CAPACITY AND CAPACITY UTILIZATION: THE CASE OF TRAWLER FISHERIES IN NHA TRANG, VIET NAM

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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. Using a mathematical programming approach - data envelopment analysis (DEA), the results from this study shows 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.

Keywords: Capacity, Capacity utilization, trawl fishery, DEA.

1 Introduction

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. In the late 1990s, FAO started treating the fishing capacity issue as a political priority with the aim to reduce overall fleet capacity.

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 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.

This study will use data envelopment analysis (DEA) to measure capacity output and CU of each trawl vessel in Nha Trang city. 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.

2 Fisheries In Nha Trang

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 (2005). They include both single trawlers and pair trawlers. Trawlers are mainly small-scale size. The number of trawlers increases sharply due to the fact that techniques are rather simple.

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. 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. 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 Definitions Fishing Capacity And Capacity Utilization.

3.1 Capacity

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 system 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,

$$Y_c = Y(E_c, S)$$

Where:
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).

3.2 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

[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)

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).

4 The Dea Framework

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.

Capacity output can be estimated by solving a mathematical or linear programming problem. Following Fare *et al.* (1989), let there be j = 1,… 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:

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

Subjetc to

$$\left.\begin{aligned}
&\theta_1 u_{jm} \le \sum_{j=1}^{J} z_j u_{jm} && m = 1, 2, \dots, M && (1)\\
&\sum_{j=1}^{J} z_j x_{jn} \le x_{jn} && n \in \alpha && (2)\\
&\sum_{j=1}^{J} z_j x_{jn} = \lambda_{jn} x_{jn} && n \in \alpha' && (3)\\
&z_j \ge 0 && j=1,2,\dots,J &&\\
&\lambda_{jn} \ge 0 && n \in \alpha' &&
\end{aligned}\right\} \quad (I)$$

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

$$\sum_{j=1}^{J} z_j = 1 \quad \text{(Madau, } et\ al.\text{, 2009).}$$

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:

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

Subject to

$$\left.\begin{aligned}
&\theta_2 u_{jm} \le \sum_{j=1}^{J} z_j u_{jm} && m = 1, 2, \dots, M && (4)\\
&\sum_{j=1}^{J} z_j x_{jn} \le x_{jn}, && n = 1, 2, \dots, N && (5)\\
&z_j \ge 0 && j=1,2,\dots,J &&
\end{aligned}\right\} \quad (II)$$

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:

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

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).

5 Data

This analysis focused on the small-scale fisheries in the coastal waters of Nha Trang city. Data are collected in two communes, Vinh Truong and Vinh Luong. 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. Since the data were collected through a personal household interview, a questionnaire was designed.

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). Estimated capacity in this research is an economic capacity measurement and (I) 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 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. 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). Besides, use of variable inputs such as fuel, ice, labour affects fishing capacity. For our analysis, days at sea, crew size per vessel, and fuel cost of vessel are used as variable inputs for the analysis.

6 Results

Table 1 shows estimated capacity, efficiency. Capacity score (θ1) and technical efficiency score (θ2) were the estimated scores obtained from DEA problems.

Table 1: Capacity and efficiency and SE measures of vessel

	Capacity (θ1)		Efficiency (θ2) VRS	
	2005	**2006**	**2005**	**2006**
Mean	1.903	1.649	1.217	1.144
St.dev	0.923	0.543	0.268	0.179

As mentioned in theory section, capacity is estimated under VRS hypothesis

$$\sum_{j=1}^{J} z_j = 1$$

From the table 1 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 3). 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 3: Average CU, number of vessels with CU equal or different to 1. (Ob-observed, ef/un - efficient/unbiased)

Vessel	2005		2006	
	CU-ob	**CU- ef/un**	**CU-ob**	**CU-ef/un**
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

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 3). This means that there were 25.9 % (2005) and 24.9 % (2006) of capacity would not be used when fishermen operate at full capacity.

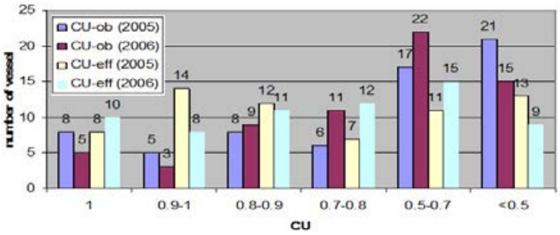

Figure 2: Distribution of capacity utilization scores in 2005 and 2006.

The distribution of capacity utilization scores for trawl vessels in Nha Trang are showed in figure 2. 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 3). The number of vessels had a CU based on efficient production (CU-efficient) higher than 0.9 were 14 (2005) and 8 (2006). There was great number of vessels that had a CU less 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 2).

7 Discussions

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. 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 2 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. As a consequence, the stock may be continuously fished down leading to the depletion of fish stocks.

Some policy implications:

This study is one of the first studies trying to measure fishing capacity of fishing fleets in Vietnam. 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. 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 that 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, 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. 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. 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. We know that in fishing activity, output and productivity depend not only on fisher's ability, but also on the variable fish stock.

8 Conclusion

Although data for the output of each species were unavailable so the analysis cannot show some detailed information for management such as capacity, or CU, for each species but this study has provided an overview about capacity, CU of small-scale trawl fishery in Nha Trang. This study's results showed that, there were great unused capacity by vessel and most of vessels were under-utilized their capacity. 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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Primary Paper Section: A

Secondary Paper Section: AH