MEASURING CAPACITY AND CAPACITY UTILIZATION IN SMALL-SCALE FISHERIES IN NHA TRANG

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ABSTRACT

To develop effective capacity management programs, it is significant to evaluate and control the fishing capacity and its utilization in order to reduce overcapacity and excess capacity and create a stable development of marine resources. This study estimate fishing capacity and capacity utilization (CU) for the multi-species small- scale trawlers in Nha Trang, Vietnam. Data were collected through a survey of 65 small-scale trawler owners in two years 2005 and 2006. Using a mathematical programming approach - data envelopment analysis (DEA), the results from this study show that most of vessels in Nha Trang were operating at less than their full capacity and there was excess capacity in the trawl fleet. Based on these findings, some policy implications for trawl fishery management in Nha Trang are also provided and discussed.

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Keyworks: Capacity, Capacity utilization, excess capacity, trawl fishery, DEA.

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List of Acronym

CFP	Common Fishery Policy
CRS	Constant Return to Scale
CRS DEA	Constant Return to Scale Data Envelopment Analysis
CU	Capacity output
DEA	Data Envelopment Analysis
EEZ	Exclusive Economic Zone
EU	European Union
FAO	Food and Agriculture Organization
GDP	Gross Domestic Product
GT	Gross tonnage
HP	Horsepower
MAGPs	Annual Guidance Programmes
MEY	Maximum Economic Yield
MSC	Monitoring, Control & Surveillance
MSY	Maximum Sustainable Yield
NPOA	Capacity National Plan of Action – Capacity
NTB-MPA	Nha Trang Bay Marine Protect Area
PPF	Production Possibility Frontier
RTS	Return to scale
SE	Scale Efficiency
SPF	Stochastic Production Function
TAC	Total Allowable Catch
TE	Technical Efficiency
TWG	Technical Working Group
UK	United Kingdom
VIU	Variable input utilization
VND	Vietnam Dong

VRS	Variable Return to Scale
VRS DEA	Return to scale Data Envelopment Analysis

1. INTRODUCTION

1.1. Background

The world's fisheries is currently facing many problems such as overexploitation of marine resources, excess number of vessels, overcapitalization of the fishing industry and excess harvesting capacity. The Food and Agriculture Organization (FAO) of the United Nations reports that about 77% of the world's marine fisheries has been fully exploited or overexploited (FAO, 2006: p.29). There is also evidence that more than 90% of predatory fish stocks has declined over the past 50 years (Myers and Worm, 2003). However, surprisingly the reduction of fish stocks occurred parallel with the use of some of the traditional management measures such as mesh size limitations, gear restrictions, quotas, and by-catch reductions (National Research Council, 2001). These imply that traditional management measures are insufficient.

Overcapacity is the key problem afflicting marine capture fishery resources. Over the two decades, 1970-1990, global harvesting capacity of world fisheries industries grew at the rate of eight times greater than the growth rate of landings from capture fisheries (FAO, 1999: p.206). This indicated that the sustainability of world fisheries, the undermining of many conservation and management efforts and significant economic waste are results of overcapacity or excess capacity. An effective fisheries management should remove the need to consider capacity as a separate issue and we should consider capacity management rather than just fisheries management (Pascoe, 2007). In the late 1990s, FAO started treating the fishing capacity issue as a political priority with the aim to reduce overall fleet capacity. Fisheries management often concentrates on exercising effective control of the global season-by-season harvest. They do not exercise effective control over the fleet size and hence, excess capacity may persist (Munro, *et al*., FAO, 2003). Finding main causes of excess harvesting capacity or overcapitalization and overexploitation on fisheries, as well as the ways to reduce it are issues that are attracting the interests of economists and fisheries managers over the world. Economists have showed that, fisheries management that focus purely on biological and technological side of fisheries (e.g. input controls such as time and gear restrictions or output controls such as TAC, disaggregated quota limitations) and the lack of well-defined property rights are fundamental causes that will lead to increase in fishing capacity and result in efficient fisheries (Armstrong, 2007). For example, an individual quota (property right) to the fish harvested is applied where firms with low costs could buy quota with higher price than those with high cost and then they could sell or lease part or the entire quota to another firm and receive the discounted future profit from use of the quota and move to another industry. This means that over time, an arbitrary distribution of quota should lead to an efficient use of effort and harvest (Harwich, *et al.*, 1998) and thus is inefficient economic. The inefficient economic along with a free entry into fishery that increase the competition in catching lead an excessive investment in capital used to harvest fish and other input factors ("capital stuffing") is also cause of excess capacity and overexploitation on fisheries. Moreover, fishermen do not have incentive to conserve marine resource so the overexploitation of fisheries would occur as an indispensable result. To develop effective capacity management programs, it is significant to evaluate and control the fishing capacity and its utilization in order to reduce overcapacity and excess capacity and create a stable development of marine resources.

Capacity and capacity utilization (CU) estimates are desirable since overcapacity is often cited as the major reason for overexploitation of fisheries around the globe (FAO, 1998). We know that in an open-access fishery, an aggregated capacity or effort will be higher than maximum economic yield- MEY, which would bring maximum benefits to sole owner board and society (i.e. in open-access fishery excess capacity exists). It is important to show benefits of reducing effort for fishermen jointly (for society) in a cooperative setting. Vessels may be still the most efficient their individual perspective for a long-time period when they operate less than 360 days per year or in uncertain weather conditions or reduce inputs used if their capacity is fully utilized and marine resources is sustainable. Through capacity and CU measures we could generally expect that fishermen in open-access fishery can evaluate whether their fishing capacity is efficient or not and can adapt their capacity and its utilization optimally. Moreover, capacity and CU estimates would give fishery managers valuable information on the commensurate level of fleet capacity that should be in place, given the availability of resources and the economic status of the fishing industry (Lindebo, et al., 2007). Capacity management thus must also consider the fleet, from resources to the exploiters of the resources (Pascoe, 2007).

In the European Union (EU) fishing capacity management has been one of the main objectives of the Common Fishery Policy (CFP). Issues such as sustainable balance between resources and fishing capacity, and the use of management tools such as TACs (Total Allowable Catches) and quotas that enforced the fisheries controls and exchange for different kinds of landing species with many countries outside the EU have also had priority (Lindebo, 2004). When considering the balance between fleet capacity and the supply of fish in long-term, sustainable resources are the most important goal. A Multi-Annual Guidance Programs (MAGPs) was introduced in 1983 to promote this.

In Southeast Asia countries, a tense competition for resources between small-scale and large-scale fishing operations, and the reduction and collapse of important fish species lead to an increasing fishing pressure and over-harvesting of fishery resources (Ahmed, *et al.*, 2006). Therefore, a perception concerning overcapacity has been interested in most fisheries in Southeast Asia. Studies on capacity and overcapacity have been conducted in Bangladesh (Rahman, *et al.*, 2003), India (Vivekanadan, *et al.*, 2003), Sri Lanka (Samaranayake, 2003) and Java Sea in Indonesia (Purwanto, 2003).

Surprisingly in Vietnam the studies on capacity measurements have not drawn attention of researchers even the number of fishing vessels and fishing effort have increased rapidly that lead to a depletion of marine resources (Zwieten *et al.*, 2002), and the Government has also built a National Plan of Action – Capacity (NPOA – Capacity). Until now, there is only one capacity measurement study, which is carried out for Tuna longline vessels in Phu Yen Province, Vietnam conducted by Binh (2010).

This study will uses data envelopment analysis (DEA), a mathematical programming approach, to measure capacity output and CU of each trawl vessel in Nha Trang city, Khanh Hoa province, Vietnam. Capacity output and CU are technical and economic concepts that reflect the ability of the vessel to catch fish (Madau, *et al,* 2009). The methodology, capacity research experiences and the results obtained from this study will open the base for later research on fishing capacity in Vietnam and contribute to perfect building objective the National Plan of Action – Capacity (NPOA – Capacity) of Vietnamese Government

Study objectives

The major goals of this research are to use DEA to measure technological-economic concepts of capacity and CU for small-scale trawlers in Nha Trang city. Through evaluating capacity and CU, this study will:

- Calculate capacity output and excess capacity of each vessel.
- Estimate how much revenues of vessels could increase (or decrease) on average if they were operating at full capacity.
- Estimate variable inputs utilization rate of vessel and show how many of each input used that fishermen could increase (or decrease) to improve efficiency.
- Measure scale efficiency (SE)

Procedure and methodology

- Data used for this study is balance panel data and supplied by the NORAD (International Development Cooperation between Norwegian Agency Project SRV2701, Nha Trang University. Data are collected from 65 samples of trawlers in two years 2005 and 2006.

- The study will use the DEA framework to measure and evaluate capacity and CU in the sample of trawlers that operate in the coastal water of Nha Trang city. The capacity and CU estimation are done through an output- orientated measure of technical efficiency of firms which incorporates multiple outputs and input technologies. Based on an output orientation, capacity output and the optimum input utilization values are solved by a linear programming

Organization of the thesis

Section 2 provides an overview of the small-scale fisheries in Khanh Hoa Province and in Vietnam. This chapter shows characteristics of small-scale fisheries, contributions of this fishery to local economic development and its impacts on marine resources and environment. Through this chapter we are conscious of the importance of effective management this fishery**.** Section 3 presents the theoretical basis of open-access fishery, capacity, capacity utilization and economic-technical efficiency of vessels. Section 4 describes the methodology and necessary data used to analyze and measure the capacity and CU. Section 5 describes the data used in this study. Section 6 is the result of the thesis. Section 7 presents discussions and Section 8 is conclusions of the thesis.

1.2. Literature reviewed

Fishing capacity is a topic that attracted the interests of many researchers and fishery managers in the world and has become a management topic of great significance in recent years (Vestargaard, *et al*., 2003). Some methods which are often used to assess technical capacity are the peak-to-peak method; data envelopment analysis or Stochastic Production Frontier (SPF). The peak-to-peak method is a simple application and it can be found in the first researches on capacity in fisheries such as Ballard and Roberts (1977), Ballard and Blomo (1978), Garcia and Newton (1997). Later, Kirkley and Squires (1999) give further discussions including the weaknesses of this method. DEA approach was developed by Fare et al. (1989, 1994) and proposed for fisheries by Kirkley and Squires (1999). SPF method was developed by Farrell (1957). After the studies of Kirkley and Squires (1999) and Kirkley and Squires (2002) were introduced, the capacity measurement methodology was standardized and widespread under FAO-lead efforts to globally manage fishing capacity and the requirements of member nations to develop national capacity management plans. Until now, literature on fishing capacity and capacity utilization is plentiful. These fishing capacity studies are carried out in many areas in the world. In the range of this study, the author will present several typical studies related to this study topic.

The studies of Kirkley and Squires (1999, 2002) defined a sequence of technological-economic definitions of capacity and excess capacity on fishing industries. By using two alternative frameworks - DEA and SPF to estimate of capacity and excess capacity for the U.S North Atlantic Sea Scallop fishery, they showed the strengths and weaknesses of these two quantitative analyses and compared across between them. According to results that are showed from the study in 2002 by these authors, the unique output results from the SPF model are more logical than those in DEA model. However in the case of multi-species fisheries, the using of DEA framework to analysis is more appropriate than the SPF framework.

Lindebo, Hoff and Vestergaad (2006) implemented a study at the Danish North Sea with trawlers. These authors used two approaches, economic and physical approach, to measure capacity by applying DEA. By using the correlation analysis, they compare and contrast the physical and economic (based on catch revenue) measures and highlight the factors that need attention in any management scheme that aims to improve efficiency. The results of this study showed that technical and allocative economic factors are dominant causes of economic inefficiency while the ability to adjust variable inputs of fisher is less important. This study also showed that the technical and economically efficiency or inefficiency of each vessel as well as the proportions each vessel needs to adjust to their technical and/or economic factors to practice on an economic frontier.

In a study on fleet segments operating in the English Channel, Tingley, Pascose, and Maedle (2003) used DEA to measure CU in multi-métier, multi-purpose fleet. The analysis presented both revenue- and weight-base measures of CU and technical efficiency (TE) for six major gear types in the case of single- and multi-output. Moreover, the analysis investigated the effects of limited “degree of freedom” when estimating CU. The results of study showed that for all gear types, the (biased) CU and TE measures based on both revenues and weights in the multi-output measures were higher than those calculated using composite ‘sing-output’. The authors also proved that multi-output analyses enable a more accurate estimation of TE and CU score than single-output measures. Single-output measures are more vulnerable to random fluctuation in the catch of any one species in the output mix, whereas multi-output data incorporates information across the range of key species into analysis that reduce the influence of random fluctuations (Tingley, *et al*., 2003).

Up till now, in Asia there are also some studies on capacity, CU, excess capacity and TE. Squires, *et al.* (2003) used DEA to measure capacity and calculate excess capacity to give policy implications for sustainable development in Java Sea fisheries. In the same way, Kirkley, *et al.* (2003) applied DEA for the case of purse seine fisheries in Malaysia (represent for developing country fisheries). By analysing on three zones (each zone has the highest abundance for some different species compared to other zones) and two seasons (non-monsoon and monsoon season), the DEA empirical results of this study compared TE and variable input utilization state between zones and calculated the number of vessels decommissioned to eliminated annual excess capacity for each zones. The findings from this study provided very useful information for fisheries managers in Malaysia. Besides the studies for fisheries in each country, there has been a study on capacity management for Southeast Asia by Salayo, *et al.* (2008). This study presents results of regional study which examines various approaches to managing excess fishing capacity of small-scale fisheries in this region.

In Vietnam most recent studies concentrate on measuring economic efficiency for Khanh Hoa fisheries and finding main factors influencing the vessel performance. The factors are used to assess economic indicators are gross revenue and (or) income. We can show here some studies of authors such as Kim Anh, *et al.* (2006), Tuan, *et al.* (2007), Long, *et al.* (2008) and Ngoc, *et al.* (2009). Through results of these studies, information for making decisions to manage and improve fisheries strategies in Vietnam and Khanh Hoa province is added.

Long, et al. (2008) used regression analysis to assess the Tuna longliners in Khanh Hoa province in 2004. This study has showed the interesting results such as: crew members earn an opportunity income and vessel-owner can make a profit margin of 12.1%. The average annual crew share is more than 90% of average annual income of labour.

However, this study indicated that there was an over-investment in single vessels that may lead to inefficiency in Khanh Hoa's longliners. The author proposed some solutions to reduce over-investment in vessels. Government should stop the direct subsidy program for fisheries and concentrate on indirect solutions such as supporting training fishermen, providing information about fish stock, forecasting weather and rescuing and life-saving activities in the high sea.

Ngoc, *et al.* (2009) used SPF to evaluate efficiency of trawlers in Nha Trang Bay, Vietnam. The study showed that technical efficiency is affected by the engine power, the number of days per trip and the household size. In addition, it also showed that technical efficiency varies with the fishing ground. The vessels operate among Nha Trang Bay Marine Protect Area (NTB-MPA) are more technical efficient than those in other places. These ¨results are the base that author will use to compare with the results that are found in this study.

2. BACKGROUND OF VIETNAM'S SMALL-SCALE FISHERIES INDUSTRY AND KHANH HOA'S FISHERIES INDUSTRY

2.1. Small-scale fisheries in Vietnam

Vietnam has a 3,260 km of coastline in length and more than 1 million km2 of EEZ (Exclusive Economic Zone) going through more than 28 coastal provinces and cities of the country. With the abundance of marine natural resources and high amount of high economic value species, marine fishing plays an important role in the development of Vietnam economy and contributes to securing the food safety and improving livelihoods and income for millions of people. In 2006, fisheries industry contributed to GDP about 4% (Pomeroy, et al, 2009), creating 9-10% export revenue of the total, and supply jobs for 3.4 millions people, equivalent to 10% of the labour force (Long, et al, 2008).

Table 1: Types of fishing gears in Vietnam 2003

Fishing gears	Percentages (%)
Gill nets (drift gillnet, mackerel gillnets, shrimp gillnets and trammel net)	31.4
Trawls (otter board trawl, pair trawl and beam trawl)	26.0
Long line and hand line	13.4
Set nets	7.1
Lift nets	5.6
Seine nets (beach seine, purse seine)	4.3
Others	12.2

Source: Son, et al, 2003

Vietnam marine fisheries are still considered as small-scale with traditionally mode of artisanal production and technologically backward capture. Most of the fishing vessels are gill netters and trawlers with more than 50% of total fishing gears (table 1) and are small – sized. There are 61,390 (over 70%) of vessels with the engine power less than 45

HP and 82,507 (90%) vessels under 20 meters (table 2) operating in coastal near-shore waters. This is the cause of high fishing pressure for near-shore fisheries resources. In recent years, there is a rapid increase in the number of mechanized marine fishing vessels. According to Pomeroy, *et al.* (2009), the number of small-scale fishing vessels (<45HP) operating in inshore waters rose 2300 vessels each year on average in the period from 1990 to 2000.

In 1991 the number of vessel was 44,000. This number rose to 85,914 in 2005 and 95,000 in 2006. The capacity due to this has also risen from 824,000 HP to 5,317,000 HP and 5,735,000 respectively (Ministry of Agriculture and Rural Development, 2008). According to Son, from 1987-1999, the three-fold increase in engine power resulted in only 1.81 times increase in the total catch (Silvestre. *et al*., 2003) that led to the overcapacity in Vietnamese fisheries. The result in size of captured species becomes smaller, especially the high economically value species that lead to overexploitation of near-shore resources. Moreover, the number of small-scale fishing vessels is added annually which becomes a reason of an increasing pressure in fishing and overexploited state of near-shore marine resources.

Table 2: The structure of fishing fleet in Vietnam 2005

Basis of the engine capacity			**Basis of the length of boat**			**Basis of the fishery**		
Capacity (HP)	**Number (vessels)**	**Rate of total (%)**	**Length (m)**	**Number (vessels)**	**Rate of total (%**	**Fishery**	**Number (vessels)**	**Rate of total (%**
<20	34,294	39.92	<8	17,296	20.13	Trawling	21,641	25.19
20 - <50	27,096	31.54	8-<12	28,127	32.74	Pure-seining	6,413	7.46
50 - <90	10,987	12.79	12-<15	24,056	28.00	Gill netting	16,331	19.01
90- <150	4,969	5.78	15-<20	13,028	15.16	Long line-trolling	15,272	17.78
150-<400	6,963	8.10	20-<30	3,373	3.93	others	25,257	30.56
>400	1,605	1.87	>30	34	0.04			
total	**85,914**	**100**	**total**	**85,914**	**100**	**total**	**85,914**	**100**

Source: Vietnamese Ministry of Fisheries, 2005

Due to the overexploitation of near-shore marine resources, earnings from fishing activities in Vietnam is reducing, in some cases may be lost (Long, 2003). This leads to increasing conflict between small- and large- scales fisheries. Besides fishermen often use smaller mesh of net than regulation; harmful fishing gears, destructive fishing techniques that contribute to increase overexploited state of near-shore marine resources. To reduce fishing pressure and overexploited state of near-shore marine resources, Vietnamese Government has adopted a support program to develop offshore fisheries. However, the program did not attain objectives because of the absence of a reliable database on offshore resources, unsuitable fishing technologies and insufficient understanding of economic realities of offshore fisheries (Long *et al.*, 2008).

2.2. Fisheries in Khanh Hoa

Khanh Hoa is located in the South Central of Vietnam with a coastline of 520 kilometers and more than 200 islands (Long, *et al.*, 2008). Fishery industry in Khanh Hoa plays an important position in socioeconomic development of local economy. In recent years, fisheries in Khanh Hoa have highly grown that have contributed to the overall development of province's economy and improved the life of fishermen. Total fish production rose from 68,100 tons (2002) to 81,992 tons (2007). Export value of fish increased from 120 millions USD to 265 millions USD during the 2001-2005 periods (Vietsea, 2009).

The fisheries in Khanh Hoa are still open-access and contain a multiplicity of species. The fishing gears used include trawl, seine net, longline and gill net. Most of fishing boats are small scale and small engine power. More than 78% of the vessels have an engine power less than 50 HP and more than 90% of total vessels are less than 90 HP (table 3).

The number of fishing fleets that can operate in the offshore water is very few. Fishing is mostly concentrated in the coastal water which in turn may negatively affect marine resources. Techniques and equipments, moreover, used in fishing fleet are very simple so fishing time is limited and fishing efficiency is not high.

Table 3: Structure of fishing boats in Khanh Hoa Province 2007

Fishery / Horsepower	Trawling	Purse seining	Gill netting	Long line trolling	Others	Total
<20 HP	106	260	235	187	1.918	2.706
20-<50 Hp	233	796	175	85	355	1.644
50-<90 Hp	289	270	157	82	19	817
90-<150 Hp	88	64	86	60	28	326
150-<190 Hp	6	5	22	9	24	66
>400 Hp				2	1	03
Total	**722**	**1.395**	**675**	**425**	**2.345**	**5.562**

Source: Khanh Hoa Fisheries services, 2007

Nha Trang is central city of Khanh Hoa province. Trawl is one of most important fishing method in Nha Trang with 725 of 2648 registered vessels (27%) (2005). Trawlers operating in this city include both single trawlers and pair trawlers. Trawls are applied in Nha Trang over 35 years. The investment in trawl is quite low compared to other fleets. Trawlers are mainly small-scale size. The number of trawlers increases sharply due to the fact that techniques are rather simple. As a consequence, the expansion of trawl fishing activities has affected heavily marine resources and environment.

In this study, the analysis concentrates on trawl fleets operating in two different fishing grounds which are primarily located in Vinh Truong and Vinh Luong communes. Vessels in Vinh Truong often operate in the area outside the buffer zone and in the vicinity of nine islands in the NTB-MPA which was created in 2001 as the pilot project for other MPAs in Vietnam. Vessels in Vinh Luong, on the other hand, operate in Nha Phu Lagoon – a short way north of Nha Trang city. Most vessels are relatively small and owner operated (Ngoc, *et al.*, 2009). Figure 1 shows a map of Vietnam and the location and boundaries of NTB-MPA.

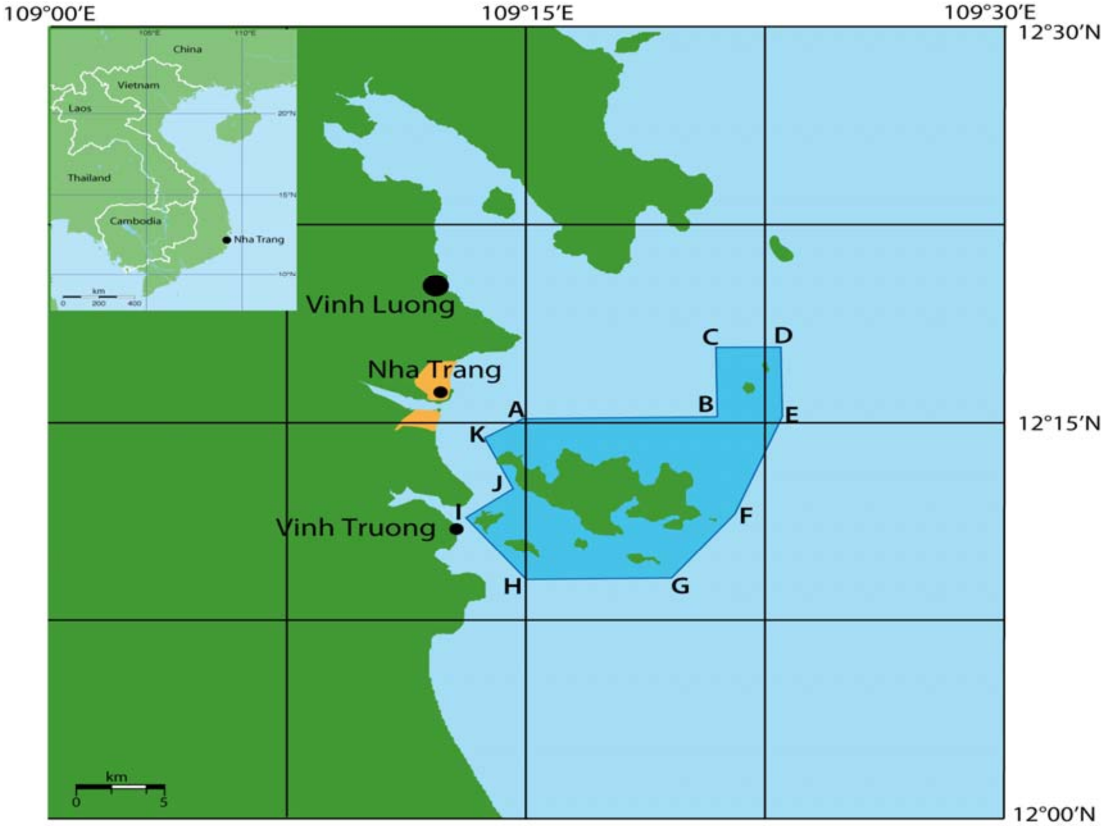

Figure 1-The location and boundary of the Nha Trang Bay Marine Protected Area, Vietnam
Source: Ngoc et al., 2009

Trawlers in Nha Trang fish year-round at depth from 40 to 50 m. Often trips are only overnight. Sometimes vessels with high engine power (40-55 HP) and larger gear have fishing time from 3 to 4 days per trip. Fishes caught from the sea are kept on only ice in plastic baskets. This is a simple technique so fish quality is not high especially when fishing time is long. Outputs of trawl fleet include mixed fish, demersal fish, trash fish, crabs and shrimp (more than 80% of the catch) (Ngoc, *et al.*, 2009).

3. THEORETICAL FRAMEWORK

3.1. Fishery theory

3.1.1. Bioeconomic model

Bioeconomic model is analyzed based on assumptions that vessels in a perfectly competitive market are homogeneous from an efficiency point of view. Thus, all vessels catch the same average cost per unit of effort (or cost per unit of effort is constant) and have the same average revenue and the price of fish is constant across of time and quantity (Flaaten, 2010). Based on the sustainable yield curve $H(E)$, the total revenue of fishing is $TR(E) = pH(E)$. $TR(E)$ and $H(E)$ curve has a same shape. The TR function and curve are both in term of effort. The average revenue per unit of effort is

$$AR(E) = TR(E) / E,$$

and the marginal revenue of sustainable fishing is

$$MR(E) = dTR(E)/dE.$$

The total cost is assumed as a simple function of effort $TC(E) = aE$ (TC is an upward-sloping straight line and linear with the effort at a constant cost per unit of effort, a, showed in the figure 1 panel (a) below.

Resource rent is measured by the vertical distance between the total revenue and the total cost, $\Pi(E) = TR(E) - TC(E)$. Under the open-access regime, if the resource rent is greater than zero it means the total revenue ($TR(E)$) is greater than the total cost ($TC(E)$) vessels will enter the fishery. Vessels only exit the fishery if total cost is higher than total revenue. When total revenue equals total cost, $TR(E) = TC(E)$, a bionomic equilibrium will be obtained (see Figure 1.a). In other words, open-access equilibrium will be at of effort (E_{OA}) where average revenue of effort, $AR(E)$, equals marginal cost of effort, $MC(E)$ (see Figure 1.b). At equilibrium level of effort, E_{OA}, the number of vessels in the fishery industry is stable. Therefore, in an open-access fishery, a level of effort either greater or smaller than open-access effort cannot be maintained indefinitely.

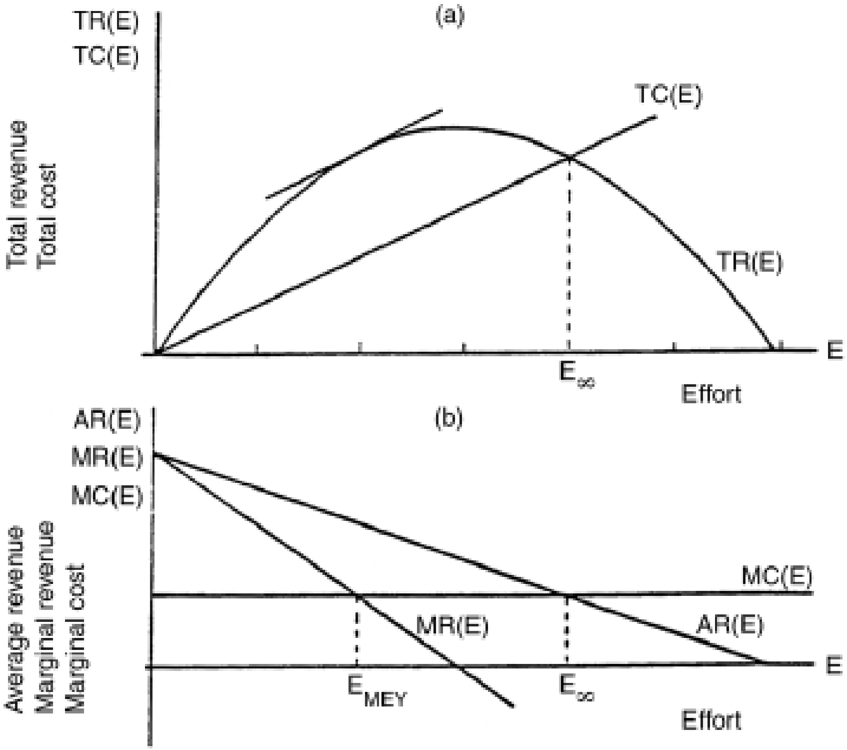

Figure 2-The maximum economic yield of fishing effort is significantly lower than the open-access level.
Source: Flaaten, 2010

As can be seen in Figure 2, we can see that the level of effort under the open-access equilibrium is E_∞ - the effort level that *TR(E)* intersects with *TC(E)* in panel (a) or *AR(E)=MC(E)* in panel (b).The effort level at which sustainable resource rent is maximised is E_{MEY}. E_{MEY} is defined by the problem max $\Pi = TR(E_{MEY}) - TC(E_{MEY})$. At this point, marginal cost equals marginal revenue, $MC(E) = MR(E)$ (panel b). The equilibrium effort under-maximising the resource rent regime is smaller than that under open-access regime, which helps to maintain a larger stock than that under the open-access case (Ngoc, *et al.*, 2009). Thus the issue of overcapacity is normally associated with the problem of open-access in fishery (FAO, 1999: p.206).

Based on the bio-economic model, concept of overcapacity is illustrated or characterized. Overcapacity occurs when there is a difference between the current effort and the effort that would generate maximum economic yield *(E_{MEY})* or maximum sustainable yield *(E_{MSY})* (E_{MSY} is the effort level that will maximise the total revenue). In an open-access fishery, the equilibrium effort is E_{∞}. Thus in this case the level of fleet overcapacity is equal to $E_{\infty} - E_{MEY}$ or $E_{\infty} - E_{MSY}$.

3.1.2. Fishing vessel economics

In the previous section we assumed that vessels are homogenous with respect to cost and catchability implying that cost per unit of effort, *a*, is constant and equal for all vessels (Flaaten, 2010). The reason for this is in the long-run perspective the adding homogenous vessels to the fleet can expand effort. In reality, the fisheries vessels usually differ with cost structure because of the differences in landing area, engine power, hull length, crew size etc. As a consequence, vessels may differ with respect to efficiency and costs (Flaaten, 2010). For example, the price of fuel is often more costly in small coastal community and remote fishing villages than in larger cities, due to transportation costs and less competition between sellers. Thus, differences in efficiency of effort and market price of inputs may all contribute to the existence of heterogeneous effort in the fish harvesting industry (Flaaten, 2010).

The economic adaptation of fishing vessels is presented through economic objectives of fishing activities, the cost structure and the size and availability of natural resources and the fish stock. The activity level of a vessel is measured by its fishing effort, *e*, and vessel's effort can be expressed by use of a standardized efficiency measure of fishing effort. The vessels can be different in effort levels due to the differences in the total number inputs needed to generate fishing effort (Flaaten, 2010). For example, trawlers can be increase engine fuel consumption to raise its speed between harbour and fishing ground i.e. increase time actual fishing and hence, the vessel's effort increase.

Before analyzing the vessel's economic adaptation of fishing effort, there are some assumptions need to be showed: (1) The price of fish is assumed under competitive market condition, it means that there is the same price (market price) of fish for all vessels and the effect of each vessel on price is very small. The fish price, p, is reputedly constant across of time and quantity; (2) There is no significant effect of vessels on the stock level and fish stock is considered as constant.

The harvest function of a vessel is assumed as the Schaefer linear function of its effort given period of time and the stock level, $h(e; X) = qeX$, where q is the catchability coefficient, X is the stock level, and e is the fishing effort of individual vessel (Flaaten, 2010). The total revenue of fishing can be calculated as follows: $TR\ (E) = ph(e; X) = pqeX$.

The total cost of effort is $tc(e) = c(e) + f$, where $c(e)$ is variable cost and f is the fixed cost. The average cost is calculated by total cost divided by the effort, $ac(e) = tc(e)/e$ and marginal cost of vessel effort is the change in total revenue as a result of small change in effort, $mc(e) = dtc(e)/de$. In firm's economic theory, marginal cost has a U- shape curve. It means firstly when the output is at the low level marginal cost may be declined to the minimum point and rises thereafter, due to the form of the production function. In the case of fisheries we may think of effort as the (intermediate) product of the production process and that this (intermediate) product is produced by regular inputs according to a regular production function (Flaaten, 2010).

The operating profit of the vessel is: $\Pi(e,X) = ph(e, X) – c(e)$ or $\Pi(e,X) = pqeX – c(e)$.
Assuming that the vessel's operator target is to maximises fishing profit, it will operate at the effort level at which $\Pi'(e,X) = pqeX – c(e) = 0$, this equivalent to $mc(e) = pqX$ (1). Solve the equation (1) we calculate the vessel's optimal effort.

The equation (1) tells that the marginal cost of vessel effort is equal to the marginal revenue of effort that is the product of fish price, catchability coefficient and stock level. The marginal revenue represents the revenue earned by the addition of unit of effort. In the traditional theory of production or the firm, marginal revenue equal to only price, *p*, so that the optimal point is the level output that *mc* = *p*, it means in the right-hand side of (1) has only *p*. But in this case of both *q* and *X* are included in addition to the price (Flaaten, 2010).

We have used the fishing effort as the fisher's decision variable and this differs from the using product in the production theory. An ordinary firm can control all input needed and the cost of production process (control its total production process). But a fish- harvesting firm does not control its most important input such as the fish stock. Fish stock is not like fuel and bait or other inputs that can be bought in the market. The fisher knows the cost per unit of effort, for example per trawl hour, and he also knows how the catch varies with stock level. Thus cost per unit of harvest will depend on both input costs and on the stock level and its catchability (Flaaten, 2010).

The important difference between this case and the theory of firm is that in this case effort is replaced to firm's quantity output that can be variable along the horizontal axis and. We may regard vessel effort as an intermediate output of the fish-harvesting firm - an output produced by use of regular inputs. The average cost curve and marginal cost curve of an open-access fishery and those of a firm are similarly (Flaaten, 2010). Based on that, we can show the adaptation of optimal effort for two profit maximising vessels, vessel i and vessel j.

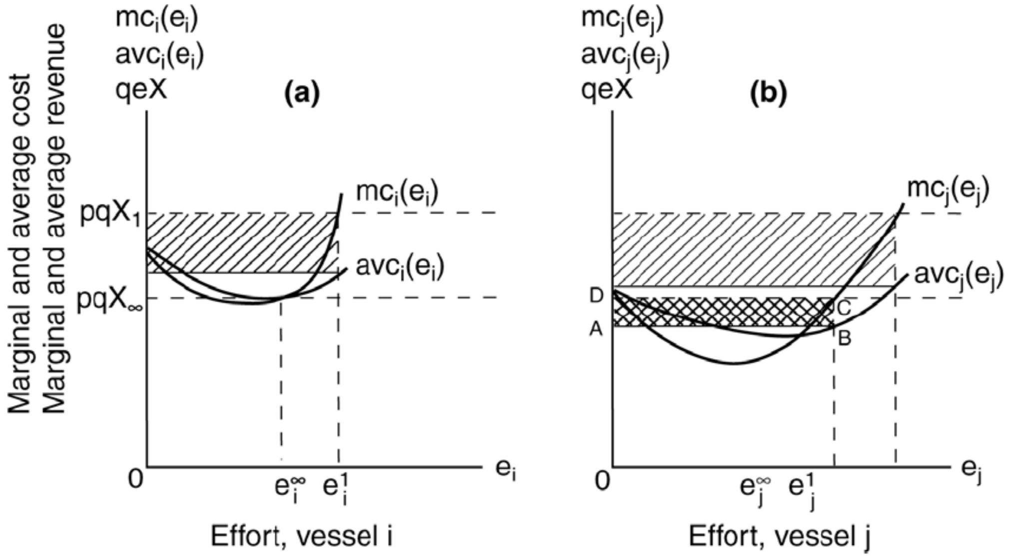

Figure 3 - Two fishing vessels: short-run adaptation of effort for a given cost structure, price of fish, catchability and stock level.
Source: Ola Flaaten, 2010

In figure 3, panel (a) shows the marginal revenue of effort at two levels of fish stock (X_1 , X_∞) is that pqX_1 and pqX_2. Following the equation (1), we can find out the optimal effort of vessel *i* is e_i^∞ for stock level X_∞ easily that is point where the marginal cost of effort equals marginal revenue of effort. Vessel *i*, however, does not make any profit, just breaks even, since the marginal revenue, pqX_∞ , equals average variable cost, $avc_i(e_i^\infty)$. If the stock level is lower than X_∞, the vessel will stop fishing because the marginal revenue is below the average variable cost at any effort level and then the result obtain can not cover variable cost. The lost of vessel will be more than fixed cost, so vessel will choose to be idle with zero profit than to operate with a negative result. Vessel *i* is a marginal vessel for stock level X_∞ since just a small reduction in the stock level will force the vessel out of operation (Flaaten, 2010).

Panel (b) shows the vessel *j* will maximal profit for effort e_j^∞ at stock level X_∞ and the profit of firm is the area ABCD in this case. This profit is called producer's surplus or quasi-rent in theory of firm and intra-marginal rent in fisheries economic theory. At stock level X_∞, the vessel *i* is a marginal vessel whereas vessel *j* is intra-marginal. Vessel j can be possible profit at stock level is lower than X_∞ (Flaaten, 2010).

If the stock level is X_1 the vessel i and j will maximise profit at stock level e_i^1 and e_j^1, respectively. Profit for each of these two vessels is single-shaded areas of panel (a) and (b). From this, we can see that higher stock level means higher marginal revenue of effort, thus encouraging each vessel increases its effort. The increase of vessel effort depends on the steepness of the marginal cost curve. If the marginal cost curve is very steep the optimal effort will hardly be expanded if stock increases (Flaaten, 2010).

In the long-run a fish harvester has different adaptation criteria from those in the short-run. If in the short-run the vessel's result suffices to cover operation cost (variable cost), then in the long-run it has to cover both fixed and variable cost. We have *tc(e) = c(e) + f* where f is the fixed cost. The average total cost is *atc(e),* the average variable cost is *avc(e)* and the marginal cost is *mc(e).* We have a figure of short-run and long-run adaptation of fishing effort flowing (Flaaten, 2010).

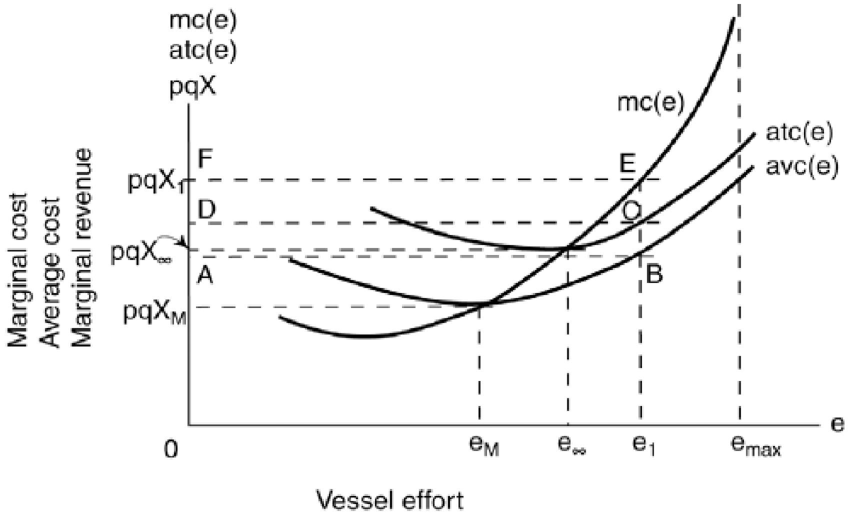

Figure 4- Short-run and long-run adaptation of fishing effort may vary due to fixed costs.
Source: Ola Flaaten, 2010

The average variable cost curve, *avc(e)*, is below the average total cost curve, *atc(e),* at any effort level, and marginal cost curve intersects the *avc(e)* and *atc(e)* curve at their minimum point.

In the short-run a vessel will operate if stock level above X_M or marginal revenue of effort is above pqX_M, which is equal to the minimum of its average variable cost. In the long-run a vessel has to cover fixed cost, it means the stock level has to be at or above X_∞ or the marginal revenue of effort is equal or greater than pqX_∞ .The X_∞ to indicate that the stock level at which marginal vessel breaks even under open-access fishing regime (Flaaten, 2010). The marginal of vessel produce at effort e_∞ level can cover all its costs, and earning normal profit-normal capital return. In the long-run, however, there are some vessels which management effectively, the stock level is kept at above X_∞, for example X_1 , the vessels will earn the gross profit is area of ABEF which include super profit DCEF shows in figure 3. The super profit in this case is the vessel's share of resource rent (Flaaten, 2010).

3.1.3. Intra-marginal rent for the most efficient vessels

In section 3.1.1 we showed that under open-access fisheries all vessels are homogeneous, the vessels will enter the fishery as long as effort at open-access level, E_∞. At this point the economic profit of all vessels equals zero, all vessels are earning the 'normal' profits - the profit is same to level of returns on their investment and labour as they might in the next best alternative industry with equivalent risk. In actual, however, the vessels are heterogeneous and thus with the different marginal cost of effort, MC(E), several vessels in fishery will earn intra-marginal rent or producer's surplus. This rent accrues to those vessels have lower cost than the marginal vessels at E_∞ (Flaaten, 2010).

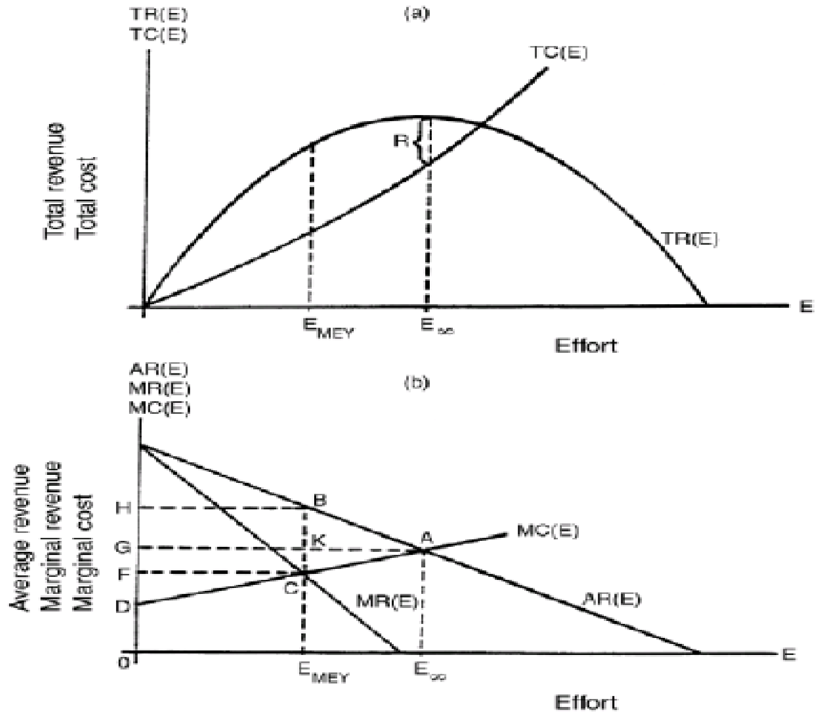

Figure 5- Equilibrium fishing effort, resource rent and intra-marginal rent under open-access and under maximum economic yield management in the case of heterogeneous effort.
Source: Ola Flaaten, 2010.

In figure 5 panel (a), the total cost of effort curve, *TC (E)*, is increasing progressively, since the *MC (E)* curve is upward sloping in figure 5 panel (b). *TR (E)* is sustainable long run total revenue curve; *AR (E)* and *MR (E)* are showed in panel (b). The open-access effort level is E_∞ where *MC (E) = AR (E)*. The total revenue equals the square $AGOE_\infty$ and total cost equals the area below the *MC (E)* curve, $ADOE_\infty$. This implies that there is an economic surplus (that is called intra-marginal rent) in the fishery, equivalent to the area AGD (in panel b). In the figure 5 panel (a), the equilibrium point is to left of intersection between the *TR (E)* and *TC (E)* curve, the difference between them being the intra-marginal rent is the line segment *R*.

The total rent of the fishery is defined as

$\Pi (E) = TR(E) - TC(E)$

As discuss in 3.1.1, the rent maximising effort level, E_{MEY}, is found where the *MC (E)* curve intersects the *MR(E)* curve. In this case the *MC (E)* curve is upward sloping and *MR(E)* is downward sloping. The relationship between revenue, cost and rent is as flows:

Total revenue	BHOE_{MEY}
= Resource rent	BHFC
+ Intra-marginal rent	CFD
+ Total cost	CDOE_{MEY}

The total rent equals to intra-marginal rent plus resource rent that is the area BHDC in figure 5 panel (b). Compare to intra-marginal rent for open-access fishery, which equals AGD, BHDC is clearly greater than it. We notice that even though total rent is greater for the effort level E_{MEY} than for E_∞, the intra-marginal rent is reduced (Flaaten, 2010).

In conclusion, in the case of heterogeneous fishing effort, the most cost-efficient vessels do make above-normal profit, called intra-marginal rent. So in fishery management, if the fishery manager wants to reduce effort from E_∞ to E_{MEY}, some vessels that have to leave the fishery will lose part of the intra-marginal rent. This may result in objections to change of management objective. However, as showed above, the total rent is highest for the E_{MEY} effort level, and some this could be used to compensate those vessels that may be in danger of losing their previous intra-marginal rent (Flaaten, 2010).

3.2. Capacity and capacity utilization in fishing industries

Capacity and CU are two important issues and bring great concern for fisheries management. It has long been recognized that in an open-access fishery, capital levels, harvest capacity, and levels of harvests will be suboptimal and there will be over capitalization and excess harvesting capacity (Vestergaad, *et al.*, 2003). Measurement and control fishing capacity have become a necessary issue both domestically and internationally and have been discussed in the political agenda. The lack of property rights and effectiveness of the polices in most managed fisheries worldwide has generated overinvestment in capital and other inputs used to harvest fish and the over-exploited in most of fisheries. While environmental factors have affected some fish stocks, excessive level of fishing capacity is thought to be the primary cause of these declines (Pascoe, *et al.*, 2006). To heighten fisheries manager's awareness of the important control capacity role, recently, the Food and Agriculture Organization (FAO) has initiated an international plan of action on management of fishing capacity (FAO, 1999) that significantly contributes to reducing illegal unreported and unregulated fishing.

3.2.1. Capacity, related concepts and fisheries

3.2.1.1. Capacity and fishing capacity

There is an abundance of definitions of capacity. The concept widely used of capacity is the maximum potential production of a single output or multi outputs by a firm, or industry, given technology, capital stock and other factors of production (Pascoe, *et al.*, 2003). In order to measure capacity, according to Morrison (1985), there are two different approaches, a technical-economic measure and a strictly economic measure (Morrison, 1985). The basic difference between the two notions is the underlying economic aspects included to measure capacity. In the technical-economic or technological-economic measure, no economic behavioral objective is explicitly assumed. Under the pure economic measure, the capacity output is defined as the output that is consistent with the output level that optimizes the behavioral objective of the firm such as profit maximization or cost minimization (Vestergaard, *et al.*, 2003).

For the economic measure, there are three definitions of capacity: (1) Capacity output can be defined as economic optimum – the output level where the short-run average and the long-run average cost curves are tangential (Klein, 1960); (2) capacity is the output corresponding to the minimum point on the short-run average cost curve (Berndt and Morrison, 1981). (3) Capacity is the output level corresponding to profit maximization- the output level that price equal to short-run marginal cost (Coelli, Grifell-Tatje and Perelman, 2001). Here, the definitions of Klein (1960) and Berndt and Morrison (1981) are developed based on the short-run cost function. Based on that concept of capacity, some authors had extended different approaches to measure capacity. For example, Segerson and Squires (1990), and Berndt and Fuss (1989) expanded the definition of capacity from a single output to multiple outputs; or Morrison (1985b) and Fousekis and Stefanous (1996) widened the single period to a multi period of the capital stock capacity concept; Squires (1987), Segerson and Squires (1993) extended capacity concept at profit - maximization aim of vessel; or Segerson and Squires (1993, 1995) and Fare, *et al.* (2000) used information on revenue and output prices to provide a revenue-based economic concept of capacity for multi-product firm. But in general, for most fisheries the capacity economic concept can not be evaluated because the economic data are often unavailable (Vestergaard, *et al.*, 2003).

The technological-economic measure is become increasing used in term of the lack of the economic data. The technological-economic measure represents the potential maximum output for a plant condition on prevailing output and input prices and demand conditions (Vestergaard, *et al*, 2003). According to Johansen (1968), the technological-economic approach capacity output is defined as "*maximum level of production in per unit of time with existing plant and equipment provided the availability of variable factors of production is not restricted*". This definition conforms to a full utilization of inputs given the fixed inputs (i.e. maximum utilization of variable inputs given the fixed factors of

production) on the production function, with the qualification that capacity represents a sustainable maximum level of output (Kein and Long, 1973).
Figure 6 depicted four concepts of capacity output.

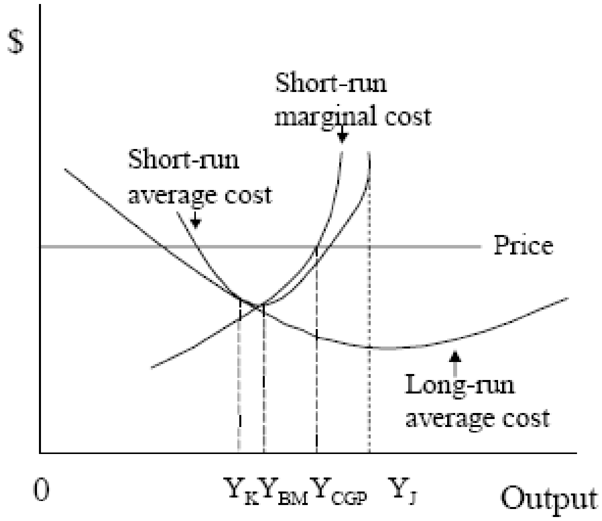

Figure 6- Economic and technological-economic concepts of capacity output
Source: FAO, 2003

In figure 6, the Y_K, Y_{BM}, Y_{CGP}, Y_J are capacity output as defined by Klein, Berndt and Morrison, Coelli, Grifell-Tatje and Perelman and Johansen, respectively. Y_J is the highest level of output. Capacity output is defined by Berndt and Morrison and capacity output is defined by Klein are equal when technology is under long-run constant return to scale.

In 1999, an International Plan of Action for Management of Fishing capacity of Food and Agricultural Organization of the United Nation (FAO) agreed which calls for all member state to achieve efficient, equitable and transparent management of fishing capacity by 2005, and to provide estimates of capacity of their fishing fleets by 2001. Under the guidelines by FAO technical working group on management of fishing capacity (FAO, 1998), capacity definition is basically the same as Johansen's definition of capacity in a production systerm where fishing capacity is "… *the maximum the amount of fish over* *the period of time (year, season) that can be produced by a fishing fleet if fully utilized, given the biomass, the age structure of the fish stock and the present state of the technology".* That is,

$Y_c = Y (E_c, S)$

With:

Y_c is current (maximum) yield or catch

E_c is current effort at produced by a fully utilized fleet (100% capacity utilization). E is function of K-capital investment and V-variable inputs

S is fish stock biomass, the fishing fleet is the stock of inputs, and assuming that management objectives are related to sustainability of the resources (FAO, 1998b). In this sense, capacity is strictly defined as a short-run concept, given the limitation on the level of fixed inputs (capital stock) (Lindebo, 2004).

In fact, the fish stock biomass, S, may be affected by some factors including fishing effort. In an open-access fishery, a small effort gives a high stock level and a relatively small catch. A somewhat higher effort level gives a lower stock level.

We can see the FAO definition above focuses only on the fleet, and fishing capacity as a short-run concept that fishermen face with the resources stock, technology and use of fixed inputs under constraint conditions. Capacity is an index representing vessel or fleet of vessel's ability to catch the maximum of fish and it can be changed due to stock fluctuation in a stock-flow production technology.

Fishing capacity is affected by main factors such as fishing time, technology and its equipment, the biomass of the fish resources and other inputs.

- Fishing time: includes productive time (time for detecting fish, looking for fishing ground and harvesting fish) and non-productive time. The fishing time use is much more or less depends on the fishing gears and methods used. In the case of trawl fishery, productive fishing time spent mostly on trawling and fishing time has a positive relationship with catch (Zhou, *et al.*, FAO, 2003).

- Technology and equipment: the influence of sciences and technology on fishing capacity is great especially for active fishing methods such as trawling and purse seining. The improvement and progress of fishing vessel and fishing gear will vary the fishing capacity. An increase in vessel numbers, gross tonnage and the engine power, the expansion of the size of fishing gear and the advance in instruments used will improve efficiency in fishing and hence capacity will increases. In the case of trawl - a mobile fishing gear, the greater engine power can allow more gear to be used and also helps the vessels to access the fishing ground more quickly so more efficiency fish and capacity will rise (Ngoc, *et al.*, 2009)

- Biomass of the fish resources: the level of resources has an important influence on catch ability of vessels. It is one of most important factors affecting total catch of firm. If fish resource is abundance then the main factors that affect actual fishing capacity may be a function of fishing vessel (e.g. the number labour used, variable inputs utilization rate, the fishing days and etc.), fishing gear and fishing technology. Whereas if the resource is at low level, then the biomass of resources may be the major factor affects on capacity (Zhou, *et al.*, FAO, 2003).

- Other variable inputs: beside the technological factor that is mentioned above the variable inputs such as labour, fuel and ice that have also affect fishing capacity. In fixed time condition and other factors are constant, an increase in variable inputs may increase catch and capacity. For example, a vessel with strong freezing allows a longer fishing time at sea, which can greatly affect the yield harvest the same as fishing capacity.

Beside the factors mention above, the skippers' experiences, fishery management policy and sea condition also influence the output and fishing capacity.

3.2.1.2. Capacity utilization

CU is an important concept related to capacity. CU is an output- oriented measurement; it presents the proportion of variable capacity that is utilized (Morrison, 1985).

In the technological-economic approach that was adopted by FAO, full CU represents full capacity[1] and its value is always less than or equal to one (CU<=1). If CU of one firm is less than one, it means that firm can increase the production with the present state of capital or equipment or on other words that firm can raise the potential production without pay more for new capital or equipment (Klein and Summers, 1966). If CU equal to 1, productive capital, other fixed inputs and variable inputs are fully utilized. There are two different ways to measure CU in this approach. First, it is measured by the ratio between the present (observed) output and the capacity output which obtainable at fully use of variable inputs of production (Nelson, 1989; Morrison, 1985). In this case, CU is called CU-observed. Second, it is measured as ratio of the output technical efficiency (the level of maximum output that vessels achieved at given set of inputs with state of technology, environment condition, and resources stocks are fixed) to the capacity output level. The observed output level may be TAC level if TACs are used (Fare, *et al.*, 1989). CU is referred as CU-efficient.

We can see a difference between two measurements of CU above. In the first approach a numerator may be technically inefficient and a denominator is technically efficient. In contrast, the second approach both numerator and denominator is technically efficient output levels (Kirkley J. E., *et al.* FAO 2003).

If the economic concept of capacity is considered, CU is not restricted to being less than one in value. If CU greater than 1, it means actual output can be larger than desired economic output and the inputs used are over-utilized. If CU is less than 1 in value, excess capacity exists, or the inputs used are under-utilized. If CU equal to 1, capacity is fully utilized and all production inputs have reached their full equilibrium levels (Pascoe, *et al.*, FAO 2003).

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[1] Full capacity is defined as an attainable level of output that can be reached under normal input condition – without lengthening accepted working weeks, and allowing for usual vacations and for normal maintenance (Klein and Long , 1973: p. 744)

3.2.2. Excess capacity

Excess capacity is a short-run concept refers to the excess use of inputs (labour and capital) to produce a potential output of firm (Kirkley and Squires, 1999). It differs from overcapacity or overcapitalization[2] concept that defines excess only capital. In fisheries industry, resources are renewable so excess capacity definition relative to biological or bio-socio-economic reference point accounts for sustainable resource use (Kirkley and Squires, 1999).

Excess capacity is defined as the difference between capacity output and desired or target level of output (Kirkley and Squires, FAO 2000). The Technical Working Group (TWG) showed that target level of output could be evaluated at both the current and target stock sizes and defined as *"... maximum amount of fish over the period of time that can be produced by a fishing fleet if fully utilized while satisfying fishery management objectives designed to ensure sustainable fisheries…"*(FAO, 1998b). Current and target capacity need to be evaluated and compared relative to the same resource stock size (FAO 1998).

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[2] Overcapitalization occurs when a firm is producing its output at the level greater than the minimum cost because its plant is larger than optimal levels of a firm's stock of capital. The tool to measure it is CU. If CU <1, the firm is experiencing overcapitalization. If CU >1, the firm is operating with deficient capacity, and hence is undercapitalized.
Overcapacity is a long-run concept is defined relative either a desired resource condition or level of production (Pascoe et al., FAO 2003)

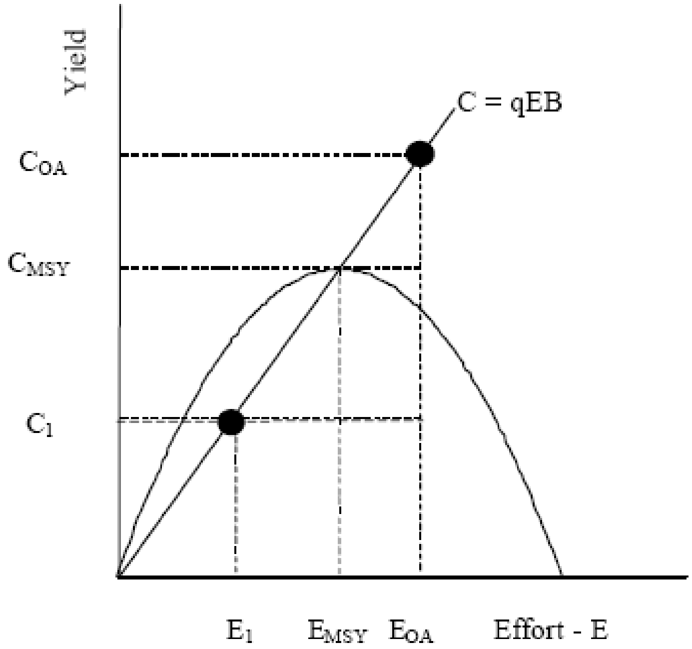

Figure 7– The sustainable yield curve

Source: Pascoe et al., FAO 2003

In Figure 7, *E* is the fishing effort, which is a combination of the number of vessels/capital stock, *K,* and the level of variable inputs, *V*; *B* is the population or biomass of resource; *q* is the catchability coefficient; Catch, $C=qEB$ – short-run yield or production function. The parabola is the sustainable yield function of Schaefer.

In Figure 7, the concepts of excess capacity and overcapacity are illustrated. In open-access fishery and the level of population supports that *MSY*. Assume that the objective of management is harvest level is *MSY*. E_{OA} is level of effort allowable, and then the short-run catch equals C_{OA}. Overcapacity is difference between level catch C_{OA} and $C_{MSY.}$ Support that in shot-run some fleets is not fully utilization (some fleets does not catch), the units of effort at E_1, the fleet lands C_1, excess capacity equals the difference between C_{OA} and C_1. Excess capacity is defined and assessed in short-run and overcapacity is defined and assessed in long-run. In terms of input base *–E,* excess capacity equals E_{OA} - E_1, overcapacity equals E_{OA} - E_{MSY} (Pascoe *et al.*, FAO 2003).

3.2.3. Measurement of capacity and the natural resources stock

In fisheries also as other renewable resource industries with stock-flow production technology, in which inputs are used to the resource stock to yield a flow of catch (output), capacity can be measured conditional upon the size and composition (e.g. age structure, species, and density) of the resource stock or without the resource stock. When capacity is measured conditionally upon the size and composition of resource stock condition, it represents the maximum potential output that is produced at given resource stock level[3]. When capacity is measured without the resource stock, it represents the potential output that could be produced in the absence of resource constraints, such as after a resource stock as begun rebuilding beyond the current depleted level (Kirkley *et al.*, 1999).

When capacity is calculated conditionally upon available resources abundance, the capacity measure does not truly reflect total potential catch. A vessel could harvest when constrained by current resource conditions which could be very low and restrictive. Whereas, exclusion of resource stock in capacity measures suit to a long-term period when current resource conditions - say of a depleted stock – do not limit capacity (Kirkley *et al.*, 1999).

In fisheries, measuring capacity in renewable resource industry is more difficult than other areas applied economic that fishermen harvest from a fixed pool of resources (where the nature limits the production and the individual fisher's ability to control catches (Prochaska, 1987)) because the measure is conditional upon the resource stock (Vestergaard, *et al.*, 2003). In order to take into account the resource stock for capacity measurements, one way that we can do is to incorporate and reflect seasonal changes in environmental conditions. Theses seasonal changes influence the abundance and availability of resources and hence influence outputs or production levels of fisheries.

3.2.4. Latent capacity

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[3] Resource stock abundance sets an upper limit on output in the stock-flow production technology.

In open-access fisheries, each single fishery or participants can enter freely that may increase in latent capacity problem. The definition and measurement capacity and capacity utilization depends on activities firm in the industry. Most fishing industries have a core of active participants, where some are more active in than other (Kirkley J. E. *et al*). The potential participants that operate at different places or fish on different species are often exists and can joint fish immediately if there are changes in resource stock or regulations or market conditions. The change allocation between the fisheries of fishing effort during the season is the origin of latent capacity problem. The number and the operation duration and intensity of potential participants lead to the issue of latent capacity (Kirkley J. E. *et al*).

3.2.5. Multiple species and heterogeneous capital stock

Most of the fisheries produce multi-species or multi-output so any empirical method for measurement of fishing capacity needs to account for multiple outputs.
The measurement of capacity and CU become problematic in case both multiple outputs and multiple (quasi-) fixed factors (Berndt and Fuss, 1986) exist. As mentioned in 2.4, fisheries industry with stock-flow production technology and resource stock is conceived of as natural capital stock, capacity and CU are short-run norm and capacity and CU estimation is made conditional upon the target resource stocks (Kirkley J. E. *et al*).

The vessel operating in fisheries can be moved from one fishery to another so a method for assessing capacity is the mobile natural of vessel. The ability to change fisheries raises complex issues in the measure of aggregating capacity output. A high level of aggregation including all fisheries within the year of the whole fleet show the overall level of capacity and CU (Vestergaard N. *et al.*, 2003)

3.3. Technical efficiency

Technical efficiency (TE) is the ability of a firm to obtain the maximum possible of output (output-oriented measure) or minimum of input (input-oriented measure) from the given of inputs or output and production technology. In this study, we mention to output-oriented measured of technical efficiency and technical efficiency is maximum of output quantities that firm can be proportionally expanded without change in the input quantities used. The firm's production is compared to a best-practice input-output relationship of production frontier and the most efficient firms establish the production frontier and the deviation of an individual firm from this best-practice frontier is measurement of technical inefficiency (Kirkley J. E. et al., 1999)

The capacity measurement by definition is output- oriented. Coelli et al (1999) illustrate the output-oriented measure by considering the case where production involves two outputs (y_1 and y_2) and single input (x)

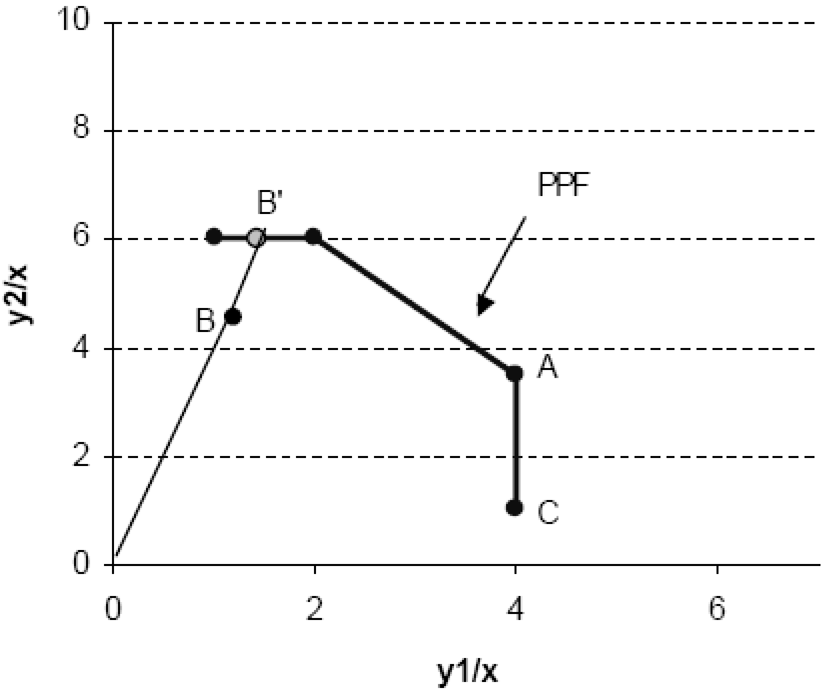

Figure 8- Technical efficiency from an output orientation.

Source: Coelli et al. 1999

The technology can be presented by a production possibility frontier (PPF). Input quantity hold fixed at a particular level.

In figure 8 the PPF is the upper bound of production possibilities. Firm B lies below the PPF and is producing output level lower than firm B' lies on PPF. Firm B is an inefficient firm and B' represent an efficiency firm. The distance defined by BB' is a measure of technical inefficiency, i.e. the amount by which output of firm B can be increased without requiring extra input. The measure output-oriented TE is defined as the radial measure ratio OB/OB'. For example, a TE score of 0.75 indicates that outputs can be increased by 33.3% (1/0.75) whilst holding the current level of input fixed. If a firm has TE score equal to 1, this firm is technically efficiency and it is on the frontier.

4. METHODOLOGY

4.1. Measuring Fishing Capacity

Technical capacity is often assessed by three different approaches: the peak-to-peak method of Klein (1960), output- and input-oriented DEA method developed by Fare et al (1989, 1994) and proposed for assessing capacity in fisheries by Kirkley and Siquires (1999); and stochastic production frontiers (SPF) method developed by Farrell (1957). The peak-to-peak and DEA are nonparametric approaches and do not require statistical analysis (Kirkley, *et al*). They have been used to estimate technical capacity in fisheries (Ward, 2000). By contrast, the SPF approach is a parametric statistical which has been used to estimate efficient (frontier) production in fisheries (Kirkley, Squires and Strand, 1995). Each method has strengths and weaknesses, and the choice of the appropriate method will vary depending on the nature of fishery, data available, and the intended aim of capacity measure (Ward, 2000).

Following the peak-to-peak method, capacity is defined by estimating the observed relationship between catch and fleets size. CU is measured by compared capacity output to actual output level in different time periods. Full capacity obtains at periods with the maximum of a ratio of catch to capital stock provided. Peak-to-peak method is best suited in the case of data are limited to catch and vessel number. In this approach the periods of full utilization that called peaks, are used as the primary reference points for the capacity index (Ward J., 2000).

SPF is an econometric approach can be used in the case of estimating the maximal potential output. The capacity of vessels can be estimated based on frontier production function estimation by predicting output with their actual fixed inputs level and a maximum variable inputs level (Ward J., 2000). SPF can be used to calculate economic efficiency include technical and allocative efficiency if data on input and output price is available (Coelli T.J. *et al.*, 2005).

DEA is also a frontier-based method (like SPF), but there are some differences between them. If SPF is a (parametric) statistical based approach, then DEA is (non-parametric) linear programming based approach. Information of catch and input are used for both methods is on individual vessels and can be estimating the potential output of each vessel separately. SPF is used in the cases of there are some differences in output between similar vessels while DEA assumes differences between similar vessels to be due to a combination of inefficiency and underutilized capacity (Kirkley J.E. et al, 2002).

The methodology used in this study to empirically estimate and assess capacity and CU is DEA. This method is chosen because it is a useful tool and widely used for measuring capacity and CU in fisheries. In addition, it is also suitable with the multi-species characteristic of trawl fisheries in Nha Trang. However it should be noted that there are several advantages and limitations of DEA. DEA can readily incorporate multiple inputs and output to calculate technical efficiency. It can also provides a set of potential role models such as maximum potential level of effort or variable input and their optimal utilization rate that a firm can look to improve its operations. DEA also allows both the output- and input-oriented approach. Through DEA, capacity can be estimated for different groups of firms (e.g., by region and vessel size class) and the number of operating unit until the total reaches a target (Ward, 2000). Moreover, DEA can calculate how much cost could be reduced as also how much revenue or profit increased by efficiently producing the optimal product mix if data on input or output price available (i.e. DEA is possible to measure allocative efficiencies[4] as well as technical efficiencies).

However, DEA has some limitations. For example: DEA only measure efficiency relative to best practice within the particular sample, so that, it is not meaningful to compare the scores between two different studies and DEA scores are sensitive to the size of the sample and input and output specification (Bhagavath, 2002)

4.2. The DEA framework

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[4] Allocative efficiency reflects the ability of firms in using the input at optimal proportion, given their respetcive prices and the production technology (Coelli *et al.,* 2005)

DEA approach is a mathematical programming technique to determine optimal solution given set of constants. This approach has been widely used to find the technical efficiency of firms (Charnes, *et al.*, 1994) and measured capacity and CU.

This study will use DEA to calculate the capacity and CU under the framework developed by Fare et al. (1989) in which only the fixed inputs are bounded at their observed level, allowing the variable inputs to vary and fully utilized. This is slightly different from the concept offered by Jonhansen (1968), because it explicitly allows the fixed factors to restrict output (Vestergaard, *et al.*, 2002).

Capacity output can be estimated by solving a mathematical or linear programming problem. Following Fare *et al.* (1989), let there be $j = 1,\ldots J$ observations or firms in the industry, u is the vector of output, x is vector of input. The inputs include fixed inputs (α) and variable inputs $(\acute{\alpha})$. There are m outputs and n inputs. The assumptions state that: First, each input is used by some firm, second, each firm uses some input and last, each firm produces some outputs ($u^j > 0$ for all j).

Following output-oriented DEA problem capacity output and the optimum or full input utilization values require solving the equation:

$$\mathrm{Max}_{\theta,\lambda,z}\ \theta_1$$

Subjetc to

$$\theta_1 u_{jm} \le \sum_{j=1}^{J} z_j u_{jm} \quad , \qquad m = 1, 2, \ldots, M \qquad (1)$$

$$\sum_{j=1}^{J} z_j x_{jn} \le x_{jn}, n \in \alpha \qquad (2) \qquad \text{(I)}$$

$$\sum_{j=1}^{J} z_j x_{jn} = \lambda_{jn} x_{jn}, n \in \acute{\alpha} \qquad (3)$$

$$z_j \ge 0 \qquad , j = 1, 2, \ldots, J$$

$$\lambda_{jn} \ge 0 \qquad , n \in \acute{\alpha}$$

Where z_j is the intensity variable for the j^{th} observation., λ_{jn} is the input utilization rate by vessel j of variable input n. θ_1 is a scalar measure of capacity or proportion by which output can be expanded when production is at full capacity production. Equation (1) represents constraint for each output. The equation (2) constraints the set of fixed factors and the equation (3) allows variable inputs to vary freely (in this case it implies that variable input is fully utilization).

The linear programming model (I) imposes a constant returns to scale (CRS) of production function. This means there is a linear relationship between inputs and output (Lindebo, *et al.*, 2007). In this case, we take into account that in the short run trawls can operate under variable returns of scale (VRS). So in the model (I), we impose the convexity constraint $\sum_{j=1}^{J} z_j = 1$ (Madau, *et al.*, 2009).

In this approach, the capacity score, θ, that indicates the percentage by which the production of each output of each firm may be increased (i.e., the score measures the distance between the observed output and the frontier) is provided. θ is greater than or equal to one, and θ -1.0 indicates the percent by which the original output level can be expanded with no change inputs. For example, if the efficiency score is 1.5 it indicates that the capacity output is 1.5 times the current observed output and output can be expanded 1.5-1.0 = 0.5 or 50% with no change inputs. The CU is equal 1/1.5 = 0.67. Through DEA approach, the optimal utilization rate of the n^{th} available inputs for the j^{th} firm or the utilization of the variable inputs required to produce at full capacity output, λ_{jn}, is also provided (Vestergaard, *et al.*, 2003).

Capacity output is estimated by multiplying θ_1 by actual production, $\theta_1 u$. Base on the observe output, CU is calculated by

$$CU(observed) = \frac{u}{\theta_1 u} = \frac{1}{\theta_1}`$$

From this approach capacity output and CU are measured in the multiple output are expanded in fixed proportions relative to their observed values condition (Segerson and Squires, 1990). By keeping all output in fixed proportions the multiple-output problem is converted into single-product problem. This ray CU measure may be biased downward because as mentioned above the numerator used in this approach is observed output which may be inefficiently produced (may not be produced in a technically efficient manner). To obtain a technically efficient measure of outputs both variable and fixed inputs must be constrained to their current levels (Vestergaard, *et al.*, 2003). An unbiased of CU is obtained by dividing a technical efficiency of output by technical efficiency of capacity output. The technical efficiency score (θ_2) shows how much the production can be increased through using all inputs (fixed and variables inputs) efficiently may be determined by solving another linear programming problem:

$$\mathrm{Max}_{\theta,\,z}\ \theta_2$$

Subjetc to

$$\theta_2 u_{jm} \le \sum_{j=1}^{J} z_j u_{jm}\ , \qquad m = 1, 2, \ldots, M, \qquad (4)$$

$$\sum_{j=1}^{J} z_j x_{jn} \le x_{jn}, \qquad n = 1, 2, \ldots, N, \qquad (5) \qquad \text{(II)}$$

$$z_j \ge 0\ , \qquad j = 1, 2, \ldots, J,$$

The DEA model (II), equation (5) constraints the set of both variable and fixed inputs factors (i.e. model (II) adds an additional constraint with respect the model (I)). This implies that if the additional constraint is binding it should reduce the value of solution (i.e. $\theta_2 \le \theta_1$). Adding the convexity constraint to (II), one can estimate VRS TE (Madau, *et al.*, 2009).

The technically efficient output vector is calculated by multiplying θ_2 by observed production. The technically efficient (TE) is estimated as:

$$TE = \frac{u}{\theta_2 u} = \frac{1}{\theta_2}$$

The technically efficient or "unbiased" ray measure of CU then given by as:

$$unbiased \qquad CU = \frac{CU}{TE} = \frac{1/\theta_1}{1/\theta_2} = \frac{\theta_2}{\theta_1}$$

Solving the problem (I) will provide a measure of technically efficient, θ_1, which corresponds to full capacity production and problem (II) will provide a measure technically efficient, θ_2, which corresponds to technically efficient production given the usage of variable inputs (Kirkley, *et al.*, 1999).

Variable input utilization

The variable input utilization outcome, λ_{jn}, measures the ratio of optimal variable input use to observed use. The optimal variable input use is the variable input level that gives full technical efficiency at the full capacity output level (Vestergaard, *et al.*, 2003 & Fare, *et al.*, 1994). If λ_{jn} exceeds 1.0 in value, there is a shortage of the *i*th variable input currently employed and the vessel should expand use of that input. If λ_{jn} is less than to 1.0 in value, then there is a surplus of the *i*th variable input currently used and the vessel should reduce use of that input. If λ_{jn} equal to 1.0, the actual usage of *i*th variable input is optimal usage (Pascoe S. *et al.*, 2001).

Scale efficiency

A scale efficiency (SE) measure indicate that a vessel might be improved efficiency by changing its scale of operations (i.e., Vessel keeps the same input mix but change the size of operation to improve efficiency). It is possible that a vessel is both technical and allocatively efficiency but the scale of operation of vessel may not be optimal.

SE is estimated as the ratio between the CRS and VRS technical efficiency (Cooper, *et al.*, 2000).

$$SE = \frac{TE_{CRS}}{TE_{VRS}} = \frac{1}{\theta_2^{CRS}} \Big/ \frac{1}{\theta_2^{VRS}} = \frac{\theta_2^{VRS}}{\theta_2^{CRS}} \quad , \qquad SE<=1$$

A scale efficiency measure can be used to indicate the amount by which productivity can be increased by moving to the point of technically optimal productive scale (Coelli, et al., 2005). SE measures the role of scale in conditioning inefficiency. A SE measure close to unity indicates that scale only slightly affects inefficiency (Madau, *et al.*, 2009).

The output-oriented measure can be used in several ways. Capacity is determined for each vessel. In the multi-species case, it can be done for each species. We emphasise, however, that summing over each vessel presents a lower bound for the industry or fleet level of capacity. It means the industry or fleet level of capacity is greater than or equal to the sum of the vessel levels of capacity (Vestergaard, *et al.*, 2003).

5. DATA

This analysis focused on the small-scale fisheries in the coastal waters of Nha Trang city. Trawlers are chosen to investigate since the number of trawlers in Nha Trang is relatively high compared to other fisheries. Data are collected in two communes, Vinh Truong and Vinh Luong. Trawlers in Vinh Truong operates mainly outside the buffer zone, in the vicinity of nine islands in the NTB-MPA while trawlers in Vinh Luong operate in Nha Phu Lagoon- a short way north of Nha Trang city. Data are collected from a survey of 65 small-scale trawlers in two years, 2005 and 2006. In that, 36 vessels were home ported in Vinh Truong, and 29 vessels were in Vinh Luong.

The survey was undertaken with independent random sample to obtain balanced panel of 65 small-scale trawlers in two years, 2005 and 2006. Since the data were collected through a personal household interview, a questionnaire was designed. In addition to the information on technical characteristics of each vessel, costs and earnings, and skipper characteristics were also collected (Ngoc, *et al.*, 2009).

The catches were measured in term of thousand VNDs of landed fish and this value is the logical measurement for output when a multi-output approach is applied to fisheries (Alvarez A., 2001). If the basic assumption is that fishermen take decisions on catch composition, as a consequence production in capacity and efficiency analysis should be measured in terms of value (Madau, et al., 2009). Thus estimated capacity in this research is an economic capacity measurement and both (I) and (II) linear programming problems reflect revenue maximization problem. Furthermore capacity utilization is interpreted as ratio between observed revenue of vessel j and maximum potential revenue (Lindebo, *et al.*, 2007).

The input data used in analysis are divided into two kinds, fixed and variable factors. In fisheries analysis, the normal fixed factors include investment capital and fish stock biomass (FAO, 1998). In the case of fisheries in a developing country like Vietnam, however, the information about biomass of the fish stock is unavailable or unreliable. In our case, there are two fleets fishing in two different grounds so the comparison of capacity or CU between them may provide some information on the state of fish stock. It may be interesting since an MPA was created and this may affect the trawlers in Vinh Truong, one of two areas that we investigate. However due to lack of data on biomass, we assume that all vessels operating in same area have same fish stock biomass and face the environment condition.

The fixed inputs usually used are the length of the vessel, the engine power and the gross tonnage. According to Madau et al. (2009), fishing capacity is often measured in terms of two characteristics, namely gross tonnage (GT) of the vessels and total engine power (kW). The number of kilowatts and GT measure are relatively straightforward to measure. In some cases, capacity is measured in terms of vessel number only (e.g., Malaysia), or a combination of different vessel characteristics. For example in Poland and UK, a combination between length of vessel and engine power have been used. In this study, however, the data of gross tonnage is not available so the length (m) and the engine power (HP) of the vessel are used as fixed factors

The variable input often used in the fisheries literature is the effort which is usually expressed in term of days at sea and crew size (Kirkley, *et al*., 2002). In addition, the experience of the skipper, the number of years the skipper had been involved in fishing activities, is also concerned since it also affects fishing capacity of vessels. High fishing experience helps the skippers have the ability to predict the direction of movement of fish, find fishing ground with high fish densities, and judge the speed of current and trend of wind (Luong, *et al.*, 2009). Besides, use of variable inputs such as fuel, ice, labour affects fishing capacity. The level of variable inputs employed and their combination with fixed inputs may be change in fishing time. And while some factors come under certain restriction, fishermen can adjust various inputs and their combination, increasing unlimited inputs that will result in an increase in fishing capacity (Zhou, *et al*., FAO 2003). For our analysis, days at sea, crew size per vessel, and fuel cost of vessel are used as variable inputs for the analysis. The summary statistic of data used is showed in the following table:

Table 4: Summary statistic of the data used in analysis

Factors	All years		2005		2006	
	Mean	St. dev	Mean	St. dev	Mean	St. dev
Revenues (1000 VND)	205,834	82,966	198,547	91,746	213,120	73,139
Engine power (HP)	35.29	12.48	35.29	12.53	35.29	12.53
Length of vessel (m)	11.64	1.84	11.64	1.84	11.64	1.84
Day at sea (days)	210.85	41.05	200.18	41.61	221.52	37.86
Crew size (persons)	3.08	0.74	3.17	0.80	2.98	0.67
Experience fishing of skipper (years)	10.38	5.75	9.89	5.74	10.88	5.76
Fuel cost (1000 VND)	102,261	44,621	84,510	39,623	120,013	42,463

Source: Calculated by author. The exchange rate VND/USD (5/2006) was 16.200d/USD
Note: Revenue in 2005 was inflated to the 2006 value by the consumer price index (CPI).

The mean of revenue is calculated for the both two years is 205.834 million VND. In 2005 and 2006 this number was 198.547 and 213.120 million VND, respectively. If compared to the average revenue of a longliner, which was 568.250 million VND (Long, *et al.*, 2006), or a gillnetter, which was 851.333 million VND (Kim Anh, *et al.*, 2006), or a purse seiner that has a similarly engine power (20-<45 HP), which was 355.590 million VND (Luong, *et al.*, 2009). It is clear that revenue of trawlers was relatively small. The cause for this is that trawlers were smaller and mostly fishing near shore water compared to other fishing gears. In addition, a number of vessels previously operated in longline and gillnet fisheries and switched into trawling due to lack of technological requirements for offshore fishing also makes trawl fleet less efficient in catching (Ngoc, *et al.*, 2009).

The majority of trawl vessels in two communes were small-scale vessels. The average length was 11.64 m. The engine power, measured in horsepower (HP) with the means being 35.3 HP. Thus, the vessels can operate only in waters close to shore. Crew size was very small, with a mean of 3.08 persons. The annual average number of day-at-sea was 210.85 (including both traveling and fishing time). The average fishing experience of skipper was about 10.4 years. The mean of fuel expenditure were 102.261 million VNDs per vessel.

6. RESULTS

In the following section, the empirical results are presented. Through using DEA analysis on 65 trawl vessels in Nha Trang in two years 2005 and 2006, fishing capacity and capacity utilization of each vessel are assessed. Capacity and CU are assessed by solving two linear programming problems: (1) CU of each vessel is estimated in condition that the effect of inefficiency is existed; and (2) CU is measured in condition that the effect of inefficiency is removed. Capacity and CU are then aggregated for all vessels that operate in two fishing areas in Nha Trang: Vinh Truong and Vinh Luong.

6.1. Capacity and Capacity Utilization

Table 5 shows estimated capacity, efficiency and scale efficiency (SE) of vessel. Capacity score (θ1) and technical efficiency score (θ2) were the estimated scores obtained from DEA problems.

Table 5: Capacity and efficiency and SE measures of vessel

	Capacity (θ1)		Efficiency (θ2) VRS		Scale efficiency (SE)	
	2005	2006	2005	2006	2005	2006
Mean	1.903	1.649	1.217	1.144	0.782	0.929
St.dev	0.923	0.543	0.268	0.179	0.215	0.092

Source: Calculated by author

As mentioned in theory section, capacity is estimated under VRS hypothesis ($\sum_{j=1}^{J} z_j = 1$).

Table 5 shows that the estimated capacity (measured under VRS hypothesis) is 1.903 in 2005 and 1.649 in 2006. It suggests that vessels could increase revenue by about 90% in 2005 and 65% in 2006 if they were operating at full capacity. The average CU-observed is 0.636 (2005) and 0.665 (2006) (table 6). This indicates that vessels were operating at less than full capacity given the set of fixed inputs (length and engine power).

Technical efficiency score is 1.217 (2005) and 1.144 (2006) under VRS hypothesis, which indicates that fishermen could increase revenue by 21.7% (2005) and 14.4% (2006) at the present state of technology by using their disposable fixed and variable inputs more efficiently.

Table 6: Average CU, number of vessels with CU equal or different to 1.

	Year			
	2005		**2006**	
Vessel	**CU-*observed***	**CU-(*efficient/unbiased*)**	**CU-*observed***	**CU-(efficient/ unbiased)**
Average	0.636	0.741	0.665	0.751
St.dev	0.25	0.24	0.19	0.20
CU =1	8	8	5	10
CU<1	57	57	60	55

Source: Calculated by author

In 2005 and 2006, the average CU-efficient was 0.741 and 0.751 with a standard deviation of 0.24 and 0.20, respectively (table 6). This means that there were 25.9 % (2005) and 24.9 % (2006) of capacity would not be used when fishermen operate at full capacity.

The distribution of capacity utilization scores for trawl vessels in Khanh Hoa are showed in figure 9. Of 65 vessels, 57 (57) vessels and 60 (55) vessels had a CU based on technical efficient production (based on observed production) less than 1 in 2005 and 2006, respectively (table 6). The number of vessels had a CU based on efficient production (CU-efficient) higher than 0.9 were 14 (2005) and 8 (2006). There were great number of vessels that had a CU les than 0.8, 43 and 47 vessels out of 65 in 2005 and 2006. Using the CU measure based on observed output (CU-observed), these numbers were 5 and 3 vessels had a CU higher than 0.9, 52 and 57 vessels had a CU less than 0.8 in 2005 and 2006, respectively (figure 9).

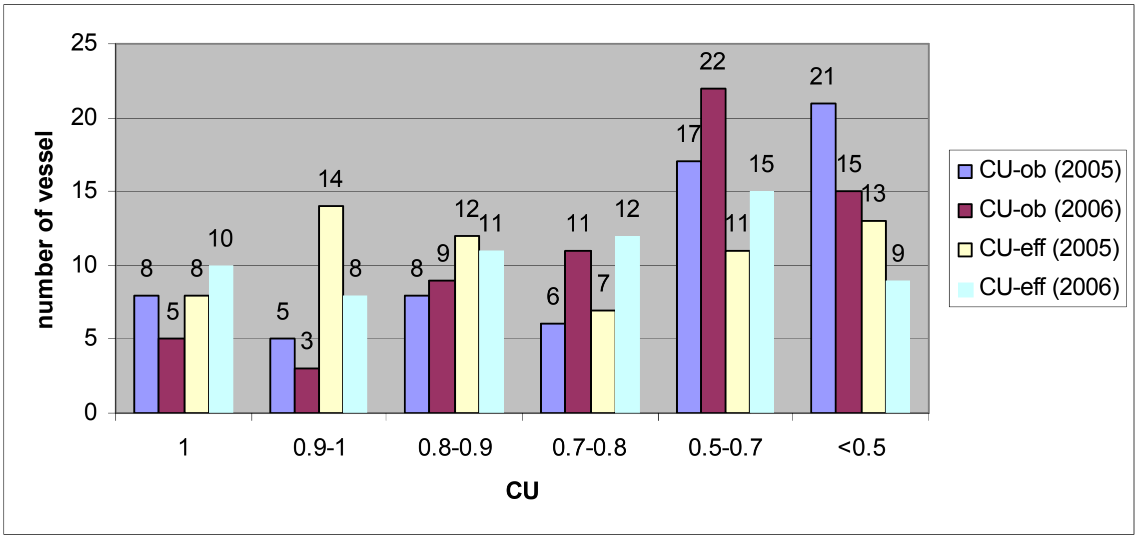

Figure 9– Distribution of capacity utilization scores in 2005 and 2006.

Source: Calculated by author

The next step of analysis is aimed at investigating the difference in CU between two communes. The distribution of capacity utilization in Vinh Truong and Vinh Luong in 2005 and in 2006 is showed in figure 10 and figure 11 below.

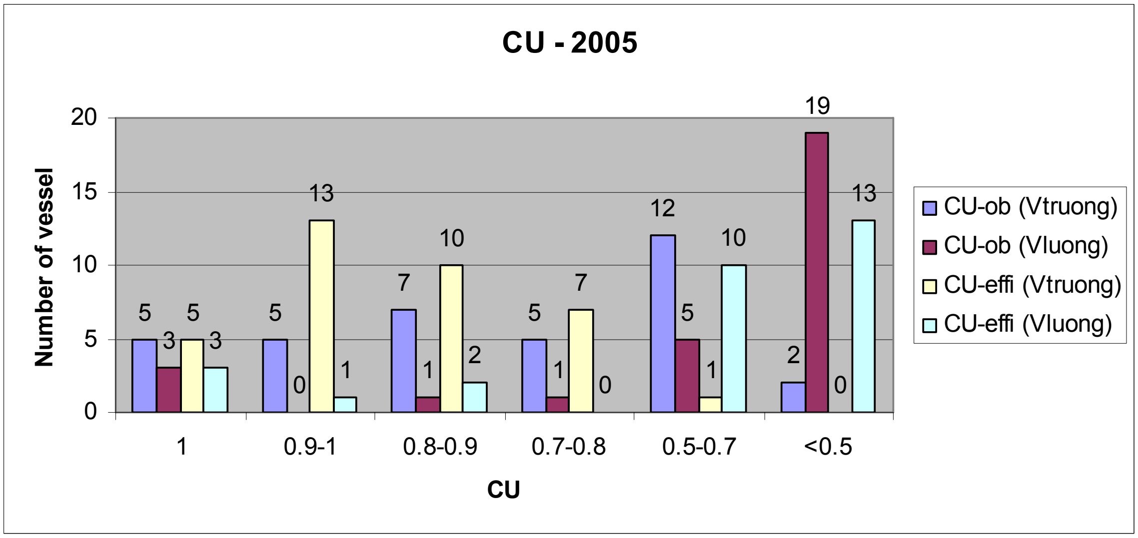

Figure 10 – Distribution of capacity utilization scores in Vinh Truong and Vinh Luong in 2005.

Source: Calculated by author

In 2005, 31 vessels out of 36 in Vinh Truong and 26 of 29 vessels in Vinh Luong had CU-efficient and CU-observed less than 1. In Vinh Truong, based on technically efficient production most of vessels were distributed at a high CU score namely13 of 36 vessels had a CU from 0.9 to 1; 10 vessels had a CU belonging to 0.8-0.9; 7 vessels had a CU higher than 0.7 and less than 0.8 and no vessel had a CU less than 0.5. By contrast, most of vessels in Vinh Luong were distributed at a low CU score. Approximately a haft of vessels (13 vessels out of 29) had a CU less than 0.5, and more than third of vessels (10) had the CU distribution in the range 0.5-0.7. Similarly, the CU-observed of the vessels in Vinh Truong had a steady distribution from 0.5 to 1 in value. The number of vessels had 0.5 < CU< 0.7 was highest (12 of 36 vessels). Whereas, there were more than 65% of vessels in Vinh Luong had CU-observed less than 0.5.

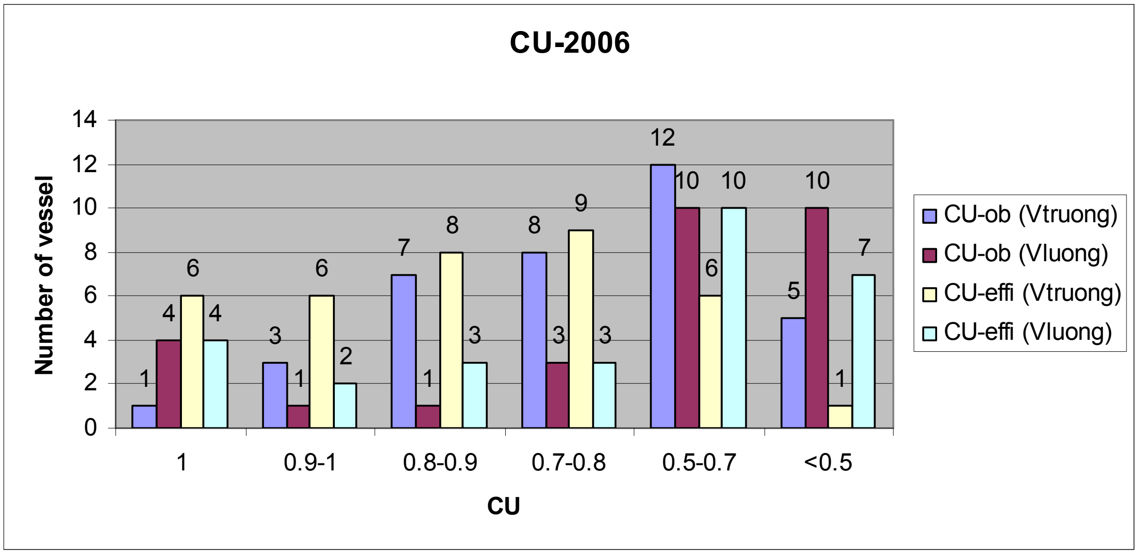

Figure 11– Distribution of capacity utilization scores in Vinh Truong and Vinh Luong in 2006.
Source: Calculated by author

In 2006, 30 and 35 vessels out of 36 in Vinh Truong had CU-efficient and CU-observed less than 1. These numbers were 25 of 29 vessels in Vinh Luong for both case of CU (CU-efficient and CU-observed). Similarly to 2005, most of vessels in Vinh Truong had CU distribution at higher CU scores than it of vessels in Vinh Luong. The number of vessels had CU-efficient less than 0.5 and less than 0.7 in Vinh Truong was only one and 6 vessels, while these numbers in Vinh Luong were 7 and 10 vessels, respectively. Using the CU measure based on observed production the vessels had 0.5 <CU < 0.7 which were the highest in both cases of Vinh Truong and Vinh Luong. However, the vessels had CU less than 0.5 in Vinh Truong were smaller than in Vinh Luong, namely there were 5 out of 36 vessels in Vinh Truong and 10 out of 29 vessels in Vinh Luong.

The variation in CU (average CU) for both capacity and technical efficiency between two years are showed in table 7. Comparing 2005 to 2006, there was a slight reducing CU based on capacity and technical efficiency of the vessels in Vinh Truong, while this was increasing for the vessels in Vinh Luong. In general, both CU-observed and CU-efficient for total vessels were increasing from 2005 to 2006.

In summary, compare CU between the two areas the vessels in Vinh Truong had a CU (-efficient and –observed) higher than that of vessels in Vinh Luong in both years (table 7) and the vessels in Vinh Truong showed less excess capacity (based on capacity and based on TE) than the vessels in Vinh Luong in 2005 but higher in 2006 in the case of calculation based on TE (i.e. in 2006 excess capacity based on TE of vessel in Vinh Truong was higher than those in Vinh Luong).

6.2. Capacity utilization and performance of trawl fleet

In this section we will investigate the performance of vessels by looking at the ranking of CU. As mentioned above, CU is simply actual output divided by capacity output (adjusted for TE). Therefore based on CU, we can see the extent to which each vessel can get potential output (revenue) given the inputs used.

From the DEA model, CU-efficient is calculated for each vessel. CU-efficient is calculated by CU-observed divide by TE. In figures 11 and 12, the vessels are ranked from the lowest to the highest according to CU-efficient value in 2005 and 2006. In this case the CU value is ranged from 0.26 and 0.28 to 1 in 2005 and 2006, respectively.

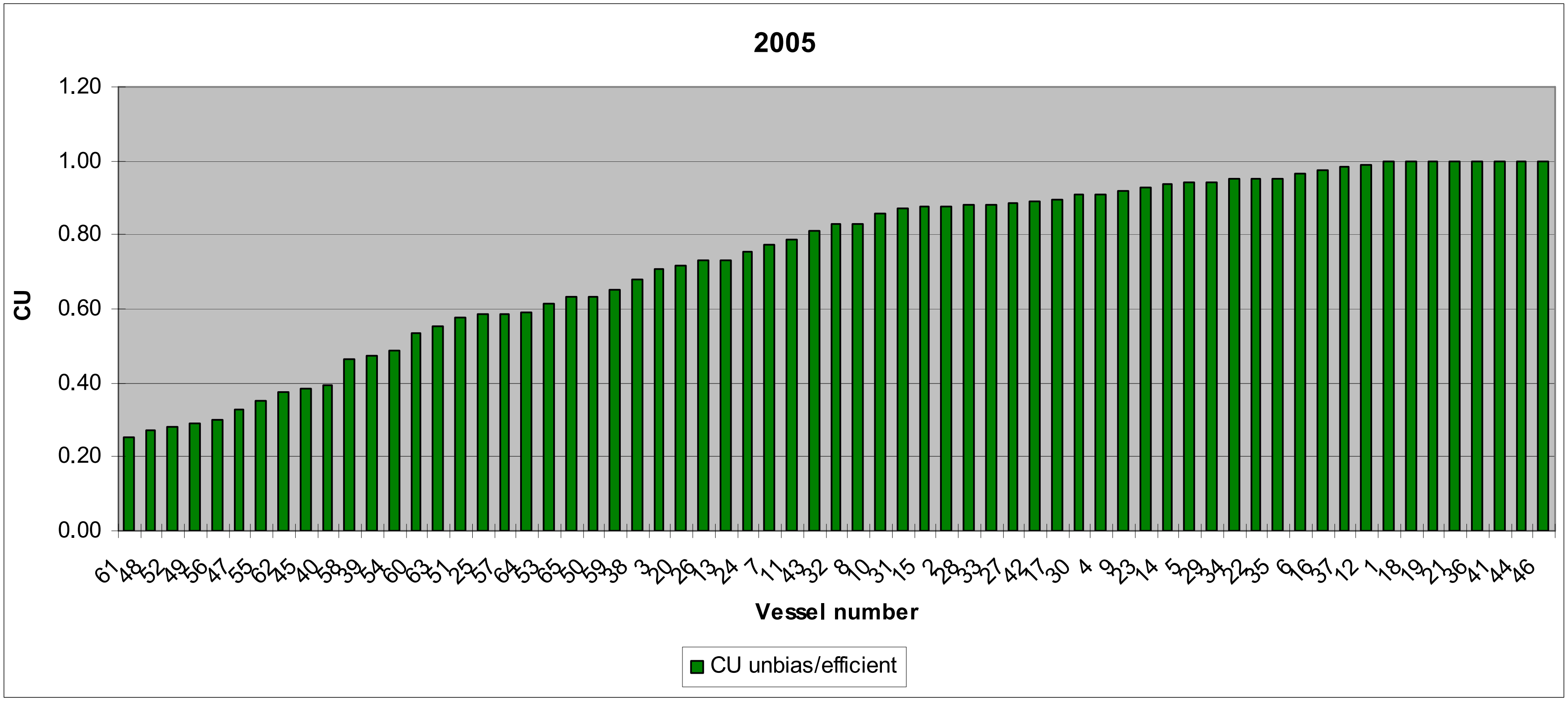

Figure 12– The increasing CU of 65 trawl vessels in 2006. The high of the bar measures CU value. Note: sorted from the lowest to the highest CU value.

Source: own data and calculations.

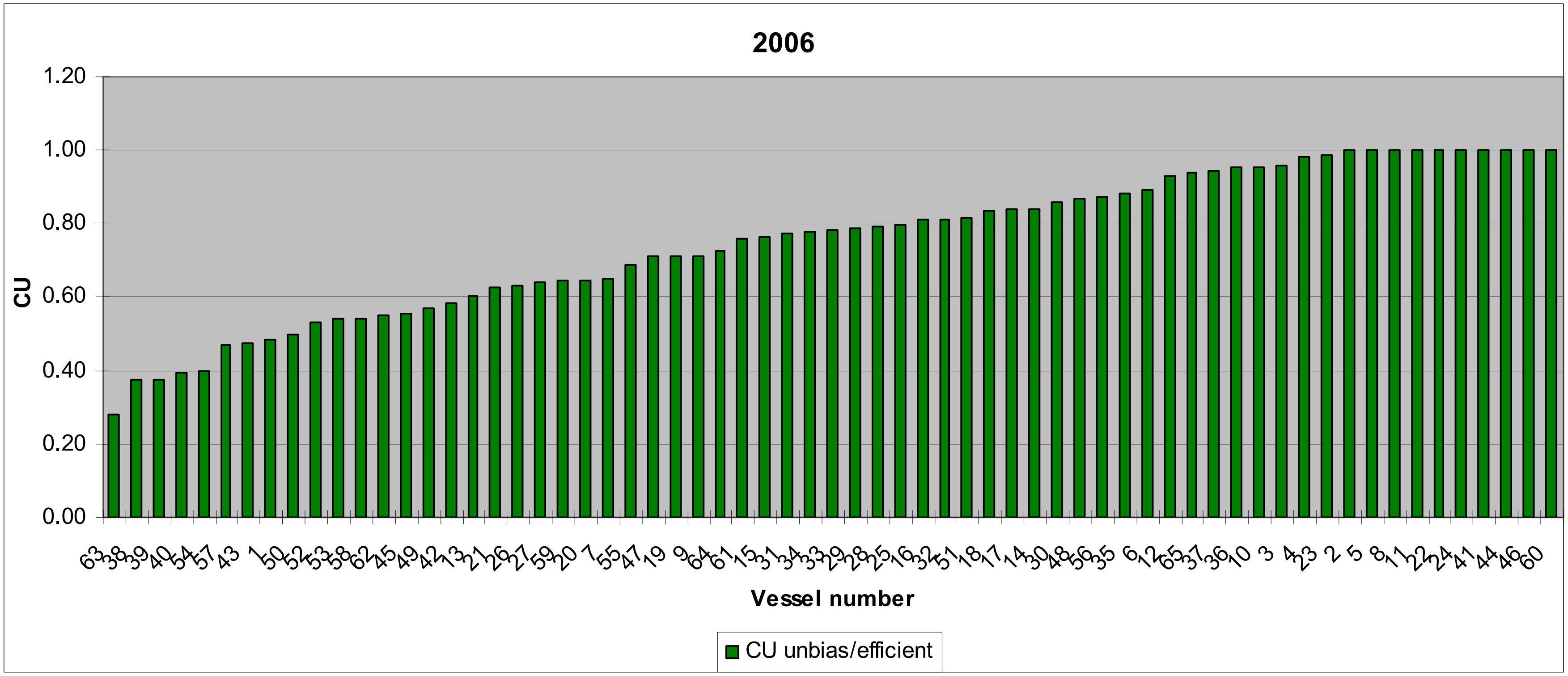

Figure 13– The increasing CU of 65 trawl vessels in 2006. The high of the bar measures CU value. Note: sorted from the lowest to the highest CU value.

Source: own data and calculations.

We can see that in 2005, 8 vessels had CU equal to 1 while this number is 10 vessels in 2006. This means that there was a higher number of vessels can get potential revenue in 2006 than in 2005. However if compare CU between two years, we can see that in 2005 there were a greater number of vessels that may get potential revenue level in the future (the vessels had CU was higher than 0.8) than in 2006 if they increase the utilization of variable input or improve technical efficiency.

In general, there were a great number of trawl vessels in Nha Trang operating under utilization of capacity and inefficient and these vessels are impossible to gain their potential revenue. While the vessels on the right-hand side of figure with a higher CU value could get or nearly get the maximum revenue level, those on the left-hand side with a lower CU will difficult to get maximum revenue if they don't change the strategies to use input factors in an efficient way

6.3. Scale efficiency

Average of SE of each vessel in 2005 and 2006 are showed in table 5.
SE measure can be obtained for each vessel by conducting both a CRS and a VRS DEA, and then decomposing the TE scores obtain from the CRS DEA into two components, (1) due to scale inefficiency and (2) due to "pure" technical inefficiency (i.e. VRS TE). The difference in the CRS and VRS TE score for a vessel, then this indicate that the vessel has scale inefficiency (Coelli, et al., 2005).

The average SE of 0.782 and 0.929 in table 9 suggests that reaching an optimal scale each vessel would reduce technical inefficiency by about 21.8% and 7% in 2005 and 2006 respectively. From VRS DEA model, we calculated that more than 80% (in 2005) and 70% (in 2006) of the vessels in the survey operate in the increasing return to scale (IRS) area, while the scale would be optimal (SE > 0.9) for 22% (2005) and nearly 50% (2006) of the vessels.

6.4. Excess capacity

This section is aimed at investigating the excess capacity for all vessels and for vessels operating in two communities in 2005 and 2006. Excess capacity is calculated for each vessel based on capacity output and technical efficient outputs.

Capacity output and technical efficient outputs were calculated using the estimated scores obtained from DEA problems. The capacity and technical efficient output levels could be calculated for each vessel and aggregated to obtain an estimate of excess capacity for all vessels. Excess capacity is calculated as fishing capacity output minus observed output and excess capacity based on TE is calculated by technical efficiency revenue level minus actual revenue. Thus, specific values of excess capacity and excess capacity based on TE for all vessels and for vessels in two areas in 2005 and 2006 are mentioned in the table 7 and are compared in figure 14.

Table 7: Revenue, capacity, CU and excess capacity and excess capacity based on TE in 2005 and 2006

	2005			2006		
	Total	**Vinh Truong**	**Vinh Luong**	**Total**	**Vinh Truong**	**Vinh Luong**
Revenue (1000 VND)	198,547	244,907	140,998	213,120	241,539	177,842
Technical efficient output (1000 VND)	237,947	288,919	174,673	241,948	282,249	191,919
Capacity output (1000 VND)	318,586	331,202	302,926	323,090	341,994	299,624
Excess capacity (1000 VND)	120,039	86,295	161,928	109,970	100,455	121,782
Excess capacity (%)	60.46	35.24	114.84	51.60	41.59	68.48
Excess capacity based on TE (1000 VND)	39,400	44,012	33,675	28,827	40,710	14,077
Excess capacity based on TE (%)	19.84	17.97	23.88	13.53	16.85	7.92
CU-observed	0.636	0.767	0.473	0.665	0.705	0.616
CU-efficient	0.741	0.882	0.566	0.751	0.825	0.659

Source: Calculated by author

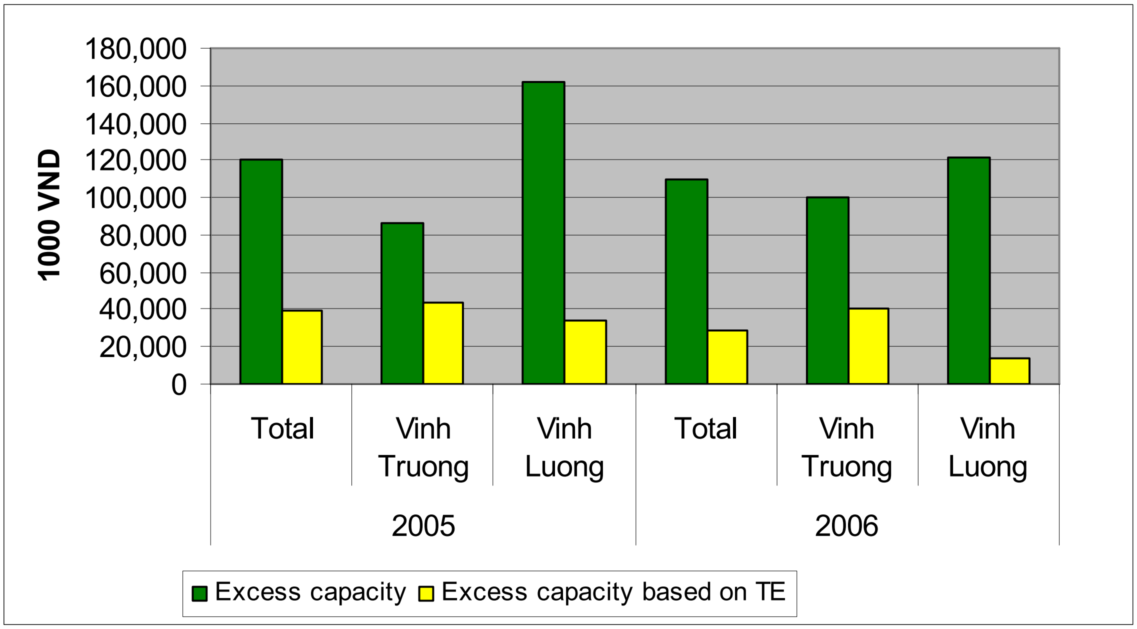

Figure 14– Excess capacity and excess capacity based on TE of all vessels and for each area (Vinh Truong and Vinh Luong) in 2005 and 2006.

Excess capacity of all vessels for each area and for both areas is estimated under the assumption that variable inputs are fully utilized. In this case, the average excess capacity for each vessel is 120,039 and 109,970 thousand VNDs in 2005 and 2006, respectively. This means that each of vessels could get full capacity if they had 120,039 and 109,970 thousand VNDs higher on average, which corresponds to an excess capacity 60.46% and 51.60% in 2005 and 2006, respectively. Comparing between two areas, we can see that in 2005 the average excess capacity level of vessels in Vinh Luong was nearly 2 times of that in Vinh Truong. Average excess capacity of vessel in Vinh Luong were 161,928 thousand VNDs while this value of vessel in Vinh Truong was 86,295 thousand VNDs that is equivalent more than 100% in Vinh Truong and more than 35% in Vinh Luong. However, these numbers were reduced in 2006 with vessels in Vinh Luong and slightly increased for vessels in Vinh Truong. In 2006, excess capacity were more than 100 million VND equivalents 41.59% in Vinh Truong and more than 121 million VND equivalents 68.48% in Vinh Luong.

Excess capacity based on TE for vessels were estimated under the usage of the variable inputs. In this case average excess capacity for each trawler which was calculated for total vessels and for vessels in each community was smaller than it in the first case (i.e. excess capacity based on TE was lower than excess capacity). Namely, excess capacity for each trawler was more than 39 million VNDs and nearly 29 million VNDs on average, equivalent 19.84% and 13.53%.in 2005 and 2006, respectively. The results also showed that the vessel in Vinh Truong had proportion excess capacity in percentage lower than it in Vinh Luong in 2005 but higher in 2006. However, if comparing between 2 years, it is obviously the vessels had a lower excess capacity in 2006 compare to 2005.

6.5. Variable input utilization

The distribution of the variable input utilization rate for all vessels in 2005 & 2006 are showed in the figure 15.

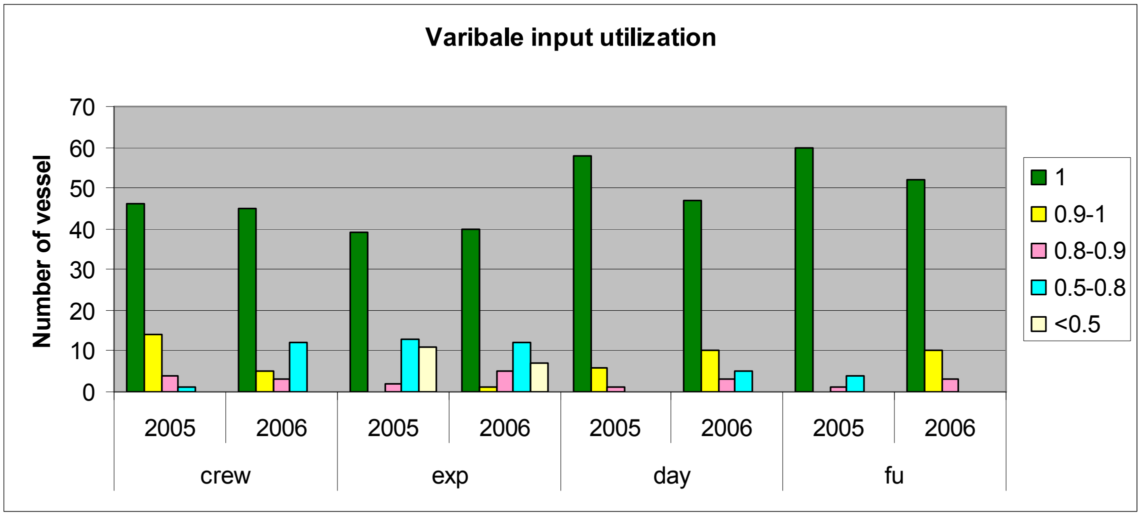

Figure 15– Distribution of variable input utilization scores (VIU) in 2005 and 2006.

From Figure 15, we can see that no variable input used had a VIU rate exceeding 1. This means that there wasn't a shortage of these variable inputs currently employed. About 60% of vessels had a VIU rate equal to 1 in all variable inputs used indicating that most of vessels had optimal usage all variable inputs and the surplus in using the variable inputs was very little. Only fishing experience of skipper variable had a surplus employed more than 50% in several vessels. However, the surplus of skipper's fishing experience does not influence the efficiency of fishing. In fact, a high skipper's experience fishing will give high efficiency in catching.

Comparing between the VIU rates of variable input factors above, it is obvious that the utilization of fuel expenditure was the most efficient factor in both year 2005 and 2006. More than 90% (in 2005) and 78% (in 2006) of vessels had a VIU equal to 1 and no vessels had a VIU rate less than 0.5, even no vessels had a VIU less than 0.8 in value in 2006. The number of days at sea was the second best efficient factor. 90% (in 2005) and nearly 75% (in 2006) of vessels had the optimal VIU and all of vessels had a surplus of this VIU rate less than 20% in 2005.

The average VIU rates for the variable inputs used in this analysis as well as the amount of each input that need to reduce to improve efficiency of vessels are showed in table 8. The number of each input need to reduce is calculated by the difference between actual variable input usage and optimal variable input usage.

Table 8: Average variable input utilization rate (λ) and value in 2005 and 2006

Factors	Year	
	2005	**2006**
Crew		
Mean	0.977	0.932
st. dev	(0.048)	(0.122)
Value (persons)	0.093	0.246
Exp		
Mean	0.814	0.864
St .dev	(0.250)	(0.209)
Value (years)	2.611	2.339
Day		
Mean	0.993	0.967
st. dev	(0.026)	(0.082)
Value (days)	1.537	8.667
Fuel		
Mean	0.976	0.985
st. dev	(0.091)	(0.035)
Value (1000 VND)	2,578	2,410

Source: Calculated by author

The average VIU rate of the day-at-sea input factor was highest in 2005. It was 0.993 this means the actual day fishing at sea used was very close to the optimal. There was a 0.7% equivalent 1.5 surplus days, however, this rate reduced to 0.967 in 2006 that led to an increasing surplus of the day at sea to 3.3% or more than 8 days. Thus compare between 2005 and 2006, the day-at-sea utilization in 2005 was more efficient.

Crew utilization were 0.977 (in 2005) and 0.932 (in 2006), which means there were 2.3% and 6.8% surplus of crew used that the vessels should reduce to improve efficiency. The surplus of crew size employed in 2006 was also higher than that in 2005.

As mentioned above, the skipper's fishing experience surplus does not reflect inefficiency in fishing. Thus, the average VIU rate of skipper's experience fishing were 0.814 and 0.864 in 2005 and 2006, respectively showed that the skippers had sufficient/full experience for fishing.

Fuel utilization was highest for vessels in 2006. This rate was 0.985 suggesting that these vessels should reduce expenditure for fuel about 1.5% or 2.4 million VND per year. This number was 2.4% equivalent more than 2.5 million VND in 2005.

In summary, the variable inputs utilization in both years was relatively efficient. Except the skipper's experience factor, most VIU rates of input factors (the crew size, the days at sea, and the fuel cost) were close to 1 and the surplus in usage these factors were less than 7%.

7. DISCUSSION

7.1. The results from DEA model

The results provided above can help us to investigate the fishing capacity of trawlers in Nha Trang. From the capacity and CU information, it is showed that the fleet as a whole was not fully utilized. There was a great room of unused capacity for the small-scale trawlers in Nha Trang and many vessels were under-utilized to a high degree. The unused capacity is calculated by 1 minus CU. This number was 0.364 and 0.335 equivalent 36.4% and 33.5% in 2005 and 2006, respectively for CU observed and was 0.259 equivalent 25.9% and 0.249 equivalent 24.9% for CU-efficient. The existence of capacity under-utilization for trawlers in Nha Trang also implies that a smaller fleet if fully utilized could take the same level of harvest. As a result, a capacity under utilization may represent the existence of overcapacity in trawl fishery, at least in the short term.

While trawlers on average operate at the below full capacity utilization, the distribution of CU in trawl fishery in figure 9 can provide useful information for management. It can be seen that, many vessels operated at or nearly full capacity however a significant number of vessels operated at low levels of capacity. For vessels operating at or nearly full capacity, it would be impossible to increase their output above current levels. However, for other vessels with low level of capacity the latent capacity may exist if economic condition changed, for example by an increase in the price or by new entrants due to the open-access management regime. As a consequence, the stock may be continuously fished down leading to the depletion of fish stocks.

For fishery managers, the capacity utilization score also provides information on the effects of management regulations. The difference in CU between two communes, Vinh Truong and Vinh Luong may reflect the differences in the stock biomass and the management conditions. As can be see in table 7 that the average of the CU measures of vessels in Vinh Truong, both based on observed and technical efficient production were always higher than those of the vessels in Vinh Luong. This suggests that trawlers in Vinh Truong were more technical efficient than those in Vinh Luong. This result is in accordance with these obtained in the study of Ngoc *et al.,* (2009) where technical efficiency is analyzed by the SPF method.

The fishing ground of vessels in Vinh Truong was affected by the creation of the Nha Trang Bay MPA from 2002. The ban on trawl fishing in a large area also issued follows the implementation of this MPA. Higher CU of vessels in Vinh Truong may imply that the stock around the MPA is more abundance than that in other areas or Nha Trang Bay MPA may have provided some benefits for adjacent fisheries by the spillover effect. Lack of data on catch and revenue of trawlers before the implementation of the NTB-MPA prevents us from testing this hypothesis. However, reports of Hon Mun Marine Protected Area pilot project such as Biodiversity Report No.7 by IUCN Hon Mun MPA Pilot Project (2002) and Biodiversity Report No.15 by Tuan et al. (2005) indicate that abundance of some species inside Nha Trang Bay MPA is higher after 3 year of creation. This implies that creation of MPA in the long term can be an appropriate measure to conserve the fish stock and manage the fisheries.

Another result from this study that should be discussed here is that there is the excess capacity in the trawl fleet. As we know, excess capacity is measured by the difference between observed revenue and the potential revenue level. In the study of Pascoe et al. (2003) excess capacity has been considered as the primary reason for the depletion of fish stocks and this in turn further reduces the profitability and economic performance of the fleets. In order to effectively manage the coastal fish stock in Nha Trang and to improve the economic performance of trawlers, it is clear that fishery managers should plan and impose appropriate regulations to reduce capacity levels or reduce the number of trawlers operating in this area.

This study has used output-oriented DEA model to measure capacity of 65 trawl vessels operating in Nha Trang in 2005 and 2006. Data are used in this analysis including six inputs (fixed and variable inputs) and one output. For the input factors, compared to alternative capacity measure studies, this study is lack of information of vessel tonnage (measured as GRT). GRT is often thought as the best factor to reflect amount of investment capital of vessels because this factor is correlated with both length and width of vessels. For the output, in contrast to other studies which often apply the catch as the output, we have used in this study the revenue. The reason behind this is that the trawl fishery is characterized by harvesting a complex ray of species, about 20 to 30 species can be found in the catch. Collecting the amount of each species in this case is an impossible task. However it should be noted that using revenue as the output can still be a reasonable approach. Lindebo (2004) showed that using revenue to measure capacity gives a more realistic portrayal of who is best placed to operate efficiently in the fishery under current conditions. In reality, we know that fishermen are not purely interested in catching fish, but also wish to maximise their profits. To maximise their profits, they seek to maximise the revenue of their catches whilst trying to minimise their costs (Lindebo, 2004).

As for the analytical method, the DEA technique has some limitations. The results from this analysis can be used as a reference index for the purpose of the fisheries management and fishermen. When using DEA to measure capacity based on the number of fishing vessels and their natural characteristics (i.e. based on information of each sample) only, the results will reflect the dispersion of efficiencies within this sample but it says nothing about the efficiency of one sample relative to the other. Thus, we should be careful when comparing the mean efficiency scores from two studies (Coelli *et al.*, 2005).

7.2. Policy implications

Fishery industry in Vietnam is importance in sustaining livelihood and supplying food for a lot of fishery communities in coastal areas. However, the exploitation of fish stock has led to a serious degradation of the resources (Zwieten *et al.*, 2002). Vietnamese Ministry of Fisheries (2004) also acknowledged that "If other marine species are included, the stable annual allowable exploiting capacity is 700,000 tons a year, lower than the output harvested annually in this region in the past years." (This number, 700,000 tons a year, is half the catch reported to FAO, and one-sixth of the estimated true catch). Even facing these challenges, it is surprising that Vietnamese Government has recently increased the subsidy in fishing capacity by supporting fuel prices and preferential bank loans. This may contribute to an unintended increase in investments in the fleet and increase capacity in Vietnam.

The studies of fishing capacity in Vietnam are so few now. Pitcher (1999, p3) stated that "*we could not find any published estimates of fishing capacity of the Vietnamese fleet, and no mention of measures aimed at reducing capacity. On the contrary, implicit in the figures quoted over recent years is a 100% increase in the numbers of fishing vessels and their engines since the 1980s*". This study is one of the first studies trying to measure fishing capacity of fishing fleets in Vietnam. The results from this study shows that trawlers in Nha Trang are operating under full capacity level and there is excess capacity in this fleet. Capacity reduction thus becomes a necessary concern at the present. The findings of this study may provide fishery managers with some policy implications.

Firstly, the Government should change traditional management methods, and have a comprehensive study on fishing capacity of fisheries in Vietnam as well as finding the way to reduce excess capacity. Besides managers need to have policies to support and create non-fishery livelihood opportunities by development other sectors such as aquaculture, agriculture and tourism as well as improve education of fishermen and local communities. If these policies are implemented well, they will help reduce the cost for labour, capital, and numbers of fishing vessels join fishing. These results help to reduce overcapacity state in fishery, and protect marine resources.

Secondly, to reduce fishing pressure and overexploitation on coastal waters it is necessary to reduce the number of small fishing vessels, manage number of fishing vessels through a vessel register from the nation to province level, promotion together with monitoring, control and surveillance (MCS) offshore fisheries for sustainable management purposes (For example: record and inspect offshore catches according to a frame survey design), and regulate coastal fishing activities in correspondence with current stock status in order to maintain and develop the fisheries in sustainable way.

Thirdly, improving economic efficiency in fishing has a significant important position because low economic efficiency may lead fishing fleets to intensify fishing effort, causing harder competition in fisheries. This leads to “capital stuffing” state in fishery. An overinvestment capital creates a surplus in inputs utilization and cause for low economic efficiency in fishery. Controlling the inputs used is necessary in controlling capacity. However, if limit on the inputs used is implemented alones, it may create opposite result. For example, if number of fishing days is restricted, the fishermen will have incentive to try to fish as much as they can during the days they are allowed to fish or limit on the number of boats does not remove the incentive to invest in making their boat more efficient in order to fish as much as possible. Thus, the broad of regulations or incentive mechanisms must be used in order to prevent fishermen from substituting between the different inputs that together determine capacity (e.g. limit number fishing day combine and vessel size. Besides, managers need to delete subsidisation on fuel and control the increase in number of fishing boats so as to match of fishing capacity and resources capacity

Lastly, the findings of study suggest that fishers can reduce overcapacity and increase revenue by using their resources more efficiently. Efficiency can be affected by scale, but the empirical results in this analysis showed that is not significant in conditioning efficiency (because the surplus rates of variable inputs utilization are very small). We know that in fishing activity, output and productivity depend not only on fisher’s ability, but also on the variable fish stock. Moreover, in the short-run the fisher’s ability is limited by natural condition (e.g. some inputs are fixed – length, engine power), fishermen’s ability (e.g. capitalization), and government regulations (e.g. kind and mesh sizes of nets used). Adjusting the inputs used is not easy. Finding the most important input that fishermen can make in order to improve productivity and efficiency is very necessary. As Alvarez (2001) emphasized that, the place where fishermen fish is significant in improving productivity and efficiency of fishery. This is shown in the result section where vessels in Vinh Truong that operate near NTB-MPA areas are more efficient than those in Vinh Luong that operate in Nha Phu Lagoon. In case coastal waters are overexploited, managers will face the question: Should they establish more marine protected areas (MPAs) in Vietnam or not? In the short-run, the establishment of MPAs should be concomitant with policies to solve the conflicts between resource users. In the long-term, government should build institutional capacity to develop coordination and partnerships among the various stakeholders such as managers, politicians and fishers. Fisher and fishing communities in particular need to participate actively in action programs at the local level. Moreover, they have to have secure access to resources for sustainable management (Salayo, *et al.*, 2008).

8. CONCLUSION

This study has measured capacity and CU of small-scale trawl vessels in Nha Trang City, Khanh Hoa Province, Vietnam based on the data collected in 2005 and 2006. Although data for the output of each species were unavailable so the analysis can not show some detailed information for management such as capacity, or CU, or excess capacity for each species but this study has provided an overview about capacity, CU and excess capacity of small-scale trawl fishery in Nha Trang. By using average revenue and compare fishing efficiency of trawlers this study's results showed that, there were great unused capacity by vessel and most of vessels were under-utilized their capacity. Based on result of CU and excess capacity of vessels in each area, this study proves that, the trawlers in Vinh Truong were more technical efficient than those in Vinh Luong. It may imply that the stock around the MPA is more abundance than that in other areas and Nha Trang Bay MPA might have provided some benefits for adjacent fisheries by the spillover effect. This conclusion is suitable to result from some studies before.

Finding in this study provide a basis for future studies. By collecting more data of species, quantity of each species and some information of stock size the later studies will give better suggestions for policy-makers, fishermen and other industries stakeholders.

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APPENDICES

APPENDIX 6.1: CAPACITY UTILIZATION BASED ON OBSERVED AND TECHNICAL EFFICIENCY PRODUCTION BY VESSEL IN 2005 AND 2006

	Year			
	2005		2006	
Vessel	**CU-*observed***	**CU-*efficient/unbias***	**CU-*observed***	**CU unbias/efficient**
1	1.000	1.000	0.485	0.485
2	0.649	0.876	0.839	1.000
3	0.444	0.707	0.818	0.957
4	0.898	0.910	0.743	0.980
5	0.757	0.941	0.752	1.000
6	0.918	0.968	0.745	0.892
7	0.774	0.774	0.648	0.648
8	0.830	0.830	0.642	1.000
9	0.733	0.917	0.467	0.713
10	0.637	0.857	0.896	0.955
11	0.573	0.786	0.915	1.000
12	0.988	0.988	0.928	0.928
13	0.653	0.732	0.430	0.602
14	0.937	0.937	0.841	0.841
15	0.875	0.875	0.762	0.762
16	0.949	0.975	0.810	0.810
17	0.895	0.895	0.839	0.839
18	1.000	1.000	0.781	0.833
19	1.000	1.000	0.467	0.713
20	0.549	0.718	0.643	0.643
21	1.000	1.000	0.367	0.625
22	0.781	0.953	1.000	1.000
23	0.600	0.930	0.768	0.988
24	0.454	0.755	0.877	1.000
25	0.584	0.584	0.681	0.795
26	0.560	0.730	0.630	0.630
27	0.595	0.887	0.565	0.640
28	0.583	0.879	0.759	0.793
29	0.863	0.942	0.517	0.790
30	0.622	0.908	0.706	0.859
31	0.718	0.874	0.647	0.771
32	0.537	0.829	0.681	0.813
33	0.883	0.883	0.559	0.781
34	0.952	0.952	0.614	0.780
35	0.820	0.954	0.881	0.881
36	1.000	1.000	0.691	0.954
37	0.786	0.984	0.942	0.942

38	0.299	0.678	0.374	0.374
39	0.318	0.475	0.377	0.377
40	0.373	0.395	0.391	0.391
41	1.000	1.000	1.000	1.000
42	0.810	0.892	0.491	0.584
43	0.550	0.811	0.474	0.474
44	1.000	1.000	1.000	1.000
45	0.386	0.386	0.556	0.556
46	1.000	1.000	1.000	1.000
47	0.326	0.326	0.623	0.712
48	0.270	0.270	0.718	0.870
49	0.250	0.291	0.568	0.571
50	0.348	0.635	0.411	0.496
51	0.577	0.577	0.569	0.817
52	0.199	0.279	0.389	0.533
53	0.423	0.614	0.541	0.541
54	0.320	0.490	0.380	0.401
55	0.353	0.353	0.527	0.688
56	0.301	0.301	0.871	0.871
57	0.587	0.587	0.469	0.469
58	0.315	0.464	0.541	0.541
59	0.603	0.650	0.643	0.643
60	0.536	0.536	1.000	1.000
61	0.255	0.255	0.758	0.758
62	0.376	0.376	0.549	0.549
63	0.370	0.554	0.279	0.279
64	0.418	0.592	0.619	0.724
65	0.361	0.634	0.793	0.937
Average	**0.636**	**0.741**	**0.665**	**0.751**
St.dev	**0.25**	**0.24**	**0.19**	**0.20**
CU =1	**8**	**8**	**5**	**10**
CU<1	**57**	**57**	**60**	**55**

APPENDIX 6.2: CAPACITY UTILIZATION AND PERFORMANCE OF TRAWL FLEET

	2005		2006	
No.	Vessel	CU-efficient	Vessel	CU-efficient
1	61	0.26	63	0.28
2	48	0.27	38	0.37
3	52	0.28	39	0.38
4	49	0.29	40	0.39
5	56	0.30	54	0.40
6	47	0.33	57	0.47
7	55	0.35	43	0.47
8	62	0.38	1	0.49
9	45	0.39	50	0.50
10	40	0.40	52	0.53
11	58	0.46	53	0.54
12	39	0.47	58	0.54
13	54	0.49	62	0.55
14	60	0.54	45	0.56
15	63	0.55	49	0.57
16	51	0.58	42	0.58
17	25	0.58	13	0.60
18	57	0.59	21	0.62
19	64	0.59	26	0.63
20	53	0.61	27	0.64
21	65	0.63	59	0.64
22	50	0.63	20	0.64
23	59	0.65	7	0.65
24	38	0.68	55	0.69
25	3	0.71	47	0.71
26	20	0.72	19	0.71
27	26	0.73	9	0.71
28	13	0.73	64	0.72
29	24	0.76	61	0.76
30	7	0.77	15	0.76
31	11	0.79	31	0.77
32	43	0.81	34	0.78
33	32	0.83	33	0.78
34	8	0.83	29	0.79
35	10	0.86	28	0.79
36	31	0.87	25	0.79
37	15	0.88	16	0.81
38	2	0.88	32	0.81
39	28	0.88	51	0.82
40	33	0.88	18	0.83
41	27	0.89	17	0.84
42	42	0.89	14	0.84
43	17	0.90	30	0.86
44	30	0.91	48	0.87

45	4	0.91	56	0.87
46	9	0.92	35	0.88
47	23	0.93	6	0.89
48	14	0.94	12	0.93
49	5	0.94	65	0.94
50	29	0.94	37	0.94
51	34	0.95	36	0.95
52	22	0.95	10	0.96
53	35	0.95	3	0.96
54	6	0.97	4	0.98
55	16	0.98	23	0.99
56	37	0.98	2	1.00
57	12	0.99	5	1.00
58	1	1.00	8	1.00
59	18	1.00	11	1.00
60	19	1.00	22	1.00
61	21	1.00	24	1.00
62	36	1.00	41	1.00
63	41	1.00	44	1.00
64	44	1.00	46	1.00
65	46	1.00	60	1.00

APPENDIX 6.3.1: CAPACITY, TE SCORE UNDER VRS AND CRS HYPOTHESIS AND SE BY VESSEL IN 2005 AND 2006

	2005				2006			
Vessel	capacity (θ1)	θ2 VRS	θ2 CRS	SE	capacity (θ1)	θ2 VRS	θ2 CRS	SE
1	1.000	1.000	1.000	1.000	2.248	1.000	1.341	0.746
2	1.540	1.349	1.579	0.854	1.192	1.192	1.192	1.000
3	2.250	1.590	1.706	0.932	1.223	1.171	1.171	1.000
4	1.114	1.013	1.341	0.755	1.346	1.319	1.321	0.999
5	1.322	1.244	1.387	0.897	1.330	1.330	1.330	1.000
6	1.089	1.054	1.146	0.919	1.342	1.198	1.200	0.998
7	1.292	1.000	1.116	0.896	1.544	1.000	1.000	1.000
8	1.205	1.000	1.210	0.827	1.558	1.558	1.558	1.000
9	1.364	1.250	1.308	0.956	2.143	1.527	1.550	0.985
10	1.570	1.346	1.858	0.725	1.117	1.066	1.189	0.897
11	1.745	1.372	1.672	0.821	1.093	1.093	1.093	1.000
12	1.012	1.000	1.000	1.000	1.077	1.000	1.000	1.000
13	1.532	1.121	1.547	0.725	2.323	1.400	1.478	0.947
14	1.067	1.000	1.000	1.000	1.188	1.000	1.000	1.000
15	1.143	1.000	1.061	0.942	1.313	1.000	1.093	0.915
16	1.054	1.027	1.275	0.806	1.235	1.000	1.125	0.889
17	1.117	1.000	1.211	0.826	1.191	1.000	1.040	0.962
18	1.000	1.000	1.013	0.987	1.280	1.067	1.072	0.995
19	1.000	1.000	1.000	1.000	2.143	1.527	1.550	0.985
20	1.822	1.308	1.478	0.885	1.554	1.000	1.161	0.861
21	1.000	1.000	1.030	0.971	2.727	1.704	1.850	0.921
22	1.281	1.220	1.384	0.882	1.000	1.000	1.000	1.000
23	1.667	1.551	1.768	0.877	1.302	1.286	1.291	0.996
24	2.201	1.663	1.770	0.939	1.140	1.140	1.140	1.000
25	1.712	1.000	1.341	0.746	1.468	1.167	1.221	0.955
26	1.786	1.304	1.370	0.952	1.588	1.000	1.010	0.990
27	1.680	1.490	1.507	0.989	1.770	1.132	1.132	1.000
28	1.714	1.507	1.507	1.000	1.317	1.044	1.072	0.975
29	1.159	1.092	1.097	0.996	1.934	1.527	1.625	0.940
30	1.608	1.461	1.465	0.997	1.416	1.216	1.220	0.996
31	1.392	1.217	1.217	1.000	1.546	1.192	1.197	0.996
32	1.863	1.544	1.563	0.988	1.467	1.193	1.194	0.998
33	1.133	1.000	1.162	0.861	1.788	1.396	1.401	0.997
34	1.051	1.000	1.000	1.000	1.628	1.270	1.312	0.968
35	1.219	1.163	1.531	0.760	1.135	1.000	1.099	0.910
36	1.000	1.000	1.000	1.000	1.446	1.380	1.391	0.992
37	1.272	1.251	1.378	0.908	1.061	1.000	1.000	1.000
38	3.342	2.267	2.818	0.804	2.672	1.000	1.363	0.734
39	3.145	1.494	1.936	0.772	2.653	1.000	1.549	0.646
40	2.683	1.060	2.133	0.497	2.554	1.000	1.401	0.714
41	1.000	1.000	3.800	0.263	1.000	1.000	1.389	0.720
42	1.235	1.102	1.227	0.898	2.038	1.190	1.450	0.821
43	1.819	1.475	1.518	0.971	2.109	1.000	1.219	0.820

44	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
45	2.588	1.000	2.691	0.372	1.800	1.000	1.194	0.837
46	1.000	1.000	1.428	0.700	1.000	1.000	1.282	0.780
47	3.068	1.000	3.025	0.331	1.606	1.143	1.265	0.904
48	3.708	1.000	2.622	0.381	1.392	1.212	1.260	0.962
49	4.002	1.164	3.135	0.371	1.761	1.005	1.022	0.984
50	2.875	1.824	2.308	0.790	2.435	1.209	1.492	0.810
51	1.732	1.000	1.227	0.815	1.758	1.436	1.438	0.999
52	5.028	1.404	2.426	0.579	2.574	1.371	1.398	0.981
53	2.361	1.451	1.727	0.840	1.849	1.000	1.082	0.925
54	3.124	1.530	2.559	0.598	2.631	1.054	1.176	0.896
55	2.832	1.000	2.827	0.354	1.898	1.306	1.495	0.874
56	3.328	1.000	2.827	0.354	1.148	1.000	1.000	1.000
57	1.705	1.000	1.831	0.546	2.130	1.000	1.169	0.855
58	3.178	1.474	2.587	0.570	1.848	1.000	1.016	0.985
59	1.658	1.078	1.560	0.691	1.554	1.000	1.154	0.867
60	1.867	1.000	2.094	0.478	1.000	1.000	1.096	0.912
61	3.917	1.000	3.184	0.314	1.319	1.000	1.016	0.984
62	2.661	1.000	1.408	0.710	1.823	1.000	1.095	0.913
63	2.701	1.498	2.254	0.665	3.584	1.000	1.458	0.686
64	2.392	1.416	2.060	0.687	1.616	1.170	1.175	0.996
65	2.767	1.755	1.977	0.887	1.261	1.182	1.182	1.000
mean	**1.903**	**1.217**	**1.711**	**0.782**	**1.649**	**1.144**	**1.238**	**0.929**
St.dev	**0.923**	**0.268**	**0.663**	**0.215**	**0.543**	**0.179**	**0.190**	**0.092**

APPENDIX 6.3.2: TECHNICAL AND SCALE EFFICIENCY UNDER CRS AND VRS BY VESSEL IN 2005

Vessel	crste	vrste	scale	RTS
1	1.000	1.000	1.000	-
2	0.633	0.741	0.854	irs
3	0.586	0.629	0.932	irs
4	0.746	0.987	0.755	irs
5	0.721	0.804	0.897	irs
6	0.873	0.949	0.919	irs
7	0.896	1.000	0.896	irs
8	0.827	1.000	0.827	irs
9	0.765	0.800	0.956	irs
10	0.538	0.743	0.725	irs
11	0.598	0.729	0.821	irs
12	1.000	1.000	1.000	-
13	0.646	0.892	0.725	irs
14	1.000	1.000	1.000	-
15	0.942	1.000	0.942	irs
16	0.784	0.973	0.806	irs
17	0.826	1.000	0.826	irs
18	0.987	1.000	0.987	irs
19	1.000	1.000	1.000	-
20	0.677	0.765	0.885	irs
21	0.971	1.000	0.971	irs
22	0.722	0.819	0.882	irs
23	0.566	0.645	0.877	irs
24	0.565	0.602	0.939	irs
25	0.746	1.000	0.746	irs
26	0.730	0.767	0.952	irs
27	0.664	0.671	0.989	irs
28	0.663	0.663	1.000	-
29	0.912	0.915	0.996	drs
30	0.683	0.685	0.997	drs
31	0.822	0.822	1.000	-
32	0.640	0.648	0.988	irs
33	0.861	1.000	0.861	irs
34	1.000	1.000	1.000	-
35	0.653	0.860	0.760	irs
36	1.000	1.000	1.000	-
37	0.726	0.799	0.908	irs
38	0.355	0.441	0.804	irs
39	0.517	0.669	0.772	irs
40	0.469	0.943	0.497	irs
41	0.263	1.000	0.263	irs
42	0.815	0.908	0.898	irs
43	0.659	0.678	0.971	irs
44	1.000	1.000	1.000	-
45	0.372	1.000	0.372	irs
46	0.700	1.000	0.700	irs
47	0.331	1.000	0.331	irs
48	0.381	1.000	0.381	irs
49	0.319	0.859	0.371	irs
50	0.433	0.548	0.790	irs
51	0.815	1.000	0.815	irs
52	0.412	0.712	0.579	irs

53	0.579	0.689	0.840	irs
54	0.391	0.654	0.598	irs
55	0.354	1.000	0.354	irs
56	0.354	1.000	0.354	irs
57	0.546	1.000	0.546	irs
58	0.387	0.679	0.570	irs
59	0.641	0.928	0.691	irs
60	0.478	1.000	0.478	irs
61	0.314	1.000	0.314	irs
62	0.710	1.000	0.710	irs
63	0.444	0.668	0.665	irs
64	0.485	0.706	0.687	irs
65	0.506	0.570	0.887	irs
mean	**0.661**	**0.855**	**0.782**	
st.de	**0.215**	**0.158**	**0.215**	

APPENDIX 6.3.3: TECHNICAL AND SCALE EFFICIENCY UNDER CRS AND VRS BY VESSEL IN 2006

Vessel	crste	vrste	scale	RTS
1	0.746	1.000	0.746	irs
2	0.839	0.839	1.000	-
3	0.854	0.854	1.000	-
4	0.757	0.758	0.999	irs
5	0.752	0.752	1.000	-
6	0.833	0.835	0.998	drs
7	1.000	1.000	1.000	-
8	0.642	0.642	1.000	-
9	0.645	0.655	0.985	irs
10	0.841	0.938	0.897	irs
11	0.915	0.915	1.000	-
12	1.000	1.000	1.000	-
13	0.676	0.715	0.947	irs
14	1.000	1.000	1.000	-
15	0.915	1.000	0.915	irs
16	0.889	1.000	0.889	irs
17	0.962	1.000	0.962	irs
18	0.933	0.938	0.995	irs
19	0.645	0.655	0.985	irs
20	0.861	1.000	0.861	irs
21	0.541	0.587	0.921	irs
22	1.000	1.000	1.000	-
23	0.775	0.778	0.996	irs
24	0.877	0.877	1.000	-
25	0.819	0.857	0.955	irs
26	0.990	1.000	0.990	irs
27	0.883	0.883	1.000	-
28	0.933	0.957	0.975	drs
29	0.615	0.655	0.940	irs
30	0.820	0.822	0.996	drs
31	0.836	0.839	0.996	irs
32	0.837	0.839	0.998	drs
33	0.714	0.716	0.997	irs
34	0.762	0.787	0.968	irs
35	0.910	1.000	0.910	irs
36	0.719	0.725	0.992	irs
37	1.000	1.000	1.000	-
38	0.734	1.000	0.734	irs
39	0.646	1.000	0.646	irs
40	0.714	1.000	0.714	irs
41	0.720	1.000	0.720	irs
42	0.690	0.840	0.821	irs
43	0.820	1.000	0.820	irs
44	0.780	1.000	0.780	irs
46	1.000	1.000	1.000	-
45	0.907	1.000	0.907	irs
47	0.731	0.876	0.834	irs

48	0.794	0.825	0.962	irs
49	0.979	0.995	0.984	irs
50	0.670	0.827	0.810	irs
51	0.696	0.696	0.999	irs
52	0.715	0.729	0.981	irs
53	0.925	1.000	0.925	irs
54	0.850	0.949	0.896	irs
55	0.669	0.766	0.874	irs
56	1.000	1.000	1.000	-
57	0.855	1.000	0.855	irs
58	0.985	1.000	0.985	irs
59	0.867	1.000	0.867	irs
60	0.912	1.000	0.912	irs
61	0.984	1.000	0.984	irs
62	0.913	1.000	0.913	irs
63	0.686	1.000	0.686	irs
64	0.851	0.855	0.996	irs
65	0.846	0.846	1.000	-
mean	**0.826**	**0.893**	**0.929**	
st.de	**0.118**	**0.122**	**0.092**	

APPENDIX 6.4.1: EXCESS CAPACITY BASED ON CAPACITY AND TE BY VESSEL IN 2005 AND 2006

	2005					2006				
Vessels	Observed revenue	Capacity revenue	TE/target revenue	Excess capacity	Ex. capacity based on TE	Observed revenue	Capacity revenue	TE/target revenue	Excess capacity	Ex. capacity based on TE
1	250,510	250,510	250,510	0	0	142,500	293,750	142,500	151,250	0
2	200,408	308,657	270,323	108,249	69,915	274,500	327,162	327,162	52,662	52,662
3	213,200	479,700	338,951	266,500	125,751	331,200	405,000	387,720	73,800	56,520
4	252,109	280,761	255,357	28,652	3,248	234,000	315,000	308,707	81,000	74,707
5	229,190	302,957	285,116	73,767	55,926	246,000	327,162	327,162	81,162	81,162
6	366,704	399,254	386,372	32,550	19,668	274,500	368,514	328,800	94,014	54,300
7	183,352	236,889	183,352	53,537	0	204,000	315,000	204,000	111,000	0
8	202,540	243,996	202,540	41,456	0	207,000	322,500	322,500	115,500	115,500
9	187,616	255,840	234,520	68,224	46,904	147,000	315,000	224,495	168,000	77,495
10	160,433	251,940	215,994	91,507	55,561	250,400	279,583	267,027	29,183	16,627
11	191,880	334,896	263,352	143,016	71,472	310,500	339,324	339,324	28,824	28,824
12	332,592	336,554	332,592	3,962	0	315,000	339,324	315,000	24,324	0
13	149,240	228,657	167,295	79,417	18,055	135,600	315,000	189,777	179,400	54,177
14	364,450	388,756	364,450	24,306	0	306,000	363,649	306,000	57,649	0
15	223,860	255,840	223,860	31,980	0	240,000	315,000	240,000	75,000	0
16	266,500	280,761	273,810	14,261	7,310	255,000	315,000	255,000	60,000	0
17	234,520	261,982	234,520	27,462	0	246,600	293,750	246,600	47,150	0
18	234,520	234,520	234,520	0	0	246,000	315,000	262,394	69,000	16,394
19	255,840	255,840	255,840	0	0	147,000	315,000	224,495	168,000	77,495
20	213,200	388,527	278,806	175,327	65,606	234,000	363,649	234,000	129,649	0
21	255,840	255,840	255,840	0	0	115,500	315,000	196,803	199,500	81,303
22	171,626	219,863	209,428	48,237	37,802	315,000	315,000	315,000	0	0
23	218,530	364,222	338,897	145,692	120,367	270,000	351,486	347,129	81,486	77,129
24	213,200	469,223	354,447	256,023	141,247	351,000	400,135	400,135	49,135	49,135
25	223,860	383,164	223,860	159,304	0	246,000	361,216	286,760	115,216	40,760

26	268,632	479,700	350,414	211,068	81,782	255,000	405,000	255,000	150,000	0
27	269,698	453,113	401,899	183,415	132,201	222,000	392,838	251,297	170,838	29,297
28	279,825	479,700	421,757	199,875	141,932	307,500	405,000	321,165	97,500	13,665
29	319,800	370,700	349,321	50,900	29,521	188,100	363,750	287,242	175,650	99,142
30	281,424	452,656	411,031	171,232	129,607	277,500	392,838	337,394	115,338	59,894
31	245,180	341,399	298,270	96,219	53,090	228,000	352,500	271,776	124,500	43,776
32	257,439	479,700	397,444	222,261	140,005	276,000	405,000	329,135	129,000	53,135
33	269,698	305,571	269,698	35,873	0	183,000	327,162	255,558	144,162	72,558
34	234,520	246,364	234,520	11,844	0	193,500	315,000	241,000	121,500	47,500
35	230,256	280,761	267,718	50,505	37,462	277,500	315,000	277,500	37,500	0
36	364,450	364,450	364,450	0	0	243,000	351,486	335,403	108,486	92,403
37	284,515	361,940	355,971	77,425	71,455	331,250	351,486	331,250	20,236	0
38	100,204	334,896	227,141	234,692	126,937	127,000	339,324	127,000	212,324	0
39	145,776	458,476	217,771	312,700	71,996	149,000	395,270	149,000	246,270	0
40	97,539	261,700	103,412	164,161	5,873	126,250	322,500	126,250	196,250	0
41	48,503	48,503	48,503	0	0	78,750	78,750	78,750	0	0
42	293,150	361,940	322,919	68,790	29,769	172,500	351,486	205,285	178,986	32,785
43	257,972	469,202	380,452	211,230	122,480	189,750	400,135	189,750	210,385	0
44	479,700	479,700	479,700	0	0	405,000	405,000	405,000	0	0
45	67,958	175,890	67,958	107,933	0	116,000	208,750	116,000	92,750	0
46	152,438	152,438	152,438	0	0	144,300	144,300	144,300	0	0
47	63,960	196,255	63,960	132,295	0	130,000	208,750	148,641	78,750	18,641
48	83,148	308,309	83,148	225,161	0	235,000	327,162	284,742	92,162	49,742
49	61,162	244,742	71,194	183,580	10,032	158,750	279,583	159,566	120,833	816
50	130,585	375,388	238,222	244,803	107,637	149,375	363,750	180,585	214,375	31,210
51	239,850	415,343	239,850	175,493	0	213,750	375,811	306,974	162,061	93,224
52	87,945	442,158	123,443	354,213	35,498	150,750	387,973	206,749	237,223	55,999
53	191,880	453,113	278,422	261,233	86,542	212,500	392,838	212,500	180,338	0
54	78,351	244,742	119,861	166,391	41,510	106,250	279,583	112,013	173,333	5,763
55	69,290	196,255	69,290	126,965	0	110,000	208,750	143,665	98,750	33,665
56	69,290	230,582	69,290	161,292	0	225,000	258,333	225,000	33,333	0
57	115,128	196,255	115,128	81,127	0	98,000	208,750	98,000	110,750	0
58	77,019	244,742	113,489	167,723	36,471	151,250	279,583	151,250	128,333	0

	59	226,418	375,388	244,081	148,970	17,663	234,000	363,750	234,000	129,750	0
	60	94,234	175,890	94,234	81,656	0	208,750	208,750	208,750	0	0
	61	50,102	196,255	50,102	146,153	0	158,250	208,750	158,250	50,500	0
	62	164,164	436,795	164,164	272,631	0	211,500	385,541	211,500	174,041	0
	63	90,610	244,742	135,708	154,132	45,098	78,000	279,583	78,000	201,583	0
	64	102,336	244,742	144,917	142,406	42,581	173,000	279,583	202,441	106,583	29,441
	65	165,710	458,476	290,745	292,766	125,035	313,500	395,270	370,440	81,770	56,940
V. Truong	**Mean**	**244,907**	**331,202**	**288,919**	**86,295**	**44,012**	**241,539**	**341,994**	**282,249**	**100,455**	**40,710**
V. Luong	**Mean**	**140,998**	**302,926**	**174,673**	**161,928**	**33,675**	**177,842**	**299,624**	**191,919**	**121,782**	**14,077**
Total	**Mean**	**198,547**	**318,586**	**237,947**	**120,039**	**39,400**	**213,120**	**323,090**	**241,948**	**109,970**	**28,827**

APPENDIX 6.4.2: AVERAGE EXCESS CAPACITY BASED ON CAPACITY AND TE BY AREAS IN 2005 AND 2006

	2005			**2006**		
	Total	**Vinh Truong**	**Vinh Luong**	**Total**	**Vinh Truong**	**Vinh Luong**
Excess capacity	120,039	86,295	161,928	109,970	100,455	121,782
Excess capacity based on TE	39,400	44,012	33,675	28,827	40,710	14,077

APPENDIX 6.5: VARIABLE INPUT UTILIZATION

	crew		**exp**		**day**		**fuel**	
	2005	2006	2005	2006	2005	2006	2005	2006
1	46	45	39	40	58	47	60	52
0.9-1	14	5	0	1	6	10	0	10
0.8-0.9	4	3	2	5	1	3	1	3
0.5-0.8	1	12	13	12	0	5	4	0
<0.5	0	0	11	7	0	0	0	0
Total	65	65	65	65	65	65	65	65