



Economic Performance and Capacity Utilisation in Vietnamese Purse Seine Fishery

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Abstract

This study identifies differences in vessel efficiency amongst purse seiners in Vietnamese fishery. Deterministic data envelopment analysis (DEA) was used to assess relative capacity utilisation of each vessel, and double bootstrap DEA was adopted to overcome some of the drawbacks of nonparametric DEA. The study was based on a survey of costs and earnings from 52 purse seiners in 2016, revealing an average vessel profit margin of 11 %. By adopting double bootstrap DEA while assuming variable returns to scale, mean capacity utilisation was found to be 0.72 (with 95 % confidence interval from 0.67 to 0.79). This indicates that to sustain the current catch levels, expected inputs should be reduced by 21–33 %. The study shows that vessel size, fishing experience, and family size of skippers, all are factors affecting the capacity utilisation.

Keywords: economic performance, capacity utilisation, DEA, double bootstrap DEA, purse seining

Introduction

It is well-established that an open-access fishery eventually leads to dissipation of natural resource rent and attracts fishing effort beyond any equilibrium level where such rent may be collected (Gordon, 1954). Scott Gordon's seminal paper also shows that given his biological assumptions only the most cost-efficient vessels, in the long run, will remain in the open-access fishery, all earning a normal profit. Hence, the standard theory suggests the fleet will, in the long term, develop towards homogeneity. However, quasi rent and intra-marginal rent may exist in most fisheries due to natural and market fluctuations, leading to fleet diversity. This paper presents a study of a Vietnamese fishing fleet operating in a *de facto* open-access situation, to assess efficiency and diversity. The fleet has become more dominated by large units over recent years. This development is believed partly to be a consequence of governmental subsidies prioritising larger vessels and engines, despite it in principle being an open access fishery. The fishery primarily targets anchovy, *Stolephorus commersonnii* Lacepède, 1803 and scads, *Decapterus russelli* (Rüppell, 1830), *Decapterus*

macrosoma Bleeker, 1851, and *Decapterus maruadsi* (Temminck and Schlegel, 1843), with some bycatch of other species (sardine, *Sardinella jussieu* (Lacepède, 1803), mackerel, *Scomberomorus guttatus* (Bloch and Schneider, 1801) and skipjack tuna, *Katsuwonus pelamis* (Linnaeus, 1758)) accounting for 2–3 % of the total catch. The fleet sails out from the port of Nha Trang (in the southern part of Vietnam), a port including more than 2500 fishing vessels with total earnings of nearly 86 million USD in 2015 (DEAGRUD, 2016).

Vietnam is a major fishing nation with annual growth in landings of almost 6 % since the early 1990s (GSO, 2018a). The fishing industry (including aquaculture) contributes about 4 % of national GDP each year (FAO, 2005). However, catch per horsepower (hp) shows a declining trend, from 0.89 ton.hp⁻¹ in 1991 (Pomeroy et al., 2009) to 0.31 ton.hp⁻¹ in 2016 (GSO, 2018a; Vasep, 2018). This reduction may reflect a decline in the resource base and technical changes in the fleet. The average vessel has become larger, and the average engine size has increased by a factor of three from 2009 to 2016, according to DECAFIREP (2010 and 2016).

Less is known about the changes in the resource base, as biological information is characteristically data-poor in Vietnam. However, the general declining trend in catch per unit of horsepower also seems to be representative for the investigated fishery.

The aim of this study was, therefore, to investigate the economic performance of the vessels participating in the Nha Trang purse seine fishery. A sample of 52 of a total of 130 vessels in the purse seine fleet was included in the study. Moreover, data envelopment analysis (DEA) was used to measure the capacity utilisation of the purse seiners, and bootstrap technique was applied to overcome some of the limitations related to the DEA method. Double bootstrap DEA method, developed by Simar and Wilson (2007), was employed to provide the bias-corrected DEA efficiency estimates, as well as statistical inference of the factors affecting capacity utilisation.

The aim was to further compare and analyse the findings based on known vessel differences, socio-economic differences and the findings of other similar studies. Can observed physical vessel differences explain possible variation in capacity utilisation or are socio-economic differences within the different crews more likely to provide an explanation? In addition, how do the findings compare with other studies from other fisheries? Are, for example, open access fisheries more exposed to large differences in capacity utilisation than regulated fisheries are?

Materials and Methods

Primary data were obtained in a survey including 52 purse seine owners selected from the 130 purse seiners registered at Khanh Hoa Department of Capture Fisheries and Resources Protection in Nha Trang, in 2016 (DECAFIREP, 2016). The 52 vessels were selected based on hull length and horsepower, to ensure similar average values in the sample as in the total population (Table 1).

Table 1. Key measures used to qualify the sample as representative for the purse seiners in 2016.

Variable	Sample size = 52		Population size = 130		t-Test
	Mean	S.D.	Mean	S.D.	
Hull length	16.05	2.60	15.94	2.86	0.30
Engine power	303.10	163.27	300.35	173.29	0.12

S.D.: standard deviation.

Additional face-to-face interviews were conducted in 2016 with vessel owners (and/or their spouses) to collect information on technical and operational

characteristics, costs and earnings of the purse seine fleet, and various economic and social factors regarding the fishers. The list of registered fishing vessels in Khanh Hoa in 2016 and other relevant information was also collected for this study.

This study employs key economic indicators (gross cash flow, profit, gross profit margin and profit margin) to measure the economic performance of the purse seiners in 2016. A capacity utilisation analysis is based on the following scheme:

Let x_j be the quantity of an input factor in the production of harvest (u_j) by vessel j . z_j is the intensity variable. j indicates the total number of vessels (52 in this study) and the DEA methodology is summarised by:

$$CU_j(u, x) = \min \theta_j$$

Subject to

$$\begin{aligned} u_j &\leq \sum_{j=1}^J z_j u_j \\ \theta_j x_j &\geq \sum_{j=1}^J z_j x_j \\ z_j &\geq 0, \quad j = 1, 2, \dots, J; \quad \sum_{j=1}^J z_j = 1 \end{aligned} \quad (1)$$

$CU_j(u, x)$ represents the observed capacity utilisation as a function of output u , and input, x . θ_j is the input-oriented capacity utilisation with a value between 0 and 1 (Castilla-Espino et al., 2006).

The difference in capacity utilisation amongst purse seiners is described by:

$$\widehat{\delta}_j = \beta Z_j + \varepsilon_j \geq 1 \quad (2)$$

In equation (2) the dependent variable is capacity utilisation score, $\widehat{\delta}_j = \frac{1}{\theta_j}$. Z_j is a set of exogenous variables, while β_j are parameters of the model to be estimated. In this equation, ε_j is a continuous, independent, and identically distributed random variable.

Simar and Wilson (2007) have proposed a double bootstrap procedure that provides confidence intervals for the capacity utilisation estimate in (1), while also enabling consistent inference within the truncated regression model explaining capacity utilisation in (2). Therefore, the DEA double bootstrap technique proposed by Simar and Wilson (2007) is employed for this.

Since the purse seine fishery in question is a multispecies fishery, revenue was chosen as the output variable in the estimation of capacity

utilisation. Total fixed cost taken as the measure of the capital value (including vessel and fishing equipment) in one year is defined by summing all the fixed costs such as maintenance and repair, insurance and fees, depreciation, and interest payment on loans (Table 2).

Fuel cost constitutes a major part of the variable cost in the purse seine fishery. Other variable costs are costs of lubricant, ice and food. For Nha Trang fisheries, labour payment is a share of the revenue minus variable costs per fishing trip. Hence, labour cost is represented by man-days at sea (number of days multiplied by the number of crew members, including skipper) in this study.

In order to explain differences in capacity efficiency amongst purse seiners, the vessel characteristics and socio-economic factors of fishers are also included in equation (2) and the truncated regression model (see table 2). In this study, hull length is a proxy of engine size, as the two are highly correlated variables. Family size is considered as a proxy for crew payment.

Table 2 shows the means and standard deviations of some core variables in the data sample of the 52 purse seiners.

The analysis is performed using the rDEA package created by Simm and Besstremyannaya (2016) in R. The double bootstrap DEA model with $L_1 = 100$ interactions for the first loop and $L_2 = 2000$ for the second loop of Algorithm 2 was applied, as developed by Simar and Wilson (2007).

Results

Table 3 shows the economic indicators of the purse seine fleet in Nha Trang in 2016. This year an average purse seiner obtained a profit of 272.11 million VND with a corresponding profit margin of 11 %.

Table 4 presents the input-oriented DEA results of the purse seine fleet after employing equation (1) and using the input variables presented in Table 2. An estimated capacity utilisation ranging from 0.42 to 1 means that the lowest capacity utilisation of this fleet is 42 %, with average capacity utilisation of this fleet being 0.74 based on the deterministic DEA technique under CRS hypothesis. The VRS figures come out somewhat above this, with average capacity utilisation of 0.81. Using the double bootstrap DEA method under the VRS hypothesis, the capacity utilisation of an average vessel is 0.72. Hence, 28 % of the capacity is not fully utilised when comparing with the most efficient purse seiner.

Table 4 shows the 95 % confidence intervals for mean capacity utilisations of the purse seine fleet in 2016. Using the double bootstrap method, the bias-corrected capacity utilisation has a 95 % confidence interval between 0.67 at the lower limit and 0.79 at the upper limit, with the width of the confidence interval equalling 0.12, under the VRS hypothesis.

The results in Table 5 show – based on the paired t-test, and Wilcoxon signed rank test – that the capacity utilisations obtained from the deterministic DEA method under both CRS and VRS are statistically significantly different and higher (levels of significance are displayed in Table 5) than those found when using the double bootstrap procedure.

Table 2. Basic statistics of variables in the sample of 52 purse seine vessels in 2016.

Variables	Measurement unit per vessel	Mean	S.D.	Min	Max
<i>Inputs and output employed in DEA model</i>					
Total fixed cost	million VND	298.82	139.61	75.97	723.96
Variable cost	million VND	757.60	280.28	228.00	1438.50
Man days at sea	days	2660.00	897.41	600.00	4500.00
Revenue	million VND	1755.44	790.14	450.00	3491.40
<i>Truncated regression model</i>					
Hull length (Z1)	meters	16.05	2.60	11.00	22.85
Skippers' experience (Z2)	years	26.81	7.16	11.00	39.00
Skippers' experience ² (Z2 ²)	years ²	769.00	364.83	121.00	1521.00
Financial stress (Z3)	yes/no	0.40	0.49	0.00	1.00
Family size (Z4)	persons	4.98	1.36	3.00	10.00

S.D.: standard deviation.

Table 3. Statistics of economic key indicators in the sample of 52 purse seine vessels in 2016.

Criteria	Mean	S.D.	Min	Max
Gross revenue	1755.44	790.14	450.00	3491.40
Variable cost	757.60	280.28	228.00	1438.50
Fuel costs	386.21	150.70	115.20	864.00
Other variable cost	371.39	157.99	83.70	743.40
Fixed cost	129.98	85.91	2.64	354.11
Maintenance and repair	126.58	85.93	0.00	350.00
Insurance and fee	3.41	1.14	0.58	5.81
Labour cost	426.92	231.28	103.49	856.56
Gross Cash Flow	440.94	347.17	-135.92	1205.59
Depreciation	133.71	64.15	53.29	310.46
Interest payment on loans	35.12	53.82	0.00	220.00
Profit	272.11	284.99	-230.76	868.32
Gross profit margin	0.21	0.12	-0.19	0.39
Profit margin	0.11	0.14	-0.31	0.34
Income per crew member	28.86	12.41	7.11	50.35

Gross cash flow = Gross Revenue - Operating cost - Labour cost; Profit = Gross cash flow - Depreciation - Interest payment on loans; Gross profit margin = Gross cash flow/Gross revenue; Profit margin = Profit/Gross revenue; S.D: Standard Deviation. Note: all the economic indicators are measured in million VND (1 million VND = 44.014 USD), except for gross profit margin and profit margin.

Table 4. Calculated capacity utilisation (CU) in the sample of 52 purse seiners, based on deterministic and double bootstrap DEA methods. CU_CRS refers to capacity utilisation while assuming constant returns to scale, and CU_VRS assumes variable returns to scale. SD refers to standard deviation and CI to confidence interval.

Criteria	Deterministic DEA			Double bootstrap					
	Mean	SD	Min	Mean	SD	Min	Max	Lower 95 % CI for mean	Upper 95 % CI for mean
CU_CRS	0.74	0.16	0.42	0.69	0.15	0.39	0.97	0.66	0.74
CU_VRS	0.81	0.15	0.48	0.72	0.13	0.42	0.92	0.67	0.79

Table 5. Mean comparison and correlations of capacity utilisation (CU) in the sample, rankings based on Spearman and Wilcoxon-signed rank test. CU_CRS refers to capacity utilisation while assuming constant returns to scale, and CU_VRS assumes variable returns to scale.

	t-ratio	Spearman rank correlation	Wilcoxon-signed rank test (P-value)
CU_CRS	11.99***	0.99***	0.000**
CU_VRS	14.94***	0.96***	0.000**

*** Significant at 1 % level; ** Significant at 5 % level.

Table 6 shows the excess use of inputs in the Nha Trang purse seine fleet in the 2016 season. The findings show that vessel owners in this industry could reduce cost in their fishing activity. The cost savings described when applying the double bootstrap technique are even larger.

Table 7 indicates that hull length is positively related to capacity utilisation within the 95 % confidence interval in the double bootstrap method. This result shows that the larger the vessel, the higher the capacity utilisation. In addition, the capacity

utilisation increases with the skippers' experience, but at a decreasing rate, with these estimates being statistically significant at the 10 % level. Furthermore, there is a negative relationship between financial stress and capacity utilisation. However, this relationship is not statistically significant.

Discussion

As pointed out in the introduction, the income of the studied purse seine fleet covered their operating costs and resulted in profits in 2016. The reason for

Table 6. Excess use of inputs defined by differences between the actual inputs and the optimal inputs in the sample of 52 purse seiners.

Criteria	Actual input	Deterministic DEA		Double bootstrap DEA	
		Optimal input	Excess use of input	Optimal input	Excess use of input
Total fixed costs					
Mean	298.82	242.14	56.68	219.51	79.31
Sum	15538.49	-	2947.42	-	4124.15
% excess	-	-	18.97	-	26.54
Variable cost					
Mean	757.60	618.60	139.00	556.00	200.91
Sum	39395.22	-	7251.46	-	10447.24
% excess	-	-	18.41	-	26.52
Man days at sea					
Mean	2660.00	2187.00	473.60	1971.00	689.20
Sum	138344.00	-	24626.00	-	35838.22
% excess	-	-	17.80	-	25.91

Table 7. Determinants of capacity utilisation score (the inverse of capacity utilisation) estimated by double bootstrap method.

Variables	Coefficient	95 % confidence interval		90 % confidence interval	
		Lower	Upper	Lower	Upper
Intercept	2.8830**	2.1966	5.4400	2.4711	5.0819
Hull length (Z1)	-0.0740**	-0.1486	-0.0327	-0.1306	-0.0386
Skippers' experience (Z2)	-0.0553*	-0.1639	0.0106	-0.1526	-0.0101
Skippers' experience ² (Z2 ²)	0.0013**	0.0002	0.0035	0.0005	0.0032
Financial stress (Z3)	0.0168	-0.1886	0.2694	-0.1403	0.2144
Family size (Z4)	-0.0049*	-0.1503	0.0091	-0.1319	-0.0024

** Significant at 5 % level; * Significant at 10 % level.

positive profit obtained for the fishing fleet was due to the low cost of labour in Vietnam. The opportunity cost of labour is related to GDP per capita (Long et al., 2008; Pham et al., 2014). For example, in 2016, the GDP per capita in Vietnam was 2,173.27 USD, substantially lower than that of China (8,113.25 USD) and Malaysia (9,360.47 USD) (IMF, 2019). Another reason for the positive profit was that the fuel price declined in 2016 by 30 % (0.53 US\$.L⁻¹) compared to 2011 (0.79 US\$.L⁻¹). The fuel costs constituted about 52 % of total variable costs in 2016.

Moreover, the average monthly income per crew member working in this fishery (3.59 million VND) is higher than the overall average for Khanh Hoa, which was 2.89 million VND per capita per month (GSO, 2018b). This shows that the crew members earned the opportunity cost of labour or above in this operating year (Duy et al., 2015)

The findings show that hull length had a significant and positive relationship with vessel efficiency. The next factor that also has a statistically significant and positive impact on the capacity utilisation in this

study was the family size, presumably impacting payment of the crew. Skippers' fishing experience (a proxy for skipper skills) is positively correlated to capacity utilisation, but at a decreasing rate. Some results are in contrast to the findings reported by Ngoc et al. (2009), where family size negatively affected the technical efficiency of the Nha Trang trawl fishery. In addition, they found that the skippers' fishing experience had a positive effect on technical efficiency. The latter results were, however, not statistically significant. Regarding financial stress, the results of the present study confirm the findings of Thap et al. (2016), showing a negative relationship between access to financial resources and efficiency in the case of intensive white-leg shrimp farming in Ninh Thuan (Vietnam). However, this factor did not obtain statistical significance in the case of the Nha Trang purse seine fishery.

The findings presented in Table 5 indicate the correlation between capacity utilisation estimated by both the deterministic and double bootstrap DEA methods applied. Regarding family size (Table 7), as a proxy for payment of crew, it relates positively to

capacity utilisation (statistically significant at the 10 % level). Fishing activities are fluctuating and may require seasonal workers from other parts of the country. Such employees often require higher wages than the local labour force since the use of family members could imply lower cost of labour. In other words, there may be a relationship between family size and low payment for the crew.

The capacity utilisation of vessels varied due to differences in cost structures. Adopting the DEA double bootstrap method under VRS, the bias-corrected efficiency of an average vessel in the Nha Trang purse seine fishery was 0.72. In addition, the single year observations also revealed that there exists an excess use of inputs in the Nha Trang purse seine fleet.

The capacity utilisation levels identified by the use of the nonparametric method are higher than those found by the double bootstrap method. This result corresponds to the observations of Simar and Wilson (2000), who found that the deterministic DEA method positively exaggerated the level of efficiency in their specific sample. The double bootstrap takes into account the sampling error and provides a bias-corrected efficiency estimate from which one may suggest broad policy implications. Other factors affecting the capacity efficiency includes the impact of subsidies, the political arguments for subsidies, variability in weather conditions, stock sizes and distributions, and possibly market variations. Such factors were not corrected for in this study.

This study cannot tell whether the purse seine fishery is characterised by overcapacity or not, as the crucial biological factors are unknown, and the data was collected over only one year. However, the results show that some vessels had low relative capacity efficiency, even below 0.5. It is not known if these vessels were more efficient in other years, due to factors such as changes in fish distribution patterns or weather conditions. Random noise in production potentially plays a significant role in fisheries, possibly reflected in fleet diversity.

Conclusion

The survey of 52 purse seiners revealed a 11 % average vessel profit margin in 2016. Three-quarters of the fleet experienced good earnings in spite of significant differences in capacity utilisation levels measured in terms of inputs to harvest production.

Excess capacity was identified in the purse seine fleet. Excess capacity represents an economic loss and may indicate a potential threat of overfishing. If the excess capacity is kept and fully utilised, instead of producing the current fishing effort with a smaller fleet (and full utilisation of the vessels), the overfishing issue could become more critical.

The study revealed that physical factors (such as hull length) and social factors (family size of skipper) affect vessel capacity utilisation. The study also showed that capacity utilisation increases at a decreasing rate based on the experience of the skipper. The purse seine fleet seems to be in a transition period from being dominated by small vessels to larger vessel sizes. This development is enhanced by subsidies, but it is not clear if the increased capacity utilisation resulting from vessel size can be explained only by this factor.

Since the study was done over a short period in 2016, it is not possible to explain the observed differences in vessel efficiency, which could be due to biological changes. However, it is equally reasonable to expect that stock changes over time could affect the different fleet segments in different ways. It may also explain the existing fleet diversity, even though this fleet seems to develop towards less diversity over time. In order to find how fleet dynamics affect capacity utilisation and efficiency paths of each vessel over time, more data points are needed. Hopefully, the current findings can be followed up by such studies in the future.

This study shows the fleet's mean capacity utilisation indicates that to sustain the current catch levels, expected inputs in this fishery could be reduced by 21 to 33 %. The role subsidies play is not clear from this study, but in general, it is known that subsidies might lead to an economically inefficient industry and an increase in the probability that fish stocks will be exploited beyond their biological limits (Sumaila et al., 2007). Instead of financial support, other types of governmental support (such as training fishermen, providing the information on the state of fish stocks, weather forecasts, rescue and life-saving activities in high seas) can contribute to reducing fleet capacity and effort expansion.

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