Decreasing
37	90	1.00000	1.00000	1.00000	Constant
38	40	2.63274	2.65577	0.96239	Increasing
39	45	1.01779	1.37858	3.73068	Decreasing
40	15	1.76587	1.78807	0.92116	Increasing
41	84	1.00000	1.07897	0.41455	Increasing
42	90	1.02142	1.06612	0.47558	Increasing
43	52	1.30460	1.33802	0.67947	Increasing

44	15	1.87847	1.89524	1.09568	Decreasing
45	54	1.00000	1.16452	0.58750	Increasing
46	48	1.00000	1.10517	0.90909	Increasing
47	50	1.84919	1.89091	0.76722	Increasing
48	12	2.49720	2.60686	0.81390	Increasing
49	48	1.00000	1.00000	1.00000	Constant
50	36	1.98587	1.99970	0.96749	Increasing
51	42	1.00000	1.10654	0.53050	Increasing
52	30	2.78631	2.78937	0.98347	Increasing
53	16	2.20645	2.21442	0.95142	Increasing
54	48	1.92058	1.94683	0.70599	Increasing
55	64	2.47523	2.62204	1.55466	Decreasing
56	180	2.40949	2.86718	0.68595	Increasing
57	42	1.00000	1.40621	0.66569	Increasing
58	42	1.00000	1.00000	1.00000	Constant
59	45	1.14312	1.20003	1.47987	Decreasing
60	30	1.00000	1.00000	1.00000	Constant
61	48	1.00000	1.20108	0.39001	Increasing

Appendix 2

Govt. Planning farm

DMU's	VRS TE	CRS TE	SE
2	0.481893	0.470846	0.977076
11	0.433604	0.433194	0.999054
13	0.967195	0.882116	0.912035
14	1	0.930657	0.930657
17	0.505758	0.495748	0.980207
19	0.395501	0.392432	0.992241
21	1	1	1
23	1	1	1
24	1	0.942084	0.942084
36	0.481448	0.477877	0.992584
37	1	1	1
39	0.982519	0.725382	0.738289
45	1	0.85872	0.85872
56	0.415025	0.348775	0.840371
59	0.874801	0.833313	0.952575

Appendix 3

Non-Government Planning farm

DMU"S	VRS TE	CRS TE	SE
1	0.428713	0.407467	0.950443
3	0.652609	0.649806	0.995705
4	0.495799	0.478228	0.964561
5	0.798027	0.796964	0.998667
6	0.833726	0.800729	0.960422
7	0.978395	0.900198	0.920077
8	0.574344	0.519415	0.904363
9	0.456653	0.423777	0.928007
10	0.373801	0.373582	0.999413
12	0.323838	0.322346	0.995391
15	0.937373	0.935802	0.998324
16	0.857055	0.845557	0.986584
18	0.416247	0.41559	0.99842
20	0.491674	0.490843	0.998309
22	0.810471	0.792491	0.977816
25	0.978261	0.859375	0.878472
26	1	0.878472	0.878472
27	0.98872	0.959846	0.970797
28	1	0.708268	0.708268
29	1	0.767405	0.767405
30	1	1	1
31	1	0.628049	0.628049
32	0.918507	0.891536	0.970636
33	0.589293	0.585473	0.993518
34	0.574345	0.553308	0.963372

35	0.408693	0.408685	0.99998
38	0.379833	0.376539	0.991329
40	0.566293	0.559264	0.987587
41	1	0.926809	0.926809
42	0.97903	0.937984	0.958074
43	0.76652	0.747375	0.975024
44	0.532349	0.527639	0.991153
46	1	0.904839	0.904839
47	0.540777	0.528846	0.977938
48	0.400449	0.383604	0.957934
49	1	1	1
50	0.503557	0.500076	0.993086
51	1	0.903716	0.903716
52	0.358898	0.358504	0.998903
53	0.453218	0.451587	0.996401
54	0.520676	0.513655	0.986516
55	0.404002	0.381382	0.944009
57	1	0.711132	0.711132
58	1	1	1
60	1	1	1
61	1	0.832582	0.832582

Appendix 4

Near from canal farmer

Farms	VRS TE	CRS TE	SE
1	0.428713	0.407467	0.950443
7	0.978395	0.900198	0.920077
8	0.574344	0.519415	0.904363
10	0.456653	0.373582	0.818087
14	1	0.930657	0.930657
24	1	0.942084	0.942084
26	1	0.878472	0.878472
29	1	0.767405	0.767405
30	1	1	1
35	0.408693	0.408685	0.99998
36	0.481448	0.477877	0.992584
37	1	1	1
38	0.379833	0.376539	0.991329
44	0.532349	0.527639	0.991153
45	1	0.85872	0.85872
46	1	0.904839	0.904839
47	0.540777	0.528846	0.977938
49	1	1	1
51	1	0.903716	0.903716
52	0.358898	0.358504	0.998903
55	0.404002	0.381382	0.944009
58	1	1	1
59	0.874801	0.833313	0.952575
60	1	1	1
61	1	0.832582	0.832582

Appendix 5

Far from canal farmers

FIRMS	TE scores	CRS	SE
2	0.481893	0.470846	0.977076
3	0.652609	0.649806	0.995705
4	0.495799	0.478228	0.964561
5	0.798027	0.796964	0.998667
6	0.833726	0.800729	0.960422
9	0.456653	0.423777	0.928007
11	0.433604	0.433194	0.999054
12	0.323838	0.322346	0.995391
13	0.967195	0.882116	0.912035
15	0.937373	0.935802	0.998324
16	0.857055	0.845557	0.986584
17	0.505758	0.495748	0.980207
18	0.416247	0.41559	0.99842
19	0.395501	0.392432	0.992241
20	0.491674	0.490843	0.998309
21	1	1	1
22	0.810471	0.792491	0.977816
23	1	1	1
25	0.978261	0.859375	0.878472
27	0.98872	0.959846	0.970797
28	1	0.708268	0.708268
31	1	0.628049	0.628049
32	0.918507	0.891536	0.970636
33	0.589293	0.585473	0.993518
34	0.574345	0.553308	0.963372
39	0.982519	0.725382	0.738289
40	0.566293	0.559264	0.987587
41	1	0.926809	0.926809
42	0.97903	0.937984	0.958074
43	0.76652	0.747375	0.975024
48	0.400449	0.383604	0.957934
50	0.503557	0.500076	0.993086
53	0.453218	0.451587	0.996401
54	0.520676	0.513655	0.986516
56	0.415025	0.348775	0.840371
57	1	0.711132	0.711132