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EVALUATION OF INPUT EFFICIENCY FOR CATFISH FARMS IN MEKONG RIVER DELTA, VIETNAM

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ABSTRACT

This study has used minimizing input-oriented Constant Return to Scale (CRS) Data Envelopment Analysis (DEA) model with one output and seven input variables. The study's purpose was to analyse technical efficiency to reduce input resource cost for catfish in Mekong River Delta, Viet Nam. The report is based on 61 samples from catfish farms with information gathered from farmers regarding production and usage of inputs. The minimizing input-oriented CRS DEA results indicate that there are 11 technically efficient catfish farms (18%) and 50 technically inefficient catfish farms (82%). The ratio of resource reduction of input variables varied from around 20% to nearly 60%. In future research, stochastic frontiers method should be used to compare results of DEA method and environmental variables should be included, for example, location and water quality.

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1 INTRODUCTION

In recent years, catfish have become one the main species of the Viet Nam aquaculture and seafood export industry, reaching 2% of GDP and over 32% of total export value of the fishery sector (VASEP, 2008). From 1998 to 2008, catfish farming areas increased 7 times, but at the same time these was a 36 fold increase in production and the export volume of fillets increased more than 40 times (AGROVIET, 2008). In 2010, the value of export reached a record of 1.5 billion USD, and catfish were exported to over 130 countries (VASEP, 2010)

However, associated with the rapid development of catfish farming prices have decreased. The average export price of catfish decreased from USD 3.76 per kilogram in 2000 (VASEP, 2008) to USD 2.14 per kilogram in 2010 (VASEP, 2010). Falling prices were not only experienced in traditional markets, but also in new markets which have been growing fast, such as the Middle East, Mexico, Saudi Arabia and Australia (VASEP, 2010). On the other hand, the production cost of catfish has been increasing over time. In 2006 production costs were estimated to be 0.59 USD/kg (Phuong *et al.*, 2007), but in 2008 costs had risen to 0.70 USD/kg (Hien, 2008). Catfish farming has been run at a loss in recent years, mainly due to reduction of product prices and increased production cost (de Silva, 2010).

In 2009, the export value of catfish reached USD 1.3 billion and many researchers argued that the industry would still develop well, but actually the farmers lost the equivalent of 10-20 US cents for every kg they produced. In 2008, about 25% of catfish farmers went bankrupt, 30% lost household’s own capital, and 40% of households could not pay the bank debt due to heavy losses (RFA, 2010).

The development of the catfish aquaculture industry indicates that it is important to look into the efficiency of the production process. Data Envelopment Analysis (DEA) is a method of analyzing, for example, input costs and identifies which part of the production costs could be reduced. The objective of this research is to analyze input resource cost of the catfish farming system in the Mekong River Delta in Viet Nam

2 DEVELOPMENT OF CATFISH FARMING IN THE MEKONG RIVER DELTA, VIET NAM

2.1 Aquaculture development in Viet Nam

Aquaculture in Viet Nam has developed rapidly in recent years. The total area of aquaculture ponds increased from 525 thousand ha in 1999 to 1.065 million ha in 2007 which were 480,000 ha of freshwater and 585,000 ha of brackish water. This exceeded the development goal set the by government, The total fisheries production increased every year in 1995-2010, but the growth of aquaculture has been more rapid than the growth of capture fisheries, and in 2007 the total production from aquaculture exceeded the capture fisheries (Figure 1). In 2010, the total fisheries production amounted to 5.2 million tons and the contribution from aquaculture was 2.8 million tons.

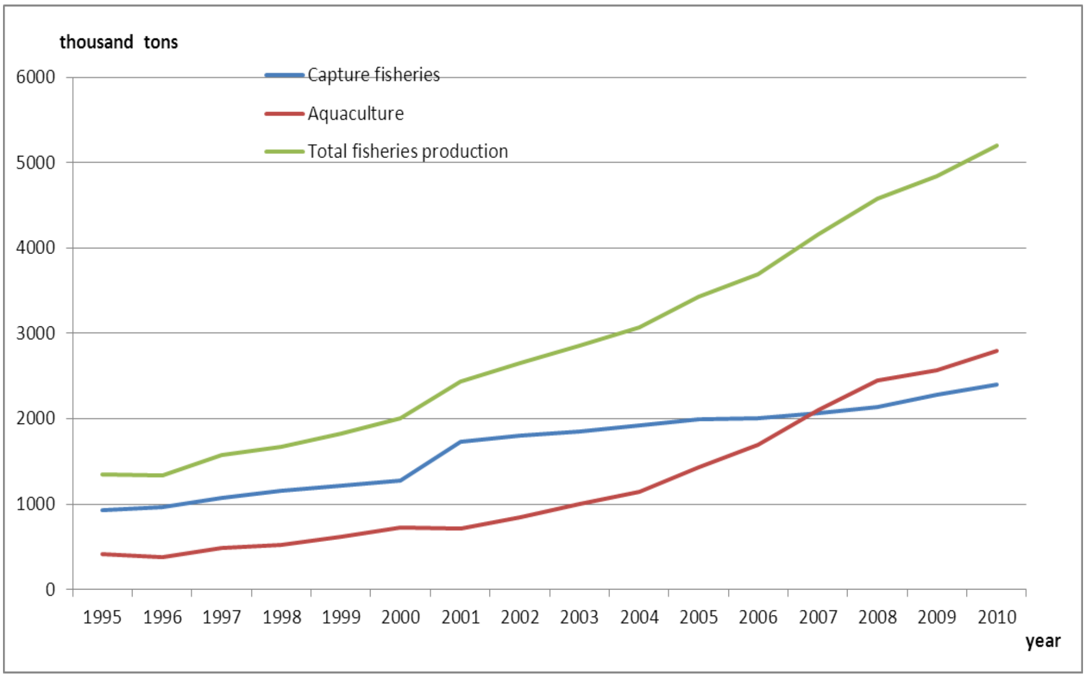

Figure 1: Fisheries production in Vietnam in 1995-2010 (VASEP, 2010)

The average annual growth of aquaculture has been greater than the growth in the capture fisheries (Table 1). During the first five years of the time period the growth was close to two times greater in the aquaculture compared to capture fisheries. Moreover, in recent years, the growth has been 14% in aquaculture or more than three times faster the growth in capture fisheries.

Table 1: Average annual growth of fisheries production in Vietnam (VASEP, 2010)

	Capture fisheries	Aquaculture	Total fisheries production
Time period			
1995-2000	7%	13%	9%
2001-2005	10%	15%	11%
2005-2010	4%	14%	9%

Total value of seafood export in Viet Nam in 2008 reached 4.5 billion USD, which is eight times greater than the value in 1995. However, in 2009, because of the world economic crisis there was a 6.2% reduction in the value of seafood export compared to 2008. In 2010, the seafood export value of Viet Nam increased again and reached 4.94 billion USD, 16% higher than in 2008 (Figure 2). In 2000, export of aquaculture accounted for 41.5%, in 2006-2007; it had increased to over 60% of the total seafood export turnover of the country.

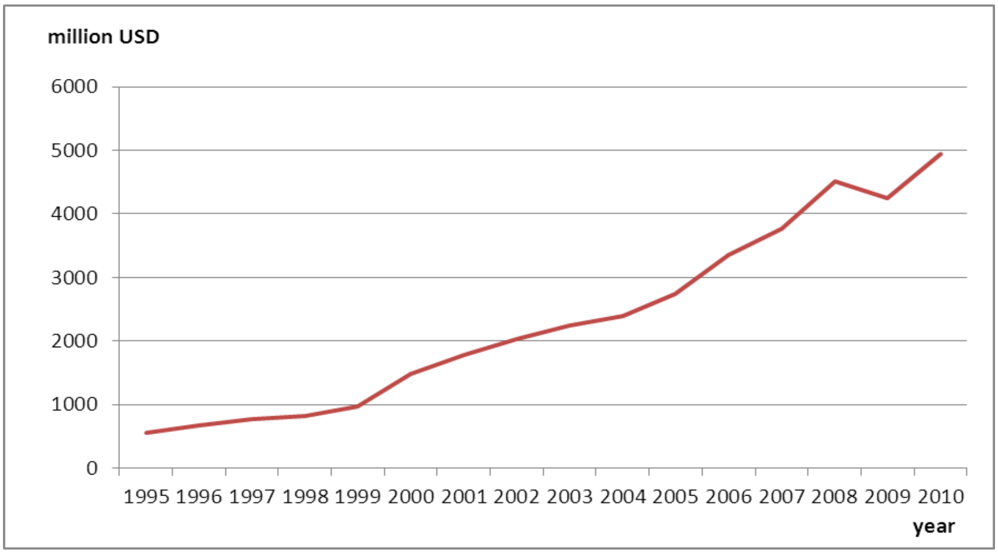

Figure 2: Fisheries export value in Vietnam in 1995-2010 (VASEP, 2010)

The Mekong River Delta area is about 39,600 km^2 or about 1/8 of the area of Viet Nam. Its population is about 17.21 million (2009) or 21 % of the total population of Viet Nam (GSO, 2009) (Figure 3). In 2003, the total aquaculture production of the Mekong Delta was 740 thousand tonnes or 61% of the total aquaculture output of Vietnam (Vietnam Fisheries Association, 2004). In 2009, the total aquaculture production of the Mekong River Delta had risen to 1,869 thousand tonnes and 72% of the total aquaculture output of Vietnam (GSO, 2009).

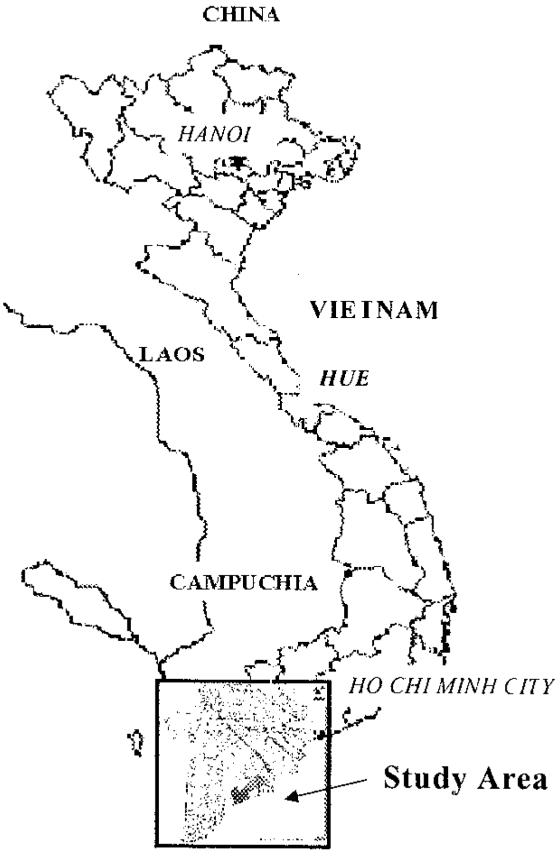

Figure 3: Map of Mekong River Delta areas in Viet Nam

2.2 Development of catfish in Mekong River Delta, Vietnam

Tra (*Pangasius hypophthalmus*) and Basa (*Pangasius bocourti*) catfish are both indigenous species of Viet Nam and the Mekong River Delta in particular. Before 1975, catfish played an important role in the domestic market, especially, in the Mekong delta. In the mid-1980s, catfish fillets were exported to Australia and in the early 1990s export expanded to include the Hong Kong and Singapore markets. In the mid-1990s export to North America and the European Union started. In the early stages, Basa catfish was mostly raised in cages, but production and productivity was low. Expanding foreign markets created opportunities for increased production and the production of the Basa catfish alone was not enough. Therefore, the market conditions for a new product similar to the Basa catfish emerged. The Tra catfish was chosen because of the same growth characteristics and fillet meat as Basa, but much higher productivity than the Basa catfish (Tung *et al.*, 2004). Today, only Tra catfish is raised in the study area and all data in this report and analysis is based on Tra catfish only.

In 2008, 105,535 workers directly participated in the catfish industry and other workers also participate in related sectors such as fingerling production (AGROVIET, 2008). About 80% of the catfish production takes place in three out of thirteen provinces in the Mekong River Delta (Hanh, 2009).

Most catfish farmers are investors from other sectors and their level of education is low. The costs have increased steadily in recent years because of the rising cost of feed as the price of fishmeal has increased. Consequently, the operating costs have become an increased concern for farmers. Feed cost accounts for 73% of total operating cost, followed by seed cost with 7% (de Silva, 2010, Figure 4).

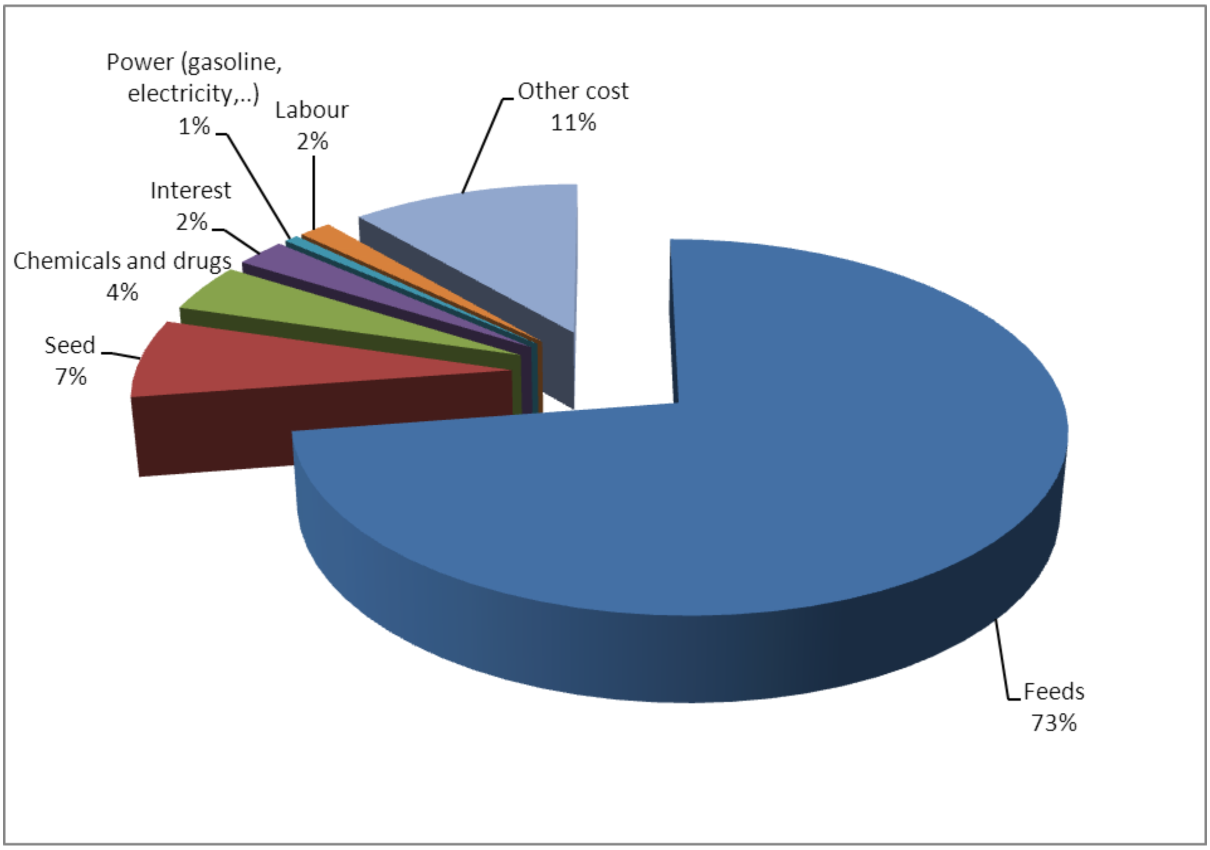

Figure 4: Operating cost of catfish farming in Mekong River Delta (de Silva, 2010)

The total area used for catfish farming in Mekong River Delta has been variable (Figure 5) and sometimes it is not part of government's program. Changes in the usage of farm area depend on the profit from the production. When the production is profitable, new farmers enter aquaculture of catfish. Similarly, when the production is not profitable, farmers exit aquaculture. To secure raw material catfish for processing, many processing enterprises have started aquaculture operations themselves or have made contracts with farmers (VASEP, 2010).

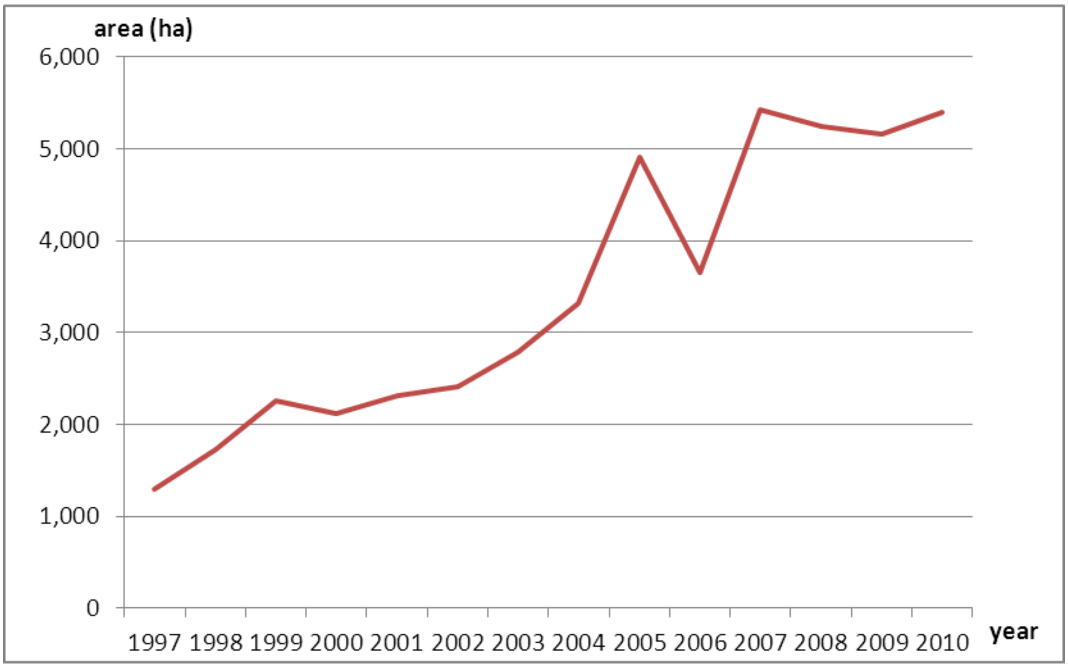

Figure 5: Farming area of catfish in the Mekong River Delta in 1997 – 2010 (VASEP, 2010)

The number and scale of catfish processing plants in Mekong River Delta has increased steadily in recent years. In 2000, there were only 15 processing plants in the entire region with a capacity of about 77,880 tonnes per year. However in 2007, there were 64 processing plants with a capacity of about 682,300 tonnes per year (Table 2). In 2006, the processing industry of catfish of Mekong River Delta employed about 116,000 full time workers. At the end of 2010, there were 281 exporting catfish enterprises; including about 100 enterprises that have processing facilities. The 20 biggest enterprises have 60% of the export segment (VASEP, 2010).

Table 2: The number and design capacity of catfish processing plants in Mekong River Delta 2000-2007 (AGROVIET, 2008)

Item	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**
Number of catfish processor	15	19	20	23	33	36	54	64
- *Single processing*	*1*	*2*	*2*	*2*	*4*	*5*	*20*	*26*
- *Multiple processing*	*14*	*17*	*18*	*21*	*29*	*31*	*33*	*37*
Design capacity (ton/year)	77,880	88,540	119,331	144,945	230,740	281,740	495,351	682,300
Processing production (tons)	689	1,970	27,980	33,304	82,962	140,707	286,600	386,870
Performance (%)	1	2	23	23	36	50	58	57

Most catfish processing plants implement quality management programs such as HACCP, SQF 2000 CM, SQF 1000 CM, ISO 9001: 2000, HALAL, BRC, and environmental management such as ISO 14000 (AGROVIET 2008)

2.3 The export of catfish

The export of catfish increased from 689 tons in 2000 to 633,000 tons in 2008 (Figure 6). However, it decreased slightly in 2009 to 607,665 tons and increased again in 2010 reaching 654,206 tons.

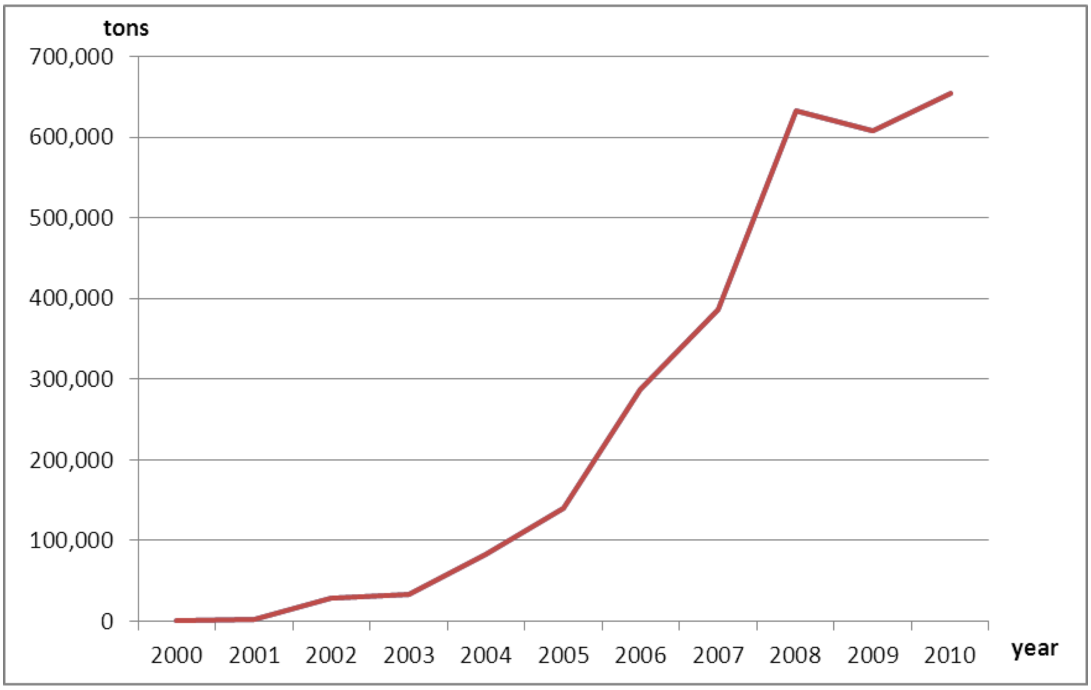

Figure 6: Export of catfish during 2000 -2010 (VASEP, 2010)

The trend of the export value for catfish has been similar to the trend in export volume. The export value for catfish increased from USD 2.6 million in 2000 to USD 1,400 million in 2008 (Figure 7). It decreased to USD 1,340 million in 2009 and increased again to USD 1,400 million in 2010.

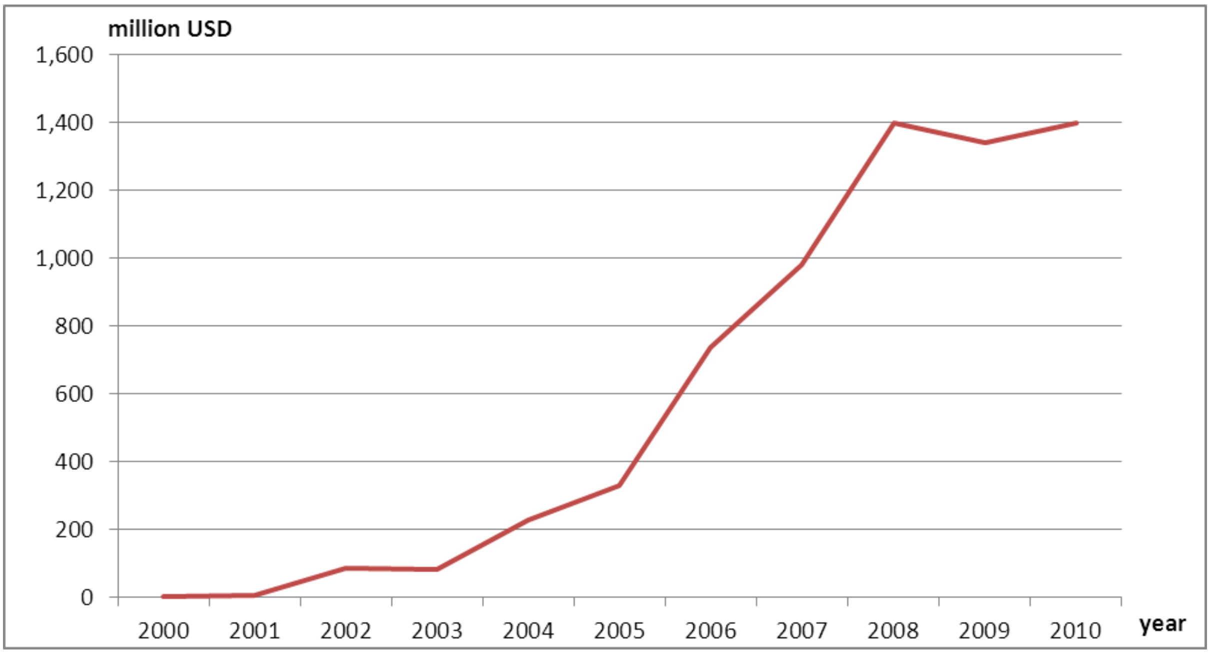

Figure 7: Export value for catfish in 2000 -2010 (VASEP, 2010)

The average export price for catfish per kilogram decreased from 2000 to 2010 (Figure 8). The average price was USD 3.76 per kilogram in 2000 but in 2010 the average price was down to USD 2.14 per kilogram.

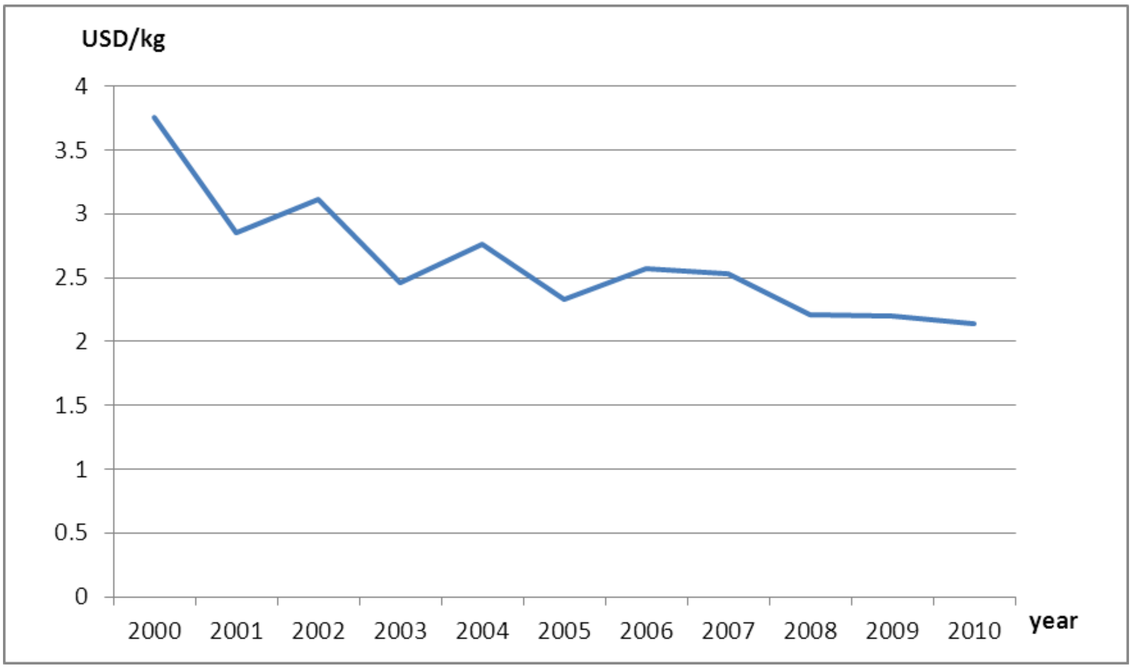

Figure 8: Average export price (USD/kg) for catfish during 2000 -2010 (VASEP, 2010)

The composition of foreign markets has changed over the years (Table 3). The market share of the US decreased dramatically due to anti-dumping regulations in 2003, but expanded in the EU and most recently, in Russia. In 2008 the EU market leads with 38% market share while United State was only 7%.

Table 3: Market structure (in %) of catfish during 2003 -2008 (VASEP, 2008)

	2003	2004	2005	2006	2007	2008
Export volume						
EU	19	27	39	43	45	38
North America	31	24	18	14	11	7
Japan	2	1	0.4	0.3	0.4	0
ASEAN	14	14	16	10	9	7
Russia	0	1	2	15	13	17
Ukraine	0	0	0,1	3	6	8
China	21	22	12	6	5	3
Australia	7	8	7	4	3	2
Other	7	4	6	5	9	17
Total	**100**	**100**	**100**	**100**	**100**	**100**
Export value						
EU	20	29	42	47	48	42
North America North	34	27	20	16	13	9
Japan	2	1	0,5	0,4	1	0
ASEAN	11	10	12	9	8	8
Russia	0	0,3	2	11	9	12
Ukraine	0	0	0,1	2	4	6
China	19	19	10	5	4	3
Australia	8	9	8	4	4	3
Other	7	4	5	6	9	17
Total	**100**	**100**	**100**	**100**	**100**	**100**

3 DATA ENVELOPMENT ANALYSIS (DEA) METHOD

The efficiency of a firm can be divided into technical efficiency and allocative efficiency. Technical efficiency is the ability of a firm to either obtain maximum output from a given set of inputs or given output given minimum usage of inputs. Allocative efficiency reflects the ability of a firm to use the inputs in optimal proportions, given their respective prices and the production technology. Economic efficiency of a firm is measured by multiplying the technical efficiency and the allocative efficiency (Coelli *et al.*, 2005).

Data Envelopment Analysis (DEA) has been applied to measure efficiencies of many different institutions and activities such as hospitals, universities, cities, courts, business firms, banks and others in many different countries.

DEA applications in aquaculture are relatively few. Sharma *et al.*, (1999) applied a DEA technique to evaluate the efficiency of Chinese polyculture fish farms, Kaliba and Engle (2006) applied the method to small- and medium-sized catfish farms in Chicot County, Arkansas, Cinemre *et al.*, (2006) to trout farms in the Black Sea Region, Turkey, and Alama *et al.*, (2008) to a prawn-carp polyculture systems by using data from 105 farmers of Bangladesh. In Viet Nam, DEA has been used in several studies of rice farms of the Mekong Delta, construction firms, aquaculture processing and food processing companies. DEA has also been used to study the efficiency of aquaculture enterprises in Vietnam, such as the culture of tiger shrimp (Cuong, 2009), *Pangasius* farming (Hanh, 2009) and black tiger prawn culture (Huy, 2009).

The DEA approach is a nonparametric or mathematical programming approach to find a solution for each decision making unit (DMU). DEA is computationally simple and has the advantage that it can be implemented without knowing the algebraic form of the relationship between outputs and inputs. Therefore, DEA has widely been used as a benchmarking technique to compare, for example, firms.

The DEA method is based on returns to scale of firms' operations. Returns to scale depend on how much the output changes if a firm decides to change its use of inputs proportionally. Firms can either exhibit Constant Returns to Scale (CRS) or Variable Returns to Scale (VRS) in their operations. If a firm changes its usage all inputs by a certain percentage and output changes by that same percentage, then a firm is said to exhibit CRS. On the other hand, a firm is said to exhibit VRS when the change in usage of all inputs by a certain percentage does not lead to the same percentage change in output production. Variable Returns to Scale can, therefore, both reflect Increasing Returns to Scale (IRS), where output rises more than in proportion to an equal increase in all inputs, or Decreasing Returns to Scale (DRS), where output increases less than in proportion to an equal percentage increase in all inputs (Perloff, 2007).

The input oriented DEA method considers how inputs may be reduced relative to a desired output level. It will identify the most efficient or best practice units and the inefficient units by comparing all resources used and outputs achieved. Theoretically, an inefficient unit should be able to reach the same efficiency as the most efficient units by reducing inputs, without affecting output. The method identifies to what extent different inputs could be reduced.

The difference between input oriented CRS and VRS DEA frontiers are presented in figure 9 using a one input, one output example. In the example, the point P is the inefficiency point. The efficiency ratio is measured as:

$$\theta = TE_{CRS} = AP_{C}/\ AP$$

$$TE_{VRS} = AP_{V}/\ AP$$

where:

TE_{CRS} : technical efficiency Constant Return to Scale [0;1]

TE_{VRS}: technical efficiency Variable Return to Scale [0;1]

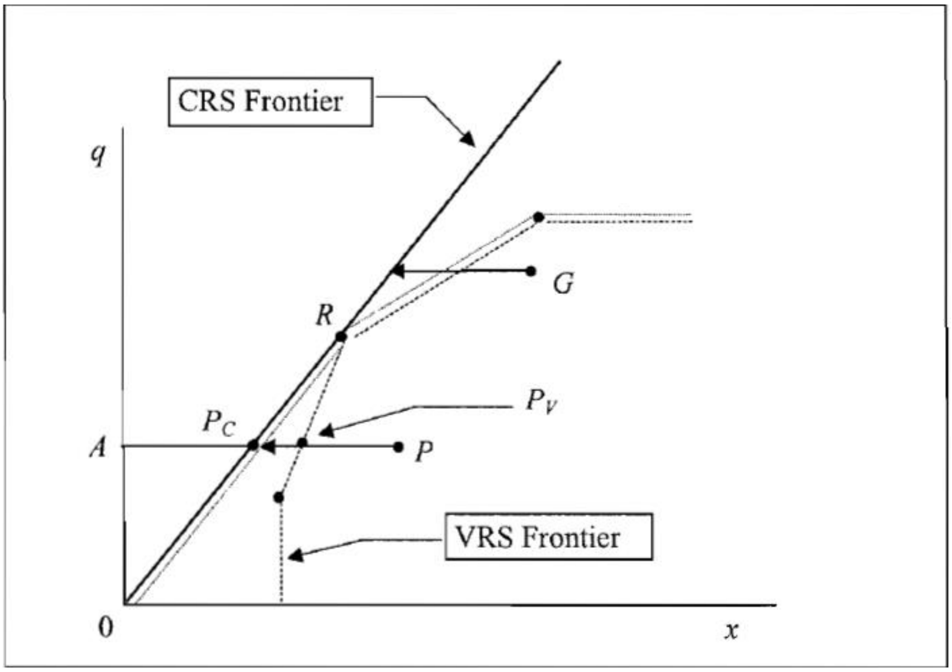

Figure 9: Scale efficiency measurements in DEA ***(Coelli et al., 2005)***

It is possible to decompose the technical efficiency scores from the CRS DEA into two components. First part is the "pure" technical inefficiency, for example poor management. Secondly, it is scale inefficiency, for example, technology and size. If there is difference between efficiency score of CRS DEA and VRS DEA , the reason is scale inefficiency:

$$\theta = TE_{CRS} = TE_{VRS} \times SE$$

because

$$AP_c / AP = (AP_v / AP) \times (AP_c / AP_v)$$

hence

$$SE = TE_{CRS}/TE_{VRS} \quad \text{or} \quad SE = AP_c / Ap_v$$

where

SE: scale efficiency [0; 1]

Table 4 presents an example for input oriented CRS and VRS DEA model:

Table 4: Example data for CRS and VRS DEA (Coelli et al., 2005)

Firm	**x**	**q**
1	*2*	*1*
2	*4*	*2*
3	*3*	*3*
4	*5*	*4*
5	*6*	*5*

Firms use one input *x* and produce one output *q*. The calculation can be conducted for firm 2, which is inefficient under both CRS and VRS DEA models (Figure 10)

$$\theta = TE_{CRS} = 2/4 = 0.5$$

$$TE_{VRS} = 2.5/4 = 0.625$$

and :

$$TE_{CRS} = TE_{VRS} \times SE$$

hence:

$$\text{Scale efficiency (SE)} = 0.5/0.625 = 0.8$$

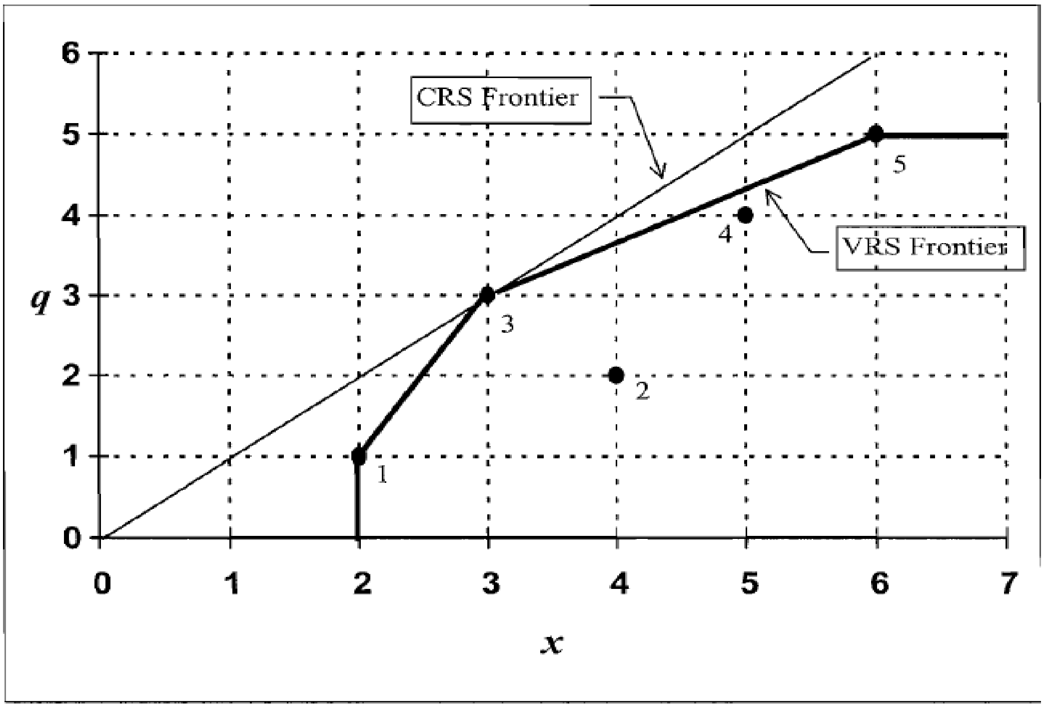

Figure 10: CRS and VRS input oriented DEA example (Coelli et al, 2005)

Firm 1 and 2 are on the increasing return to scale (IRS) portion of the VRS frontier while firms 4 and 5 are on the decreasing returns to scale (DRS) portion (Table 5).

Table 5: CRS, VRS, SE input oriented DEA results (Coelli et al., 2005)

Firm	***CRS TE***	***VRS TE***	***Scale***	
1	*0.500*	*1.000*	*0.5000*	*IRS*
2	*0.500*	*0.625*	*0.800*	*IRS*
3	*1.000*	*1.000*	*1.000*	-
4	*0.800*	*0.900*	*0.889*	*DRS*
5	*0.833*	*1.000*	*0.833*	*DRS*
Mean	**0.727**	**0.905**	**0.804**	

Minimizing input-oriented Constant Return to Scale (CRS) Data Envelopment Analysis (DEA) model with one simple model which gets two inputs x_1, x_2 and an output q is shown in figure 11. The technically efficient farms are located on the SS' frontier; hence, C and D are technically efficient points. On other hand, A and B are the non-technical efficiency points. Technical efficiency of farms A and B presented as:

$$(\theta_A) = TE_A = OA'/OA \; [0; 1]$$

and $$(\theta_B) = TE_B = OB'/OB \; [0; 1]$$

Meanwhile, farm A can reduce the using of inputs from A to A', and farm B can reduce the use of inputs is from B to B’ without reducing output (Coelli *et al.*, 2005). Farms that are efficient have theta (θ) equal to one and farms that are inefficient have theta (θ) less than one.

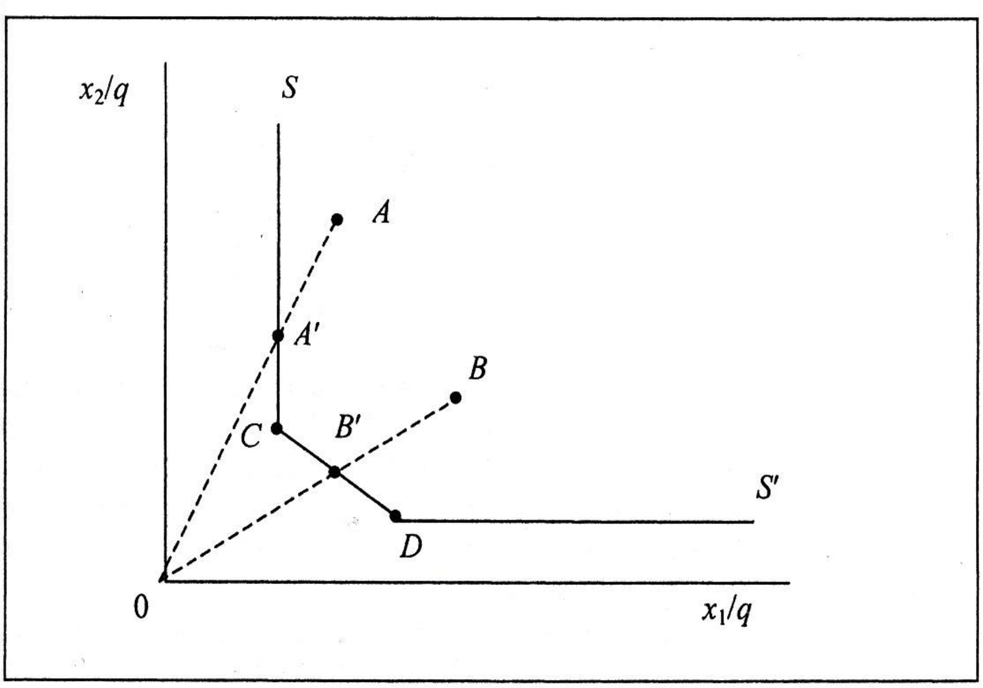

Figure 11: Minimizing input-oriented Constant Return to Scale Data Envelopment Analysis (DEA) model (Coelli et al, 2005)

The difference between the target and the actual input levels indicates the potential resource reductions (and cost savings) for each input based on the actual performance of other best practice units. That is:

Resource reductions = actual inputs – input oriented target

All of the input reductions together would increase that units' productivity to the best practice level. This information and the efficiency rating provide a unique insight that makes DEA so valuable for performance management. The efficiency reference set (ERS) indicates the relatively efficient units against the inefficient units.

On other hand, the output oriented DEA method based measure indicates how output could be expanded given the input level. Meanwhile, it will identify the most efficient units or best practice units and the inefficient units by comparing all output as revenue, profit, etc. The inefficient unit will reach efficiency as the most efficient units if it expands output level without to use of additional resources. This has resulted in improving the productivity of inefficient units, and increasing profitability (Sherman and Zhu, 2006).

A two output example of an output oriented DEA is represented as figure 12. The point P is projected to the point P'.

$$\theta = TE = OP/OP'$$

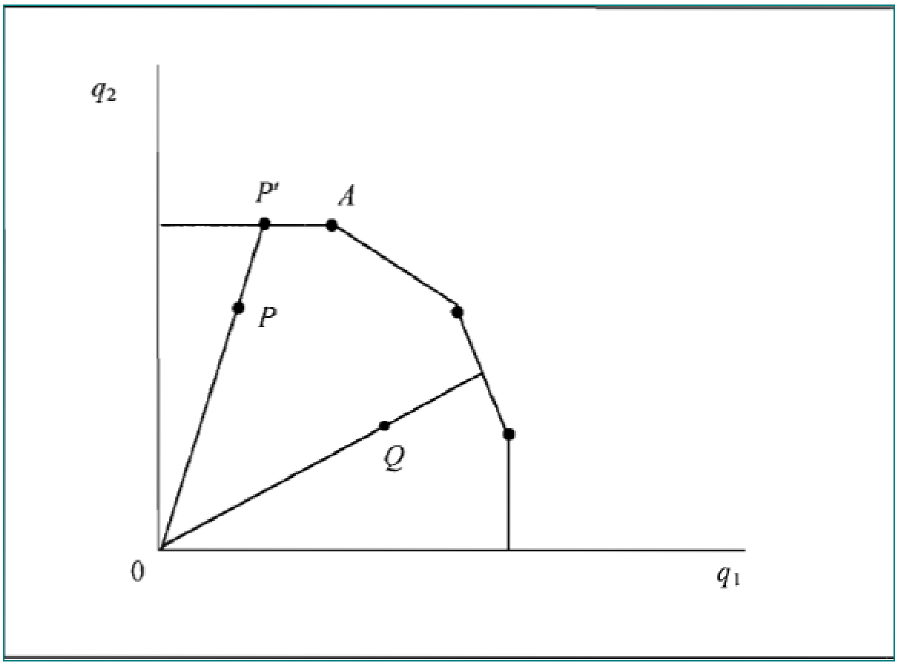

Figure 12: Output oriented DEA (Coelli et al, 2005)

Both the input and output oriented DEA models will estimate the exactly same frontier. Therefore, the method will identify the same set of efficient firms. The efficiency measures of inefficient firms may, however, be different between the two methods (Coelli *et al.*, 2005).

In this paper, the CRS model is used which looks at minimizing inputs to reduce the input cost given a constant output. Minimizing input-oriented Constant Return to Scale Data Envelopment Analysis (DEA) model is used in this research because most of catfish farms in the Mekong River Delta are small and most farmers are poor and they often have to borrow capital from the bank.

The DEA method has limitations and possible problems. Common with all quantitative analysis, measurement errors and other noise can influence results and in the case of DEA, the estimated frontier curve. Moreover, outliers can influence the results and provide skewed results. In order to get unbiased results, the researcher must include all important inputs and outputs. When there are few observations in the data sample, many firms will appear on the frontier curve and hence the DEA method does not provide meaningful results. Unlike other econometric methods, no statistical tests are fully efficient in measuring the quality of the DEA analysis.

The DEA method provides efficiency scores that are only relative to the most efficient firms in the sample. Therefore, one must be careful when comparing the efficiency scores from two different studies. The results only indicate the distribution of efficiency scores within each study and do not provide a direct comparison between studies. Non-traditional inputs such as environmental factors can influence the efficiency of firms and they are not considered to be under the control of the manager. For example, locational characteristics and labour union power are not under the control of most managers (Coelli *et al.*, 2005).

4 DATA AND PROCEDURE

Data used in this project is for 61 catfish farms in 2008. The data was collected in January 2009 by Hanh for her study on the relationship between farm financial exposure and technical efficiency in the *Pangasius* farming. Catfish farms were selected randomly in the Mekong River Delta and the data was gathered by directly interviewing farmers about their operations in 2008. The questionnaire was developed by Hanh and corrected by experts.

The interviews were conducted by the staff of the Departments of Agriculture and Rural Development. Most of interviewers had knowledge of *Pangasius* farming operations and experience on collecting data. The selected interviewers were trained prior to conducting the questionnaire to make them acquainted with the questionnaire. The survey experienced several problems common to some agricultural sectors experiences. It took time to approach the household head who could supply correctly the information in the questionnaire.

The data collected can be affected by some perception bias of the respondents, although the questionnaire was carefully prepared. Farmers usually do not keep standard accounting books (balance sheet and income statement). Therefore, farmers had to recall rely on memory, when asked for some detailed information about past activities. Cross-checking the data during and after the survey did not reveal any extremely incorrect or impossible answers, hence, the answers of farmers can be believed.

An overview of the data which is used in this project is presented in table 6 below.

Table 6: Output and input variables of catfish farms are used in analysing for 2008

Variable	Maximum	Minimum	Mean	Standard Deviation
Output				
Production (ton)	2,000	30	285.311	390.896
Input				
Investment (million VND)	670	35	216.862	144.038
Labour (person)	15	1	4	3
Fuel cost (million VND)	210	1.5	24.853	40.357
Electricity cost (million VND)	160	1	21.939	29.831
Chemical cost (million VND)	265	5	36.656	47.259
Seed (fingerling)	1,200,000	35,000	259,590	275,642
Feed (ton)	3,330	50	523.885	717.726

Investment is measured in millions of Vietnam dong (VND) which is calculated as a sum of machinery and equipment, buildings and improvements, and other fixed assets.

Labour is measured in number of persons and includes both full time family and hired labour. Labourers prepare the fish feed, feed catfish every day and harvest at the end of the farming cycle. The fish require great amounts of nutrition and the number of feeding times every day also increases as the production cycle goes on, hence, labour is also the important input in farming. In this study the smallest farm had only one labourer and the less 15 which size of farms.

Fuel, chemicals (including veterinary drugs) and electricity are aggregated inputs, and they are measured in monetary value.

The most important inputs in the model are seed, are measured in number of fingerlings, and feed measured in tons. The cost of feed and seed are the highest ones among the costs for all inputs in farming. Most seed are locally produced and its quality is mostly controlled by government officers.

In this research, the author uses a software program's DEA Excel Solver of Zhu (Zhu, 2006) to evaluate minimizing input-oriented Constant Return to Scale Data Envelopment Analysis (DEA) model as described earlier.

5 RESULTS

Result of minimizing CRS DEA analysis in this research show that 11 of 61 farms (18%) were technical efficient, meanwhile, 82% farms were technical inefficient (see appendix 1 for detailed list of all farms as well as their possible resource cost savings). Majority of farms or 38 have a TE score below 0.6, 12 have a TE score between 0.6 and 1 and 11 have a TE score equal to 1 (Figure 13).

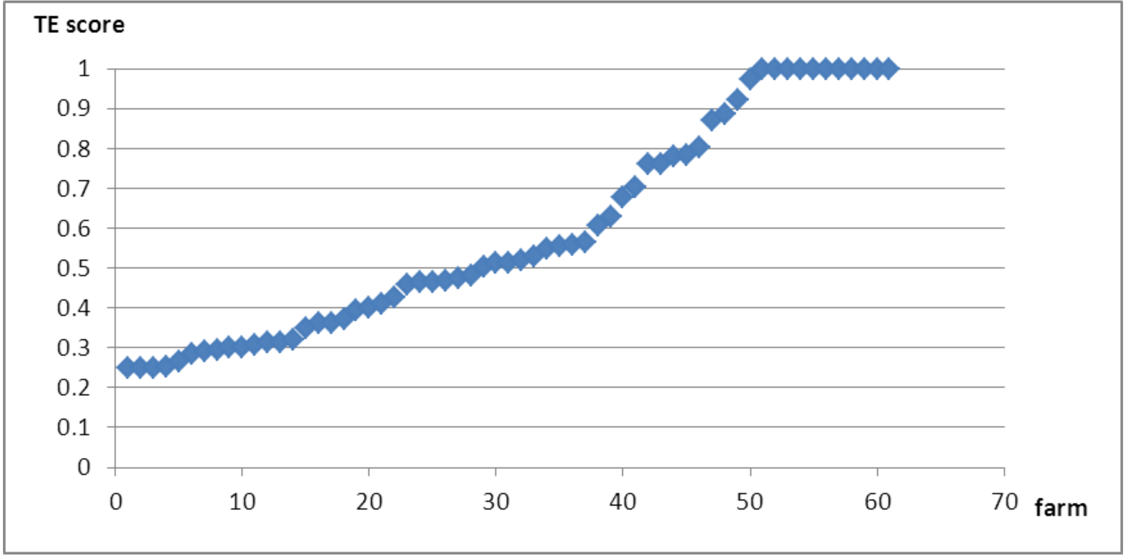

Figure 13: Distribution of technical efficiency score for catfish farms in Mekong River Delta, Viet Nam

Table 7: Summary of technical efficiency score

	TE Efficiency score
Mean	*0.59*
Standard Deviation	*0.27*
Minimum	*0.25*
Maximum	*1.00*

Average technical efficiency rating (θ*) of catfish in Mekong River Delta, Viet Nam which are based on all inputs combined was 0.59, minimum was 0.25, maximum was 1.00, standard deviation was 0.27 (Table 7). Mean total technical efficiency for all farms is 0.59 which means that, on average, catfish farmers in Mekong River Delta are producing catfish at about 59% of the potential frontier production levels at the present state of technology and input levels. It also means that, all other things being equal, the farms should be able to reduce their inputs by 41% and still have the same level of production.

The ratio of possible resource reduction chemicals was highest with 53%, and the labour, electricity and investment cost, old higher than 50% and as uses, fuel cost was nearly 50% (Figure 14).

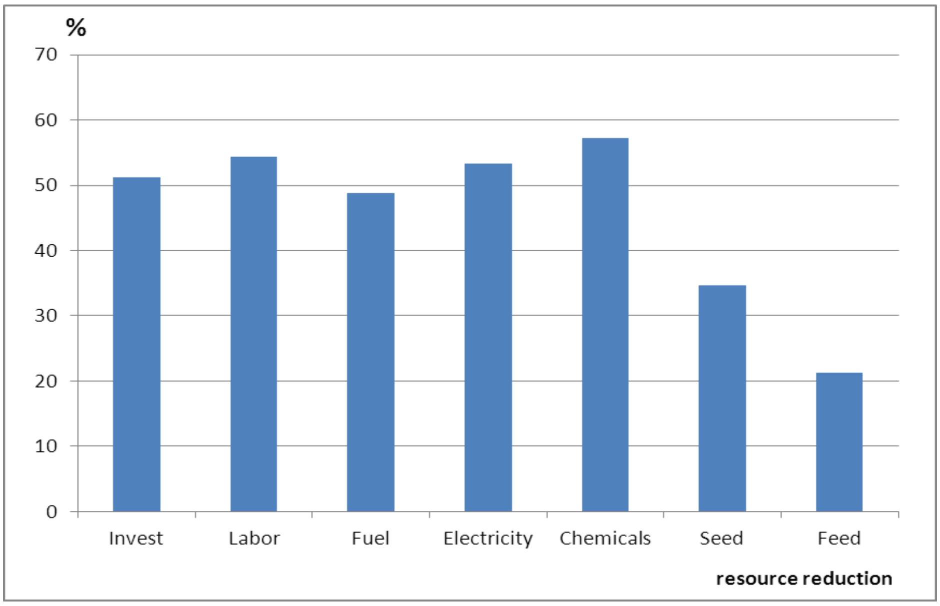

Figure 14: The ratio of resource reduction in actual input of catfish samples in Mekong River Delta, Viet Nam

The ratio of resource reduction of actual input for every farm to reach technical efficiency is presented in appendix 2.

The majority of the technically efficient farms produce much greater amounts of catfish than the average farm (Figure 15). However, some farms that produce in the 250-500 tons range also show quite high technical efficiency scores.

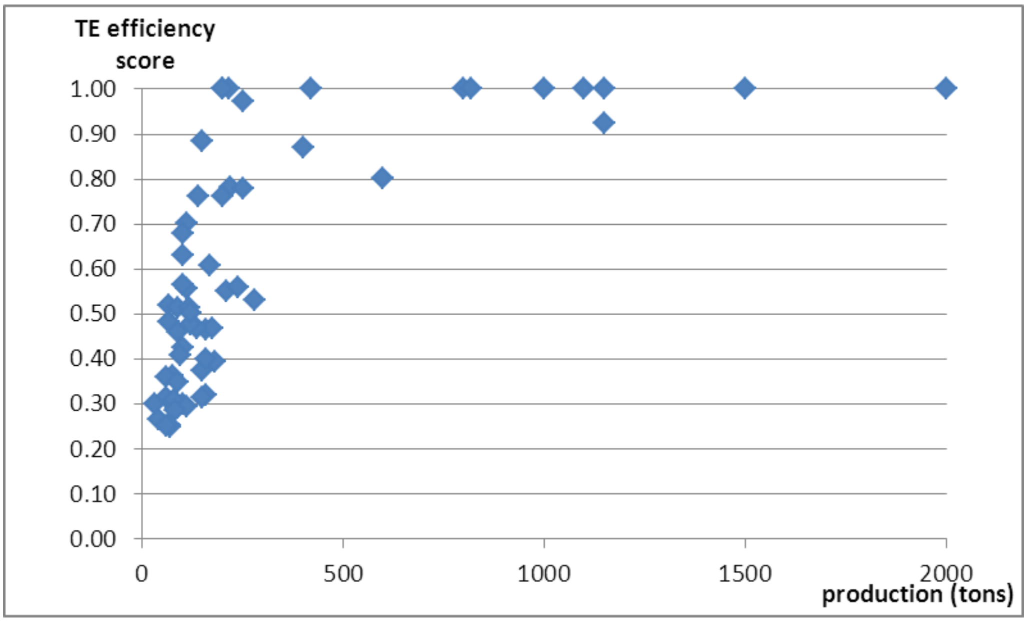

Figure 15: Technical efficiency score and production

In order to analyse the results further, the data set was divided into three groups based on the farms' production. Figure 16 describes technical efficiency score for farms with production equal or less than 100 tons.

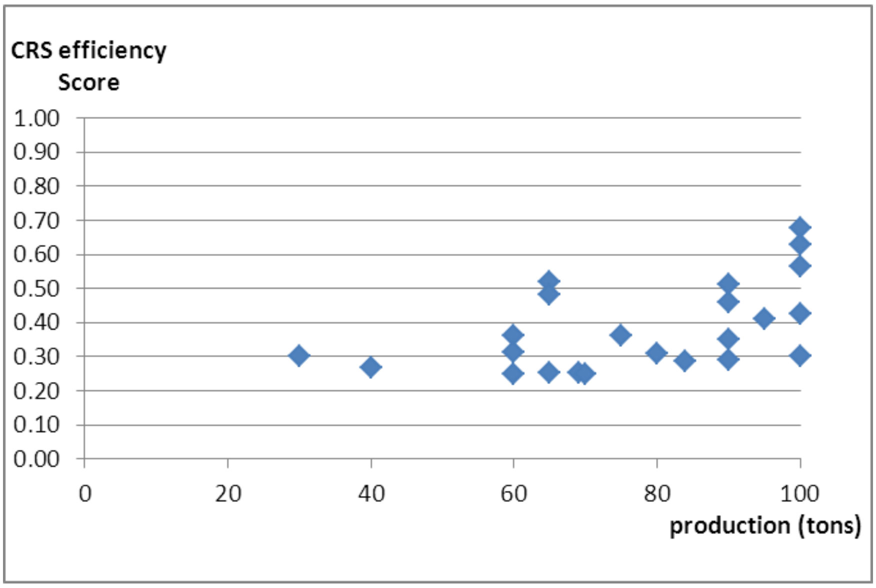

Figure 16: Technical efficiency score for farm with production equal or less than 100 tons

Table 8 shows the summary statistics for the group of farms with the lowest production. The average technical efficiency score is 0.38 and, hence, considerably lower than the technical efficiency score for all 61 farms.

Table 8: Summary statistic for technical efficiency score for farms with production equal to less than 100 tons

	Efficiency	*Production*
Mean	*0.38*	*77.30*
Standard Deviation	*0.13*	*19.88*
Minimum	*0.25*	*30*
Maximum	*0.68*	*100*

Figure 17 describes the technical efficiency score for farm with production greater than 100 tons and equal or less than 280 tons

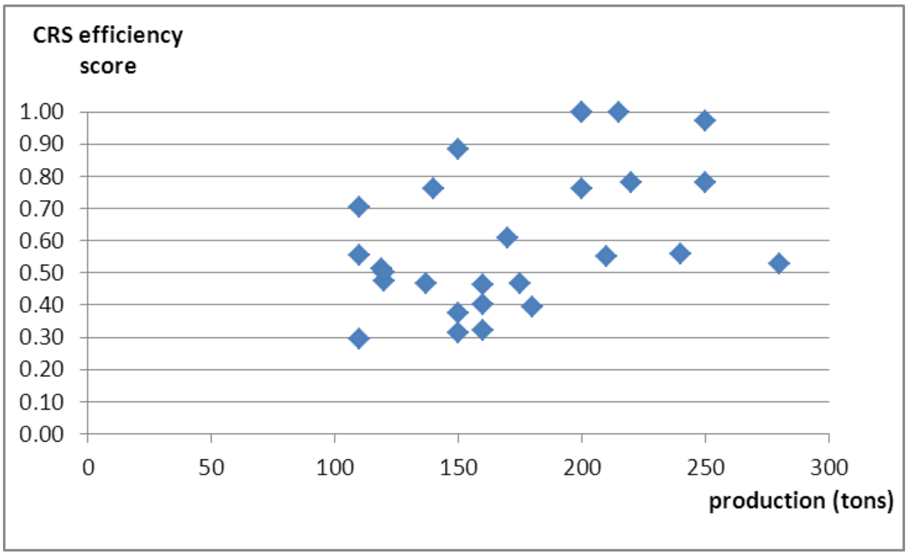

Figure 17: Technical efficiency score for farm with production greater than 100 and equal or less than 280 tons

Table 9 shows the average technical efficiency score, 0.61, for this group of farms is higher than the average score for the 61 farms and much higher than for the smallest farms. In total, there are four farms with a score higher than 0.8.

Table 9: Summary statistic for technical efficiency score for farms with production greater than 100 and equal to less than 280 tons

	Efficiency	*Production*
Mean	*0.61*	*173.56*
Standard Deviation	*0.22*	*48.16*
Minimum	*0.29*	*110*
Maximum	*1.00*	*280*

Figure 18 describes the technical efficiency score for farm with production greater than 280. Relatively few farms are in this group and the technical efficiency score is much higher than for other groups or 0.96.

Figure 18: Technical efficiency score for farm with production greater than 280 and equal or less than 2000 tons

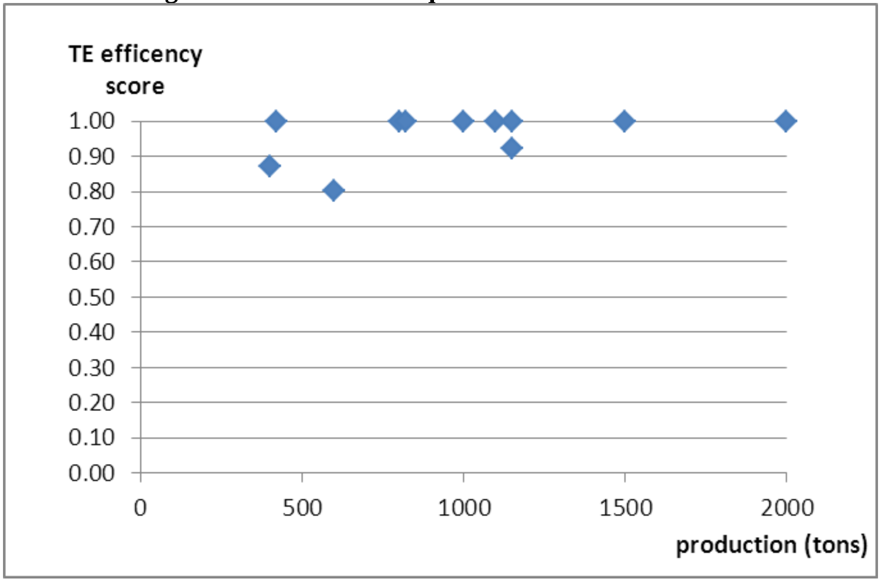

Table 10 shows the summary statistics for the farms with the greatest production.

Table 10: Summary statistic for technical efficiency score for farms with production greater than 280 and equal to less than 2000 tons

	Efficiency	*Production*
Mean	*0.96*	*994.55*
Standard Deviation	*0.07*	*472.60*
Minimum	*0.80*	*400*
Maximum	*1*	*2000*

6 CONCLUSIONS AND DISCUSSION

This study used minimizing input-oriented CRS DEA model to analyse the efficiency of catfish farms in the Mekong River Delta with one output as production and seven input variables, based on data from 61 randomly selected catfish farms in the Mekong River Delta. The average technical efficiency rating (θ*) of catfish farms in the Mekong River Delta is 0.59 and the farm in the sample with the lowest technical efficiency had a rating of 0.25. Eleven farms (18%) were technically efficient and 50 farms (82%) that are technically inefficient in the sample.

The ratio of resource reduction of chemical, labour, electricity, investment, fuel cost in actual input was high or around 50%. Farmers should be able to run their farms in a more efficient way by reducing their resource costs. The possible reduction for feed and seed is from 20% to 35%. The results for feed and seed are not surprising because these two inputs constitute to about 80% of the operational costs and indicate that farmers are concerned about their operations costs. By lowering their operations costs, the farmers will be more likely is able to meet their obligations to financial institutions, such as banks.

The average resource reduction in actual input of the catfish farms indicated in this study can be the reference point for state agencies managers to change management policies as well as support farmers in the design, organization, technology transfer, and production methods to reach efficiency. Moreover, farmers can use the result to improve the inputs, making their farming more efficient, improving profitability and reducing risk.

The results from the CRS DEA method of the 61 samples in this study indicate that large farms are more efficient than small farms. It may be that there is a minimum size required to make catfish farms efficient. This must be studied in terms of the production cycle and what factors may be critical to enable increased efficiency in farms operations. Policy makers should focus on small scale farmers and improve their efficiency. Education and age of farmers do not appear to be indicators of relative efficiency (Appendix 3). This can in part be explained by the lack of information about education which does not involve information about short course training such as financial management in aquaculture. Future research should include information about participation in such short courses.

Differences in the technical efficiencies are evident in the results for farms with similar production. This difference strongly suggests that the efficiency of those farms can be improved but could be explained by the limits in data gathering for this study. For example, the information on important variables such as environmental conditions such as land and water quality was not collected. Therefore, it is possible that unmeasured variables such as land and water quality explain the efficiency difference between farms better than the usage of inputs.

In this study, the efficiency scores of catfish farming in Mekong River Delta are much lower in comparison to the efficiency scores of aquaculture sector in other countries. For example, for trout pond farming in the Black Sea Region, Turkey the efficiency score was estimated 0.82 (Cinemre *et al*., 2006), for tilapia pond operations in Philippines the score was estimated as 0.83 (Kumar *et al*., 2004), for the prawn-carp farming of Bangladesh, the score was estimated 0.83 (Sharma *et al*., 1999) and 0.85 (Alam, *et al*., 2008). One must be very careful to compare the scores between countries and studies because they only measure the relative efficiency of their given sample. However, the results indicate that there is considerable scope to raise catfish production using the existing level of input and technology.

This study only analysed technical efficiency for the development and management of catfish farms to minimize resource costs. Although DEA method has some limitations and possible problems, as presented in methodology part, the method is increasingly used because of its advantages. In future research, efficiency measurement using stochastic frontiers and DEA method should be used to compare results of DEA involving the use of linear programming and stochastic frontiers which involve the use of econometric methods. Allocative efficiency estimates are also needed for research to understand better the cost minimisation and profit maximisation. Estimates of economics efficiency would base on technical efficiency and allocative efficiency.

The different management schemes and development programmes should be based on specific case studies. In order for such studies to be meaningful, it is necessary to collect and analyse data on the biological, economic and social aspects of catfish as well as its past and present. Information on biological aspects should cover environment variables, for example, land and water quality. The required economic data should include information about prices and costs, especially, the financial performance of farms such as debt and assets as well as income statements. Information on social aspects should cover relationship with other aquaculture, organization of production (sharing system), marketing channels and customary relationships between farmers and middlemen to determine the competitiveness of the catfish market.

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APPENDIX

- Appendix 1: Efficiency and Target (minimizing CRS DEA) for catfish in Mekong River Delta, Viet Nam

Table 1: Technical efficiency score

Inputs	**Outputs**
invest	Production
Labor	
Fuel	
Electricity	
Chemicals	
Seed	
Feed	

DMU No.	DMU Name	Input-Oriented CRS Efficiency	Σλ	RTS	**Benchmarks**									
1	A01	0.45997	0.054	Increasing	0.018	A35	0.036	A55						
2	A02	0.24849	0.045	Increasing	0.019	A35	0.025	A55						
3	A03	0.70258	0.107	Increasing	0.105	A35	0.003	A55						
4	A04	1.00000	1.000	Constant	1.000	A04								
5	A05	0.36174	0.044	Increasing	0.001	A04	0.009	A54	0.034	A55				
6	A06	0.36072	0.039	Increasing	0.019	A35	0.021	A55						
7	A07	0.46378	0.159	Increasing	0.071	A26	0.034	A34	0.001	A52	0.054	A55		
8	A08	0.46729	0.111	Increasing	0.048	A35	0.064	A55						
9	A09	0.78204	0.313	Increasing	0.197	A26	0.043	A54	0.073	A55				
10	A10	0.55531	0.131	Increasing	0.009	A22	0.039	A34	0.057	A37	0.027	A55		
11	A11	0.88510	0.187	Increasing	0.110	A22	0.045	A55	0.031	A60				
12	A12	0.51846	0.189	Increasing	0.042	A22	0.013	A34	0.125	A37	0.008	A55	0.001	A60
13	A13	0.25290	0.048	Increasing	0.017	A26	0.001	A52	0.030	A55				
14	A14	0.51282	0.057	Increasing	0.024	A35	0.033	A55						
15	A15	0.51251	0.088	Increasing	0.011	A26	0.010	A52	0.027	A54	0.040	A55		
16	A16	0.25055	0.054	Increasing	0.021	A26	0.002	A52	0.031	A55				
17	A17	0.97265	0.472	Increasing	0.316	A26	0.017	A52	0.098	A54	0.041	A55		
18	A18	0.29147	0.052	Increasing	0.004	A34	0.010	A35	0.038	A55				
19	A19	0.39288	0.215	Increasing	0.010	A22	0.030	A34	0.114	A37	0.061	A55		
20	A20	0.46655	0.220	Increasing	0.141	A22	0.019	A34	0.017	A37	0.039	A55	0.004	A60
21	A21	0.47506	0.095	Increasing	0.070	A35	0.025	A55						
22	A22	1.00000	1.000	Constant	1.000	A22								
23	A23	0.48148	0.051	Increasing	0.036	A35	0.014	A55						
24	A24	0.50236	0.083	Increasing	0.016	A22	0.021	A34	0.047	A55				
25	A25	0.67873	0.143	Increasing	0.038	A35	0.081	A37	0.023	A55				
26	A26	1.00000	1.000	Constant	1.000	A26								
27	A27	0.56527	0.197	Increasing	0.163	A26	0.002	A52	0.032	A55				
28	A28	0.42614	0.059	Increasing	0.018	A35	0.041	A55						
29	A29	1.00000	1.000	Constant	1.000	A29								
30	A30	0.52957	0.152	Increasing	0.049	A52	0.103	A55						
31	A31	0.37340	0.084	Increasing	0.010	A34	0.000	A35	0.005	A37	0.069	A55		
32	A32	0.77956	0.299	Increasing	0.017	A34	0.160	A35	0.096	A37	0.026	A55		
33	A33	0.26580	0.021	Increasing	0.001	A04	0.000	A54	0.020	A55				
34	A34	1.00000	1.000	Constant	1.000	A34								
35	A35	1.00000	1.000	Constant	1.000	A35								

36	A36	0.34884	0.047	Increasing	0.003	A35	0.043	A55				
37	A37	1.00000	1.000	Constant	1.000	A37						
38	A38	0.30000	0.050	Increasing	0.050	A55						
39	A39	0.40921	0.060	Increasing	0.016	A35	0.005	A37	0.039	A55		
40	A40	0.60714	0.115	Increasing	0.061	A35	0.055	A55				
41	A41	0.31250	0.030	Increasing	0.030	A55						
42	A42	0.32000	0.080	Increasing	0.080	A55						
43	A43	0.25000	0.030	Increasing	0.030	A55						
44	A44	0.30000	0.015	Increasing	0.015	A55						
45	A45	0.92303	0.666	Increasing	0.151	A29	0.514	A55				
46	A46	0.31250	0.075	Increasing	0.075	A55						
47	A47	0.63025	0.073	Increasing	0.046	A35	0.027	A55				
48	A48	0.76173	0.202	Increasing	0.020	A34	0.102	A35	0.046	A37	0.033	A55
49	A49	0.30769	0.040	Increasing	0.040	A55						
50	A50	0.76265	0.105	Increasing	0.040	A34	0.034	A35	0.031	A55		
51	A51	0.80260	0.370	Increasing	0.280	A52	0.090	A55				
52	A52	1.00000	1.000	Constant	1.000	A52						
53	A53	0.29412	0.055	Increasing	0.055	A55						
54	A54	1.00000	1.000	Constant	1.000	A54						
55	A55	1.00000	1.000	Constant	1.000	A55						
56	A56	0.40000	0.087	Increasing	0.015	A35	0.073	A55				
57	A57	0.28571	0.042	Increasing	0.042	A55						
58	A58	0.86990	0.294	Increasing	0.179	A34	0.027	A35	0.088	A55		
59	A59	0.54999	0.278	Increasing	0.182	A26	0.016	A34	0.006	A52	0.074	A55
60	A60	1.00000	1.000	Constant	1.000	A60						
61	A61	0.55996	0.139	Increasing	0.038	A35	0.101	A55				

(Results from software program's DEA Excel Solver of Zhu (Zhu, 2006))

Table 2: Efficiency input target

Second Stage

Inputs	**Outputs**
invest	Production
Labor	
Fuel	
Electricity	
Chemicals	
Seed	
Feed	

Input-Oriented

CRS Model Target

DMU	***DMU***	***Efficient Input Target***							**Efficient Output Target**
No.	***Name***	***invest***	***Labor***	***Fuel***	***Electricity***	***Chemicals***	***Seed***	***Feed***	**Production**
1	A01	30.57240	0.32290	3.03578	0.45000	1.40290	42868.82453	64.39523	90.00000
2	A02	24.17572	0.26703	2.19169	0.35000	1.10703	38108.62620	55.91054	70.00000
3	A03	43.59251	0.64370	1.05386	0.55000	1.96370	127110.07026	170.02342	110.00000
4	A04	335.00000	7.00000	60.00000	70.00000	10.00000	100000.00000	1050.00000	420.00000
5	A05	24.54970	0.34328	3.20362	0.54261	1.46473	21704.46103	63.30468	75.00000
6	A06	20.89780	0.23591	1.80361	0.30000	0.95591	34773.54710	50.50100	60.00000
7	A07	47.76901	0.81174	5.10154	3.71021	5.14736	82643.44713	162.32187	160.00000
8	A08	60.46729	0.66869	5.46729	0.87500	2.76869	95607.47664	140.18692	175.00000
9	A09	65.30000	1.47892	9.14982	9.22275	10.25844	93844.31496	282.04380	220.00000
10	A10	59.49305	0.67995	2.77656	2.77656	3.59308	61084.35482	138.82808	110.00000
11	A11	69.92324	0.74263	4.77956	5.42173	11.89269	61957.30545	185.09257	150.00000
12	A12	81.39767	0.51967	1.55537	5.18457	4.34360	33699.67433	93.32218	65.00000
13	A13	20.48505	0.22136	2.64030	0.99389	1.53165	22531.51995	37.93529	65.00000

14	A14	31.07692	0.34308	2.82051	0.45000	1.42308	48923.07692	71.79487	90.00000
15	A15	35.67100	0.75242	6.66269	1.32433	4.95232	41001.14615	155.80436	119.00000
16	A16	21.29691	0.24605	3.00662	1.17905	1.97542	25236.43972	43.84657	69.00000
17	A17	67.11277	2.49807	13.42255	14.58973	18.98290	126444.34552	512.01192	250.00000
18	A18	29.73042	0.32595	3.14793	0.46837	1.46637	38316.49068	62.95854	90.00000
19	A19	107.65565	0.91398	5.65747	5.10744	5.45362	78576.01908	169.72420	180.00000
20	A20	75.11425	0.77123	4.47886	2.79929	6.02482	55985.77667	146.96266	137.00000
21	A21	44.23753	0.56950	2.56532	0.60000	2.00950	98850.35629	136.81710	120.00000
22	A22	240.00000	2.00000	7.80000	8.00000	20.00000	60000.00000	320.00000	215.00000
23	A23	23.83333	0.30333	1.44444	0.32500	1.08333	52000.00000	72.22222	65.00000
24	A24	40.41787	0.52413	4.01888	0.80378	2.51994	50235.99738	102.37913	120.00000
25	A25	70.40724	0.52941	2.44344	3.35068	3.00000	67873.30317	108.59729	100.00000
26	A26	35.00000	2.00000	6.00000	40.00000	30.00000	220000.00000	360.00000	200.00000
27	A27	27.13278	0.53718	3.95686	6.85897	6.25730	57178.01180	96.09525	100.00000
28	A28	33.88494	0.35540	3.40909	0.50000	1.55540	46619.31818	70.31250	100.00000
29	A29	230.00000	8.00000	20.00000	160.00000	20.00000	999999.99986	1360.00000	800.00000
30	A30	79.43478	1.05913	18.01739	1.52174	12.84348	110782.60870	230.08696	280.00000
31	A31	50.40864	0.52741	5.60096	0.98005	2.56323	52275.63118	95.21633	150.00000
32	A32	133.41563	1.47665	3.89782	4.67738	6.22146	233869.00015	350.80350	250.00000
33	A33	13.18638	0.12754	1.64370	0.26580	0.60985	11960.93974	21.26389	40.00000
34	A34	300.00000	10.00000	8.00000	10.00000	38.00000	1000000.00000	2380.00000	1100.00000
35	A35	400.00000	6.00000	8.00000	5.00000	18.00000	1200000.00000	1600.00000	1000.00000
36	A36	29.51163	0.28047	3.48837	0.45000	1.36047	30139.53488	48.83721	90.00000
37	A37	495.00000	2.00000	4.00000	36.00000	20.00000	100000.00000	300.00000	200.00000
38	A38	32.50000	0.30000	4.00000	0.50000	1.50000	30000.00000	50.00000	100.00000
39	A39	34.05932	0.33910	3.27367	0.63732	1.55145	42966.88044	65.88255	95.00000
40	A40	59.80357	0.69214	4.85714	0.85000	2.73214	105642.85714	151.78571	170.00000
41	A41	19.50000	0.18000	2.40000	0.30000	0.90000	18000.00000	30.00000	60.00000
42	A42	52.00000	0.48000	6.40000	0.80000	2.40000	48000.00000	80.00000	160.00000
43	A43	19.50000	0.18000	2.40000	0.30000	0.90000	18000.00000	30.00000	60.00000
44	A44	9.75000	0.09000	1.20000	0.15000	0.45000	9000.00000	15.00000	30.00000
45	A45	369.21053	4.29737	44.18421	29.35526	18.46053	460000.00005	720.26316	1150.00000
46	A46	48.75000	0.45000	6.00000	0.75000	2.25000	45000.00000	75.00000	150.00000
47	A47	35.96639	0.43866	2.52101	0.50000	1.63866	71596.63866	100.84034	100.00000
48	A48	91.40744	1.10781	3.80864	2.71067	4.52979	167580.29777	258.98773	200.00000
49	A49	26.00000	0.24000	3.20000	0.40000	1.20000	24000.00000	40.00000	80.00000
50	A50	45.75871	0.79298	3.05058	0.88132	3.06931	99902.25554	181.50956	140.00000
51	A51	128.41616	3.06159	63.24942	3.70088	58.76266	334194.14770	818.65304	600.00000
52	A52	250.00000	9.00000	200.00000	10.00000	200.00000	999999.99999	2600.00000	1500.00000
53	A53	35.75000	0.33000	4.40000	0.55000	1.65000	33000.00000	55.00000	110.00000
54	A54	260.00000	15.00000	50.00000	14.00000	50.00000	160000.00000	3200.00000	820.00000
55	A55	650.00000	6.00000	80.00000	10.00000	30.00000	600000.00000	1000.00000	2000.00000
56	A56	52.00000	0.48000	6.40000	0.80000	2.40000	48000.00000	80.00000	160.00000
57	A57	27.30000	0.25200	3.36000	0.42000	1.26000	25200.00000	42.00000	84.00000
58	A58	121.78612	2.47800	8.69901	2.80328	9.91989	264201.98282	556.73655	400.00000
59	A59	60.49920	1.01914	8.24989	8.24989	9.43100	106130.66416	192.49745	210.00000
60	A60	450.00000	8.00000	10.00000	130.00000	265.00000	899999.99999	3330.00000	1150.00000
61	A61	80.81381	0.83255	8.39944	1.20000	3.71255	105765.74895	161.26925	240.00000

(Results from software program's DEA Excel Solver of Zhu (Zhu, 2006))

- Appendix 2: Resource reduction for catfish in Mekong River Delta, Viet Nam

Table 2.1: Resource reduction for catfish in Mekong River Delta, Viet Nam

Order	Norm		A01	A02	A03	A04	A05	A06	A07	A08	A09	A10	A11
1	Actual inputs	Invest	100	109	670	335	175	138	103	184	83.5	117	79
		Labour	4	2	4	7	2	2	3	5	5	2	4
		Fuel	6.6	8.82	1.5	60	10	5	11	11.7	11.7	5	5.4
		Electricity	6.65	7	10.5	70	1.5	5	8	25	33	5	48
		Chemicals	20	20	6	10	10	10	25	100	57	25	30
		Seed	100,000	180,000	450,000	100,000	60,000	200,000	245,000	230,000	120,000	110,000	70,000
		Feed	140	225	242	1050	175	140	350	300	528	250	370
2	Input oriented target	Invest	30.6	24.2	43.6	335.0	24.5	20.9	47.8	60.5	65.3	59.5	69.9
		Labour	0.3	0.3	0.6	7.0	0.3	0.2	0.8	0.7	1.5	0.7	0.7
		Fuel	3.0	2.2	1.1	60.0	3.2	1.8	5.1	5.5	9.1	2.8	4.8
		Electricity	0.4	0.4	0.5	70.0	0.5	0.3	3.7	0.9	9.2	2.8	5.4
		Chemicals	1.4	1.1	2.0	10.0	1.5	1.0	5.1	2.8	10.3	3.6	11.9
		Seed	42,868.8	38,108.6	127,110.1	100,000.0	21,704.5	34,773.5	82,643.4	95,607.5	93,844.3	61,084.4	61,957.3
		Feed	64.4	55.9	170.0	1050.0	63.3	50.5	162.3	140.2	282.0	138.8	185.1
3	Resource reductions [(3) =(1)-(2)]	Invest	69.4	84.8	626.4	0.0	150.5	117.1	55.2	123.5	18.2	57.5	9.1
		Labour	3.7	1.7	3.4	0.0	1.7	1.8	2.2	4.3	3.5	1.3	3.3
		Fuel	3.6	6.6	0.4	0.0	6.8	3.2	5.9	6.2	2.6	2.2	0.6
		Electricity	6.2	6.6	10.0	0.0	1.0	4.7	4.3	24.1	23.8	2.2	42.6
		Chemicals	18.6	18.9	4.0	0.0	8.5	9.0	19.9	97.2	46.7	21.4	18.1
		Seed	57,131.2	141,891.4	322,889.9	0.0	38,295.5	165,226.5	162,356.6	134,392.5	26,155.7	48,915.6	8,042.7
		Feed	75.6	169.1	72.0	0.0	111.7	89.5	187.7	159.8	246.0	111.2	184.9

(Source: Results from software program's DEA Excel Solver of Zhu (Zhu, 2006) and calculating by author)

Table 2.2: Resource reduction for catfish in Mekong River Delta, Viet Nam

Order	Norm		A12	A13	A14	A15	A16	A17	A18	A19	A20	A21	A22

1	***Actual inputs***	***Invest***	157	81	243	69.6	85	69	102	275	161	171	240
		Labour	3	2	2	6	6	3	7	6	5	6	2
		Fuel	3	10.44	5.5	13	12	13.8	10.8	14.4	9.6	5.4	7.8
		Electricity	10	12	15	30	15	15	12	13	6	7	8
		Chemicals	25	19	20	35	30	45	20	38	18	20	20
		Seed	65,000	100,000	100,000	80,000	260,000	130,000	200,000	200,000	120,000	210,000	60,000
		Feed	180	150	140	304	175	600	216	432	315	288	320
2	***Input oriented target***	***Invest***	81.4	20.5	31.1	35.7	21.3	67.1	29.7	107.7	75.1	44.2	240.0
		Labour	0.5	0.2	0.3	0.8	0.2	2.5	0.3	0.9	0.8	0.6	2.0
		Fuel	1.6	2.6	2.8	6.7	3.0	13.4	3.1	5.7	4.5	2.6	7.8
		Electricity	5.2	1.0	0.4	1.3	1.2	14.6	0.5	5.1	2.8	0.6	8.0
		Chemicals	4.3	1.5	1.4	5.0	2.0	19.0	1.5	5.5	6.0	2.0	20.0
		Seed	33,699.7	22,531.5	48,923.1	41,001.1	25,236.4	126,444.3	38,316.5	78,576.0	55,985.8	98,850.4	60,000.0
		Feed	93.3	37.9	71.8	155.8	43.8	512.0	63.0	169.7	147.0	136.8	320.0
3	***Resource reductions [(3) =(1)-(2)]***	***Invest***	75.6	60.5	211.9	33.9	63.7	1.9	72.3	167.3	85.9	126.8	0.0
		Labour	2.5	1.8	1.7	5.2	5.8	0.5	6.7	5.1	4.2	5.4	0.0
		Fuel	1.4	7.8	2.7	6.3	9.0	0.4	7.7	8.7	5.1	2.8	0.0
		Electricity	4.8	11.0	14.6	28.7	13.8	0.4	11.5	7.9	3.2	6.4	0.0
		Chemicals	20.7	17.5	18.6	30.0	28.0	26.0	18.5	32.5	12.0	18.0	0.0
		Seed	31,300.3	77,468.5	51,076.9	38,998.9	234,763.6	3,555.7	161,683.5	121,424.0	64,014.2	111,149.6	0.0
		Feed	86.7	112.1	68.2	148.2	131.2	88.0	153.0	262.3	168.0	151.2	0.0

(Source: Results from software program's DEA Excel Solver of Zhu (Zhu, 2006) and calculating by author)

Table 2.3: Resource reduction for catfish in Mekong River Delta, Viet Nam

Order	**Norm**		***A23***	***A24***	***A25***	***A26***	***A27***	***A28***	***A29***	***A30***	***A31***	***A32***	***A33***
1	***Actual inputs***	***Invest***	241	250	114	35	48	160	230	150	135	500	200
		Labour	3	3	4	2	1	2	8	2	2	3	1

		Fuel	3	8	3.6	6	7	8	20	210	15	5	24
		Electricity	6	1.6	7	40	70	70	160	70	5	6	1
		Chemicals	10	15	30	30	25	19	20	35	30	30	20
		Seed	150,000	100,000	100,000	220,000	120,000	160,000	1,000,000	300,000	140,000	300,000	45,000
		Feed	150	300	160	360	170	165	1360	480	255	450	80
2	***Input oriented target***	***Invest***	23.8	40.4	70.4	35.0	27.1	33.9	230.0	79.4	50.4	133.4	13.2
		Labour	0.3	0.5	0.5	2.0	0.5	0.4	8.0	1.1	0.5	1.5	0.1
		Fuel	1.4	4.0	2.4	6.0	4.0	3.4	20.0	18.0	5.6	3.9	1.6
		Electricity	0.3	0.8	3.4	40.0	6.9	0.5	160.0	1.5	1.0	4.7	0.3
		Chemicals	1.1	2.5	3.0	30.0	6.3	1.6	20.0	12.8	2.6	6.2	0.6
		Seed	52,000.0	50,236.0	67,873.3	220,000.0	57,178.0	46,619.3	1,000,000.0	110,782.6	52,275.6	233,869.0	11,960.9
		Feed	72.2	102.4	108.6	360.0	96.1	70.3	1360.0	230.1	95.2	350.8	21.3
3	***Resource reductions [(3) =(1)-(2)]***	***Invest***	217.2	209.6	43.6	0.0	20.9	126.1	0.0	70.6	84.6	366.6	186.8
		Labour	2.7	2.5	3.5	0.0	0.5	1.6	0.0	0.9	1.5	1.5	0.9
		Fuel	1.6	4.0	1.2	0.0	3.0	4.6	0.0	192.0	9.4	1.1	22.4
		Electricity	5.7	0.8	3.6	0.0	63.1	69.5	0.0	68.5	4.0	1.3	0.7
		Chemicals	8.9	12.5	27.0	0.0	18.7	17.4	0.0	22.2	27.4	23.8	19.4
		Seed	98,000.0	49,764.0	32,126.7	0.0	62,822.0	113,380.7	0.0	189,217.4	87,724.4	66,131.0	33,039.1
		Feed	77.8	197.6	51.4	0.0	73.9	94.7	0.0	249.9	159.8	99.2	58.7

(Source: Results from software program's DEA Excel Solver of Zhu (Zhu, 2006) and calculating by author)

Table 2.4: Resource reduction for catfish in Mekong River Delta, Viet Nam

Order	***Norm***		***A34***	***A35***	***A36***	***A37***	***A38***	***A39***	***A40***	***A41***	***A42***	***A43***	***A44***
1	***Actual inputs***	***Invest***	300	400	180	495	472	90.5	100	300	262	240	272
		Labour	10	6	2	2	1	2	2	1	2	1	7
		Fuel	8	8	10	4	40	8	8	8	21	24	11
		Electricity	10	5	10	36	5	17	14	9	9	9	7

		Chemicals	38	18	20	20	18	25	30	8	10	15	8
		Seed	1,000,000	1,200,000	120,000	100,000	140,000	105,000	210,000	60,000	240,000	80,000	35,000
		Feed	2380	1600	140	300	180	161	250	96	250	120	50
2	***Input oriented target***	***Invest***	300.0	400.0	29.5	495.0	32.5	34.1	59.8	19.5	52.0	19.5	9.8
		Labour	10.0	6.0	0.3	2.0	0.3	0.3	0.7	0.2	0.5	0.2	0.1
		Fuel	8.0	8.0	3.5	4.0	4.0	3.3	4.9	2.4	6.4	2.4	1.2
		Electricity	10.0	5.0	0.5	36.0	0.5	0.6	0.8	0.3	0.8	0.3	0.2
		Chemicals	38.0	18.0	1.4	20.0	1.5	1.6	2.7	0.9	2.4	0.9	0.5
		Seed	1,000,000.0	1,200,000.0	30,139.5	100,000.0	30,000.0	42,966.9	105,642.9	18,000.0	48,000.0	18,000.0	9,000.0
		Feed	2380.0	1600.0	48.8	300.0	50.0	65.9	151.8	30.0	80.0	30.0	15.0
3	***Resource reductions [(3) =(1)-(2)]***	***Invest***	0.0	0.0	150.5	0.0	439.5	56.4	40.2	280.5	210.0	220.5	262.2
		Labour	0.0	0.0	1.7	0.0	0.7	1.7	1.3	0.8	1.5	0.8	6.9
		Fuel	0.0	0.0	6.5	0.0	36.0	4.7	3.1	5.6	14.6	21.6	9.8
		Electricity	0.0	0.0	9.5	0.0	4.5	16.4	13.2	8.7	8.2	8.7	6.8
		Chemicals	0.0	0.0	18.6	0.0	16.5	23.4	27.3	7.1	7.6	14.1	7.5
		Seed	0.0	0.0	89,860.5	0.0	110,000.0	62,033.1	104,357.1	42,000.0	192,000.0	62,000.0	26,000.0
		Feed	0.0	0.0	91.2	0.0	130.0	95.1	98.2	66.0	170.0	90.0	35.0

(Source: Results from software program's DEA Excel Solver of Zhu (Zhu, 2006) and calculating by author)

Table 2.5: Resource reduction for catfish in Mekong River Delta, Viet Nam

Order	***Norm***		***A45***	***A46***	***A47***	***A48***	***A49***	***A50***	***A51***	***A52***	***A53***	***A54***
1	***Actual inputs***	***Invest***	400	162	500	120	165	60	160	250	130	260
		Labour	7	2	3	4	3	4	8	9	2	15
		Fuel	100	40	4	5	80	4	100	200	40	50
		Electricity	55	7	16	5	6	70	15	10	15	14
		Chemicals	20	16	5	15	10	11	80	200	12	50
		Seed	900,000	180,000	120,000	220,000	160,000	200,000	700,000	1,000,000	140,000	160,000

		Feed	1500	240	160	340	130	238	1020	2600	187	3200
2	***Input oriented target***	***Invest***	369.2	48.8	36.0	91.4	26.0	45.8	128.4	250.0	35.8	260.0
		Labour	4.3	0.4	0.4	1.1	0.2	0.8	3.1	9.0	0.3	15.0
		Fuel	44.2	6.0	2.5	3.8	3.2	3.1	63.2	200.0	4.4	50.0
		Electricity	29.4	0.8	0.5	2.7	0.4	0.9	3.7	10.0	0.5	14.0
		Chemicals	18.5	2.2	1.6	4.5	1.2	3.1	58.8	200.0	1.7	50.0
		Seed	460,000.0	45,000.0	71,596.6	167,580.3	24,000.0	99,902.3	334,194.1	1,000,000.0	33,000.0	160,000.0
		Feed	720.3	75.0	100.8	259.0	40.0	181.5	818.7	2600.0	55.0	3200.0
3	***Resource reductions [(3) =(1)-(2)]***	***Invest***	30.8	113.2	464.0	28.6	139.0	14.2	31.6	0.0	94.2	0.0
		Labour	2.7	1.6	2.6	2.9	2.8	3.2	4.9	0.0	1.7	0.0
		Fuel	55.8	34.0	1.5	1.2	76.8	0.9	36.8	0.0	35.6	0.0
		Electricity	25.6	6.2	15.5	2.3	5.6	69.1	11.3	0.0	14.5	0.0
		Chemicals	1.5	13.8	3.4	10.5	8.8	7.9	21.2	0.0	10.3	0.0
		Seed	440,000.0	135,000.0	48,403.4	52,419.7	136,000.0	100,097.7	365,805.9	0.0	107,000.0	0.0
		Feed	779.7	165.0	59.2	81.0	90.0	56.5	201.3	0.0	132.0	0.0

(Source: Results from software program's DEA Excel Solver of Zhu (Zhu, 2006) and calculating by author)

Table 2.6: Resource reduction for catfish in Mekong River Delta, Viet Nam

Order	***Norm***		***A55***	***A56***	***A57***	***A58***	***A59***	***A60***	***A61***	***Average***
1	***Actual inputs***	***Invest***	650	235	265	140	110	450	250	***182.5426***
		Labour	6	3	4	5	4	8	4	***3.377049***
		Fuel	80	22	39	10	15	10	15	***22.61213***
		Electricity	10	2	5	20	15	130	13	***18.3377***
		Chemicals	30	30	70	150	25	265	170	***31.52459***
		Seed	600,000	200,000	120,000	400,000	220,000	900,000	300,000	***229,016.4***
		Feed	1000	240	147	640	350	3330	288	***462.082***
2	***Input***	***Invest***	650.0	52.0	27.3	121.8	60.5	450.0	80.8	***93.05217***

	oriented target	***Labour***	6.0	0.5	0.3	2.5	1.0	8.0	0.8	***1.621693***
		Fuel	80.0	6.4	3.4	8.7	8.2	10.0	8.4	***11.11035***
		Electricity	10.0	0.8	0.4	2.8	8.2	130.0	1.2	***8.709651***
		Chemicals	30.0	2.4	1.3	9.9	9.4	265.0	3.7	***14.85075***
		Seed	600,000.0	48,000.0	25,200.0	264,202.0	106,130.7	900,000.0	105,765.7	***157,027.6***
		Feed	1000.0	80.0	42.0	556.7	192.5	3330.0	161.3	***373.4823***
3	***Resource reductions [(3) =(1)-(2)]***	***Invest***	0.0	183.0	237.7	18.2	49.5	0.0	169.2	***89.49045***
		Labour	0.0	2.5	3.7	2.5	3.0	0.0	3.2	***1.755356***
		Fuel	0.0	15.6	35.6	1.3	6.8	0.0	6.6	***11.50178***
		Electricity	0.0	1.2	4.6	17.2	6.8	0.0	11.8	***9.628054***
		Chemicals	0.0	27.6	68.7	140.1	15.6	0.0	166.3	***16.67384***
		Seed	0.0	152,000.0	94,800.0	135,798.0	113,869.3	0.0	194,234.3	***71988.84***
		Feed	0.0	160.0	105.0	83.3	157.5	0.0	126.7	***88.59972***

(Source: Results from software program's DEA Excel Solver of Zhu (Zhu, 2006) and calculating by author)

Appendix 3: The relation between technical efficiency and education and age (for efficiency rate is greater than 0.6 and production equal to and less than 820 tons