CAPITAL UTILIZATION AND INVESTMENT DECISIONS: A CASE STUDY FOR THE NETHERLANDS

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ABSTRACT

In this paper a data envelopment model is presented to evaluate short term investment decisions in the Dutch beam trawl and demersal fleet. We investigated how short run profit drives investment decisions and how a data envelopment analysis can be used to show what the optimal level of capital use is and how investment in variable and fixed inputs can optimize the output of the sector. The degree of capital utilization can be seen as a measure of whether firms should invest or disinvest in their capital assets. Capital utilization also measures to which extent idle and excess capacity is present in a firm. Differences in capital utilization mainly depend on the degree in which a firm can adjust fixed capital in the short run. It therefore should be a key economic parameter to evaluate the performance of a sector. We measured the physical capital utilization for the Dutch beam trawl and demersal fleet for 2005 and decomposed the capacity utilization into technical efficiency, economic capital utilization and optimal capacity idleness. Furthermore we illustrated how the economic capacity measure can be used to predict investment decisions in the fleet. Results show that economic capital utilization inefficiency is on average 13%, which indicates that landings could have been 13% higher then they were if the fleet operated 100% efficiently. About 1% of the capacity utilization inefficiency is caused by idle/excess capacity. This very low percentage indicates that there are few indivisibilities in the input for the Dutch beam trawl and demersal fleet. Based on short term profit maximization it is clear that it is optimal to make as much use of the available capital as possible. The remaining 12% can be attributed to economic capacity inefficiency and technical inefficiency in the fleet. Vessels with a low capital utilization are more likely to disinvest than vessels with a high capital utilization. Vessels with a capital utilization that is higher than unity almost always will choose to invest.

Keywords: Fishery economics, Data envelopment, investment decisions.

INTRODUCTION

Fisheries managers often implicitly assume that fishing vessels are fairly homogenous in terms of efficiency and capital utilization. If such would be the case, reducing the number of vessels in a fleet would result in a proportional reduction of fishing effort and thus fishing mortality. However numerous studies have shown that reducing the physical capital in the fleet does not have a linear effect on the fishing effort. (Pascoe et al, 2001; Vestergaard et al., 2003; Tingley et al, 2003). Fleets are both likely to have excess capital and the relation between effort, catch and capacity is likely to be non linear. Thus it is of importance to determine both how much excess capacity is available in the fleet and how capacity, effort and catches are related. This can be measured with capital utilization.

Capital utilization can be seen as a measure of whether firms should invest or disinvest in their capital assets. Capital utilization also measures to which extent idle and excess capacity is present in a firm. Differences in capital utilization mainly depend on the inability of a firm to adjust fixed capital in the short run, thus creating a structural inefficiency. It therefore should be a key economic parameter to evaluate the performance of a sector.

A standard tool for evaluating the available capacity and potential output in the fleet is Data Envelopment Analysis (DEA). DEA methodology uses information on physical inputs, to provide multi-output distance functions/frontiers to determine how these inputs relate to the capacity level of output. With the help of a DEA analysis it can be determined what the overall efficiency level of the fleet is and thus the capital utilization of the fleet and what factors contribute to a less than optimal production.

DEA estimates the degree to which vessels are performing relative to other vessels using similar amounts of inputs. The capacity of a vessel can thus be determined as the maximum level of output that could be expected under normal circumstances. A vessel operating below its capacity level, due to an underutilization of fixed inputs, inefficient use of its variable inputs or a combination of these two can be considered to be technical inefficient. Differences in efficiency levels may be caused by the skipper effect, age of vessel, differences in navigational aids etc.

In this paper we will go into the question how short run profit drives investment decisions and how a data envelopment analysis can be used to show what the optimal level of capital use is and how investment in variable and fixed inputs can optimize the output of the industry. We will measure the physical capital utilization for the Dutch beam trawl and demersal fleet in this paper and decompose the capacity utilization into technical efficiency, economic capital utilization and optimal capacity idleness. Furthermore we will illustrate how the economic capacity measure can be used to predict investment decisions in the fleet.

MODEL DESCRIPTION

Capital utilization and idleness

The production capacity of a vessel can be measured by its potential output, given its observed factors of production. Data envelopment analysis is a method to assess what the potential output of a vessel is. In such an approach a model assesses the best practice frontier technology that represents the most efficient combination of various input and output variables.

Capital utilization is normally defined as the ratio between actual output to some measure of potential output. There are two dominant approaches toward defining the potential output: a technological approach and an economic approach (Sahoo and Tone, 2009). The technological approach was first defined by Johansson (1968) as the maximum potential output that could be produced per unit of time with existing plant and equipment, provided that the availability of variable inputs is not restricted. This definition of capacity utilization was first made operational in a DEA setting by Färe et al (1989).

The economic approach is based on the concept that the maximum potential output should take into account maximizing profits as fully using available capital will not necessary lead to maximum profits. Coelli et al (2002) showed that it is almost always optimal for firms to have some optimal idle capacity. They decompose the physical measure of capital utilization in terms of outputs into three components: output technical efficiency, economic capital utilization and optimal capacity idleness.

Idle capacity in general can arise because of indivisibilities in inputs (i.e. fixed inputs), a fluctuating demand for an existing product or uncertainties in the expected demand for an existing product. Idle capacity is of great importance to investment decisions as a large amount of existing idle capacity can be used to diversify in other products, without investing into new capital.

In this paper we will use data envelopment analysis (DEA) to determine the available idle capital in the Dutch fishing fleet and based on these measures we will be able to determine whether capital utilization can be used to predict investment decisions in the fishing fleet. To do this we will follow the decomposition of the capital utilization as presented by Coelli at al (2002).

Formal definitions of capacity

Before introducing the DEA models used some definitions about capital and capital utilization are useful. The capacity of a vessel, y_c, is defined as the maximum possible production given technology *S* and fixed input vector x_f; the variable input x_v can take any positive value.

Capacity utilization θ can be defined as the ratio between observed output *y* and the maximum capacity of the vessel y_c. That is $\theta = y/y_c$. Capital utilization can take a value between 0 and 1. A value of 1 indicates that the vessel is operating a full capacity.

In the case that multiple outputs are considered, the capacity of the vessel should be redefined. Eilon and Soesan (1976) showed that in the case of multiple outputs and inputs a radial expansion of the output vector can be used. That is by how much the output vector can be proportionally expanded given the current technology and the fixed input vector.

The ray capacity y_c can be defined as y/θ. Where 1/θ is the largest scalar amount the output vector y can be radially expanded using technology S and fixed input x_f when the variable input vector x_v may take any non-negative value. The ray capacity utilization θ is defined as the inverse of the largest scalar amount by which the output vector can be expanded. The ray capacity utilization will be same as the capacity utilization if the number of output is equal to one.

Simple two-output example

The definitions of the previous section are illustrated in Figure 1. Suppose there are *m* firms that produce two outputs y_1 and y_2. $P(x_v,x_f)$ illustrates the production curve if vessels are operating on a technical efficient level. The technical efficiency indicates whether vessels are producing optimal witch both keep fixed inputs and variable inputs at their current level. $P(x_c^v, x_f)$ illustrates the production curve if vessels are operating on capital utilization maximizing level, which indicates whether a vessel is operating at full capacity while only keeping its fixed inputs at its current level.

Vessel *A* produces a level of output y_1 and y_2 that is clearly inefficient. This vessel should be able to produce at a level *B* is it was operating at a technical efficient level. If vessel *A* was maximizing their capital utilization it would even be able to produce on level *D*.

To test whether a vessel is operating on the ray economic efficient level we need to determine whether the vessel is maximizing the short term profit. To do this we add a slope determined by the prices of the 2 outputs *G'* $(-p_1/p_2)$ to figure 1. Point *F* represents the point where a vessel is operating in a technical efficient manner and is also maximizing its short term profits. However the output mix is changed in point *F*, if it is assumed that the 2 outputs are linked and the outputs can only be radial expanded the economic efficient technical output would be equal to Point *C*. The same analysis can be done for the capital utilization. A vessel maximizing short run profit and operating at capital utilization level would be able to produce at level *E*. Point *E* represents the ray economic capital utilization. In the remainder of this paper this will be shortened to economic capital utilization.

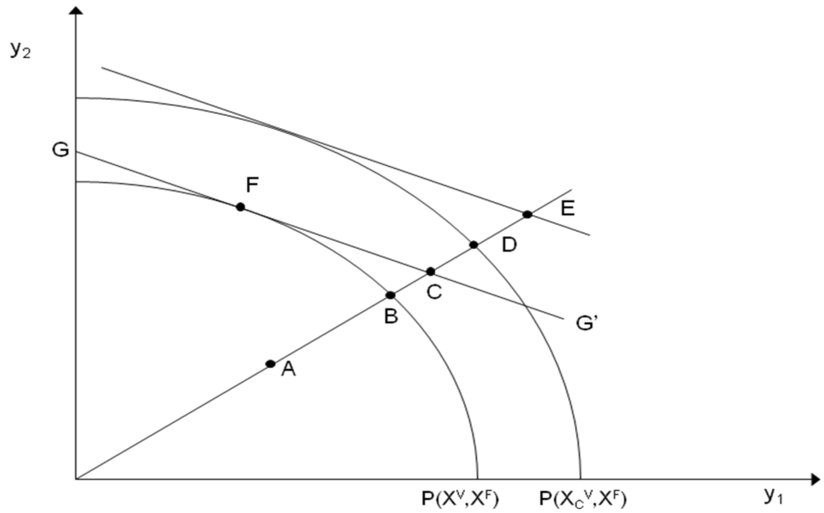


Figure 1 A two output example of efficiency scores

Model

To calculate the possible capacity of a vessel we need to estimate the unknown production technology. For this we have chosen to apply data envelopment analysis and need to solve three linear programs.

Technical *efficiency*

First of all we can calculate the technical efficiency that is how much a vessel should be able to produce given both the current fixed and variable inputs. To calculate the technical efficiency of the vessel we use a standard DEA LP model as can be found in Färe et al (1994).

$$
\begin{aligned}
& Max\,\theta_{TE} \\
& \text{subject to:} \\
& \sum z_i y_{im} \geq \theta_{TE} y_{jm} \qquad \forall m \\
& \sum z_i x_{in} \leq x_{jn} \qquad n \in F_x \cup V_x \\
& \sum z_i = 1 \\
& z_i \geq 0 \quad \forall i,
\end{aligned}
$$

Where θ_{TE} is the efficiency score of firm i, y_{jm} is the amount of output m produced by firm j, F_x and V_x are the sets of fixed and variable inputs respectively, x_{jn} is the amount of input n used by firm j and z_i is the intensity variable for firm i. The technical efficiency score is equal to:

$$TE = \frac{1}{\theta_{TE}}$$

Capital utilization

While calculating the technical efficiency, we assume that the variable inputs should remain on their observed level. If instead we would assume that a firm can adjust its variable inputs to increase its output, we can calculate the capital utilization. The model is changed to:

$$
\begin{aligned}
& Max\,\theta_{CU} \\
& \text{subject to:} \\
& \sum z_i y_{im} \geq \theta_{CU} y_{jm} && \forall m \\
& \sum z_i x_{in} \leq x_{jn} && \mathrm{n} \in F_x \\
& \sum z_i x_{in} \leq \lambda_{jn} x_{jn} && \mathrm{n} \in V_x \\
& \sum z_i = 1 \\
& z_i \geq 0 \quad \forall i, \qquad \lambda_{jn} \geq 0 \quad \forall j,n
\end{aligned}
$$

Where λ_{jn} is the input utilization rate by firm *j* of variable input *n*. Note that the fixed inputs, like size or engine power are assumed fixed on the short run and can not be changed. Variable inputs, like fuel consumption, are allowed to vary in the model. The capital utilization score is defined by:

$$CU = \frac{1}{\theta_{CU}}$$

Economic capital utilization

Following Coelli et al (2002), the economic capital utilization can be calculated by maximizing the short run profits, given that the outputs can only be radially expanded. The model used to calculate the economic capital utilization looks as follows:

$$
\begin{aligned}
& Max \sum_m p_m \beta_i y_{im} - \sum_v w_{vi} x_{vi}^{rec} \\
& \text{subject to:} \\
& \sum z_i y_{im} \geq \beta_i y_{jm} && \forall m \\
& \sum z_i x_{in} \leq x_{vi}^{rec} && n \in V_x \\
& \sum z_i x_{in} \leq x_{fi} && n \in V_f \\
& \sum z_i = 1 \\
& z_i \geq 0 \quad \forall i, \qquad \lambda_{jn} \geq 0 \quad \forall j,n
\end{aligned}
$$

Where β is the factor by which output can be radially expanded. The economic capital utilization is calculated by:

$$CU_{econ} = \frac{1}{\beta_i}$$

Optimal level of idleness
The idea of optimal idleness of capital is hinged on the idea that the short term profit curve is downward sloping. Up till certain point it wont be beneficial anymore to increase production as the marginal costs of producing an extra product exceed the profit gained by it. This idea is shown in Figure 2. A firm with an idleness score of unity, should use its capital to the fullest extent. A firm with an idleness score of less than unity will earn more short profits by decreasing production..

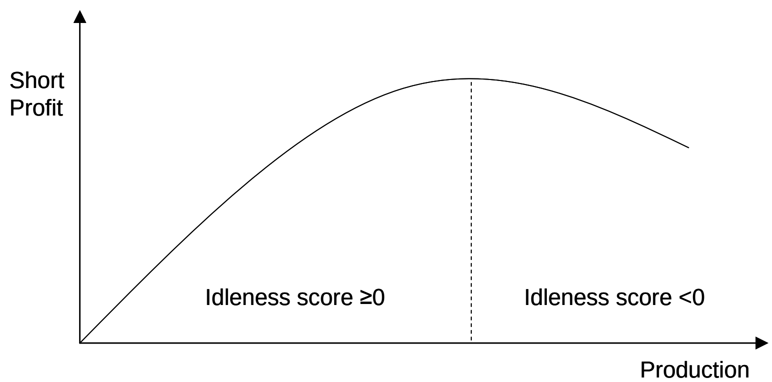


Figure 2 An illustration of idleness scores

The optimal level of idleness is defined as the ratio between the optimal production considering economic capital utilization and the optimal production considering capital utilization.

$$Idle = \frac{\beta_i y_i}{\theta_{CU} y_i} = \frac{CU}{CU_{econ}}$$

Calculation of capital price based on data envelopment analysis

The relationship between measures of economic capacity utilization and investment can be explained in terms of incentives to invest in physical capital . An economic capital utilization score of less than unity suggests that the company is not using their available capital to the maximum. This may mean that they either could increase their variable inputs to increase production or that they have to much capital and thus a reason to disinvest. The shadow price of capital in this case is higher than the actual price of capital. We are using the economic capital utilization measure here as this measure does not include the optimal idleness anymore in contrast to the physical capital utilization.

A firm with an economic capital utilization of more than unity is overusing its available capital. This means that it has an incentive to invest in its capital because that would increase short term profits. In this case the shadow price of capital is lower then the actual price of capital. A firm with an economic capital utilization of 1 has no reason to either invest or disinvest.

RESULTS

We estimated the three models described in the previous section using length and age of the hull as fixed input; gear cost, fuel costs and personnel cost as variable inputs and sole, plaice, other species with a low price and other species with a high price as outputs. As this paper focuses on short term profits and investments, these variables were chosen because of their strong link to profits and investments. Although there is some autocorrelation and heteroscedasticity between the variables used, especially between length and employment, data envelopment analysis is not affected by this even more research has shown that DEA-based estimators are the best estimators of efficient output under heteroscedasticity (Banker et al, 2003). The models will only be applied to the Dutch beam trawl and demersal fleet. To ensure that vessels are comparable we selected only vessels that catch at least 5 tonnes of sole and plaice per year.

Data

Data has been obtained from both the official vessel registry and a panel maintained by LEI. In this panel, cost and revenue of about one third of the fleet is collected. Table 1 shows the average revenues and landing of the vessels in the used sample for the time period 1999-2005. It is notable that on average, vessels catch less fish, however the value of the landings is relatively stable through out the years, indicating that the price of fish is increasing.

Table 1 Average revenues and landings 1999 to 2005 of the beam trawl and demersal fleet

	Revenue (1000 Euro)				Landings (tons)			
Year	Sole	Plaice	Other: Low price	Other: High price	Sole	Plaice	Other: Low price	Other: High price
1999	581.3	343.1	149.2	164.1	74.7	166.1	103.2	34.7
2000	613.3	274.3	135.3	163.2	68.5	153.8	89.4	30.4
2001	563.1	259.0	136.4	145.4	61.1	145.0	69.6	24.7
2002	519.9	233.0	126.1	144.7	55.4	125.7	71.1	23.7
2003	512.0	245.8	126.2	119.9	56.9	117.9	73.9	17.9
2004	505.9	189.2	120.6	105.0	56.4	101.0	71.1	15.3
2005	579.5	227.4	147.7	126.6	55.2	114.6	78.3	17.0

On average the vessels have become slightly older indicating that only few owners have been investing in their fixed capital as table 2 shows. The average length of a vessel has remained fairly constant over the years. Both fuel consumption and horsepower has been steadily declining over the period 1999-2005, most likely due to the increase in the fuel price. Investment in gear has also been declining over the years, the same holds for the number of persons employed.

Table 2 Average use of fixed and variable inputs in the period 1999-2005

	Fixed inputs		Variable Inputs		
Year	Age	Length	Fuel consumption (1000 litre)	Gear cost (1000 Euro)	FTE
1999	14.9	35.8	1,432.3	64.7	7.5
2000	15.6	35.8	1,382.3	62.6	7.4
2001	16.3	35.3	1,287.8	54.1	7.4
2002	16.3	35.1	1,230.3	53.4	7.4
2003	16.5	34.0	1,134.3	48.9	5.8
2004	17.4	33.2	1,003.3	42.7	5.5
2005	16.1	35.3	1,171.4	47.3	5.7

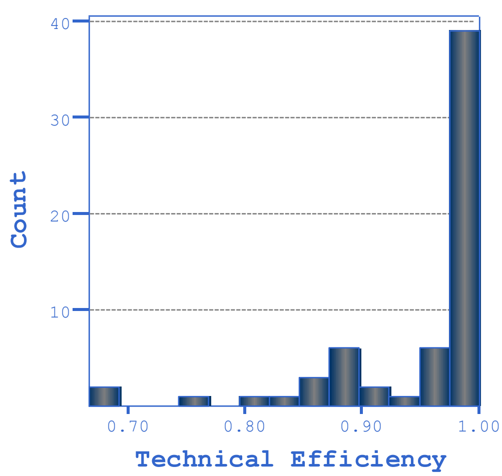
Results: Efficiency scores in 2005

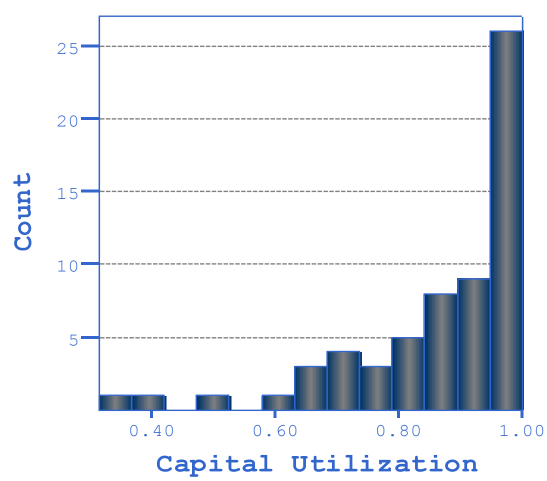
The various efficiency scores calculated by the models are shown in figure 3.a through 3.d for the year 2005. Figure 3.a shows the technical efficiency scores. Many of the vessels were considered technical efficient. This means that many vessels are producing optimal given the available fixed and variable inputs. Or in other words they produce the maximum output given the level of inputs employed. The average technical efficiency score in 2005 was 0.95 indicating that outputs could be increased by 5% if all vessels were operating technically efficient.

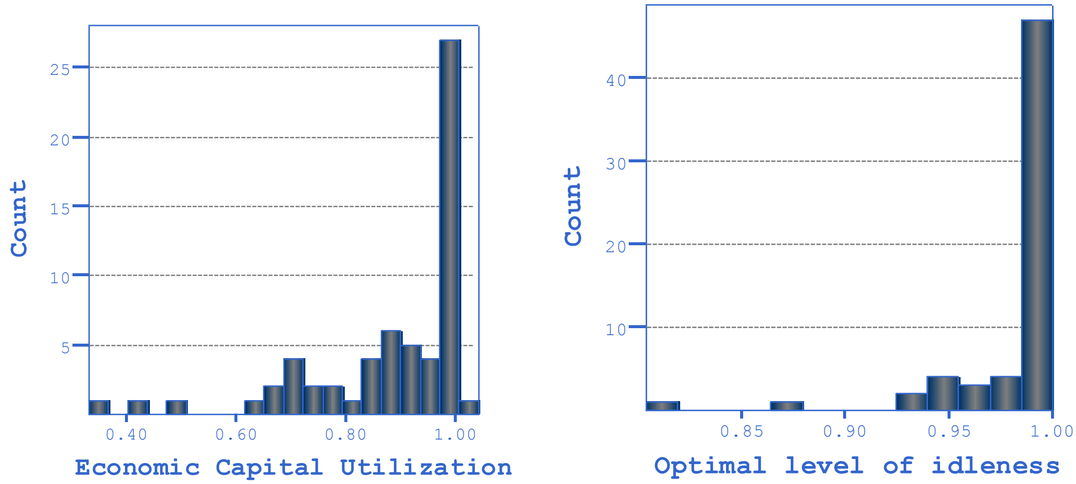
Figure 3.b shows the capital utilization. The capital utilization indicates whether a vessel could make better use of its fixed capital by employing their variable inputs more efficiently. Compared to the technical efficiency it is clear that fewer vessels are optimizing their capital utilization. Vessels could improve output if more variable inputs were available or used. However the overall capital utilization of the fleet is relatively high. Indicating that the variance in the fleet is low and many vessels are producing close to optimal. The average capital utilization was equal to 0.87 in 2005.

Figure 3.c shows the economic capital utilization, which takes into account short term profits while maximizing output. Several vessels have an economic capital utilization of more than 1. These vessels are overusing their available capital and could increase profits by reducing their production. The average economic capital utilization was equal to 0.89 in 2005.

Finally figure 3.d shows the optimal level of capital idleness. A score of unity indicates that it is optimal for that vessel to fully use their capital. A score less than 1 indicates that it is optimal for that vessel to leave part of its capital idle if the vessel wants to maximize short term profits. For most of the vessels in the fleet it is optimal to fully use their capital, only for a small number of vessels the optimal level of idleness is less than unity. The average idleness score in 2005 was 0.99, indicating that it is optimal to leave only 1% of the available capital idle in the Dutch flatfish fleet







Average	Mean	Minimum	Maximum	Std Deviation
Technical efficiency	0.95	0.67	1.00	0.08
Capital utilization	0.87	0.31	1.00	0.16
Economic Capital utilization	0.89	0.33	1.04	0.16
Idleness	0.99	0.80	1.00	0.03

Figure 3 Efficiency scores in 2005

Relation between different efficiency measures

By plotting the relationship between the different efficiency measures we can explore the significance of the different measures further and show which of these measures are more suitable to base investment decisions on.

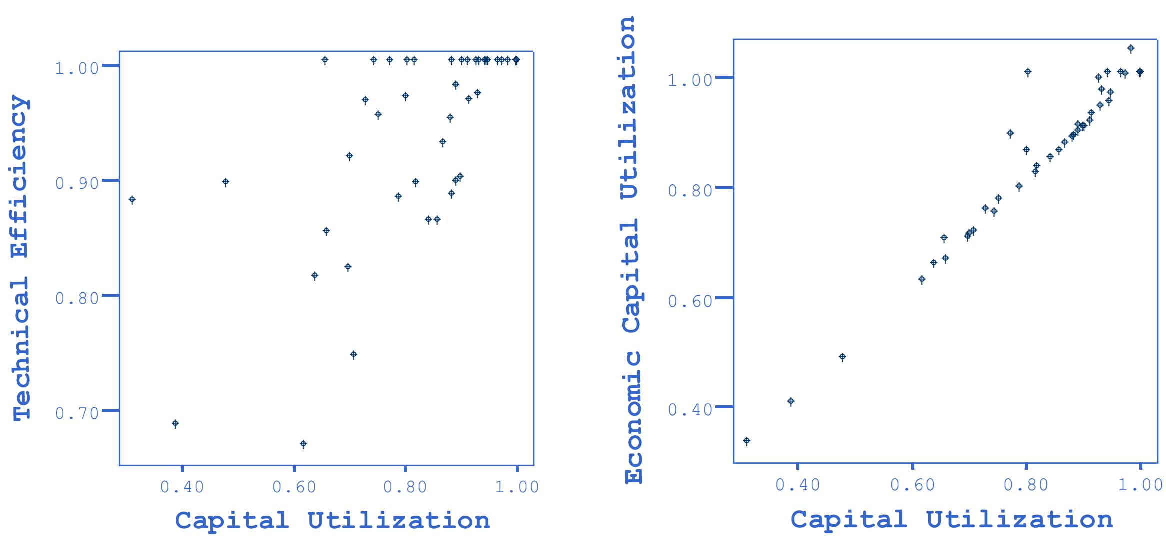


Figure 4 Technical Efficiency and economic capacity utilization versus Capital Utilization.

There clearly is a relationship between technical efficiency and capital utilization; a high technical efficiency goes in line with a high capital utilization. There is however a number of vessels that although they operate in a technical efficient way, could still increase production by using their fixed capital more efficiently as figure 4 shows.

The economic capital utilization and the capital utilization are closely linked. Like seen before for most of the fleet it is optimal to use all capital to the fullest and thus the economic capital valuation and the capital valuation are very close or equal. This is quite clear from figure 5. Quite a lot of the vessels that do not operate at full capital utilization have an equally low economic capital utilization indicating that short term profits would not increase by increasing the variable inputs.

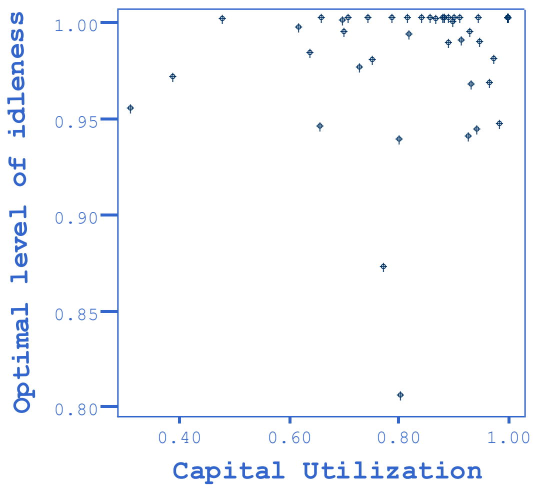


Figure 5 Optimal level of idleness versus capital utilization.

Finally figure 5 shows the relationship between the optimal level of idleness and the capital utilization. Many vessels that have a capital utilization of less then unity also have an optimal level of idleness that is less than unity. This indicates that while these vessels could increase output by increasing their variable inputs, this would not be preferable if the vessels want to maximize their short term profits. These vessels have too much capital in their possession and it may be optimal for them to disinvest in their capital.

As investment decision will be closely based on profit analyses and since we have shown here that economic capital utilization is strongly linked with capital utilization we will in the remainder of result section concentrate on the economic capacity utilization measure.

Predicting investment decisions based on economic capital utilization

Economic capital utilization can be used to predict investment decisions. Like shown in the model section, if the economic capital utilization is higher than unity that vessel will have an incentive to invest because the shadow price of capital is higher than the actual price of capital. Likewise a vessel with a low economic capital utilization will have an incentive to disinvest because the shadow price of capital is lower than the actual price of capital.

To determine whether the measure economic capital utilization can be used to predict investment decisions we have plotted the economic capital utilization of two years back versus the decision whether to invest in the capital or to disinvest. The results are shown in figure 9

This figure shows that in most years the average economic capital for vessels that disinvest is lower than that of vessels that chose to invest. All vessels that had a economic capital utilization of above unity choose to invest. The figure shows that the variance of the is high. The economic capital utilization is not the only reason vessels decide to invest or disinvest. However in table 7 it is tested whether the mean of the capital valuation is different between the group of vessels that choose to disinvest or invest and a two-tailed T-test shows that for most years the difference is indeed significant.

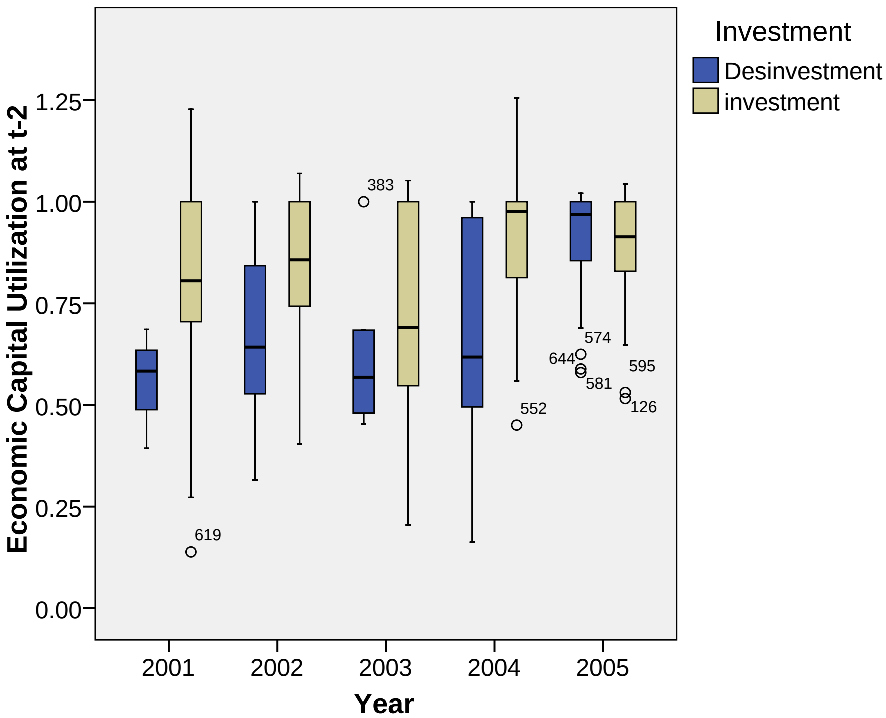


Figure 6 Investment decisions based on capital utilization

Table 3 Statistical difference between investment decisions

Year	Investment	N	Mean economic CU	Std. Deviation	Std. Error Mean	Sig. (2-tailed)
2001	Disinvest	3	0.55	0.15	0.09	0.05
	Invest	62	0.80	0.21	0.03	
2002	Disinvest	18	0.66	0.21	0.05	0.00
	Invest	41	0.85	0.16	0.03	
2003	Disinvest	6	0.63	0.20	0.08	0.34
	Invest	46	0.73	0.24	0.04	
2004	Disinvest	15	0.65	0.28	0.07	0.00
	Invest	35	0.90	0.16	0.03	
2005	Disinvest	25	0.90	0.14	0.03	0.61
	Invest	23	0.88	0.16	0.03	

Discussion

Based on the results presented above it is striking that the average capacity utilization of the fleet is rather high for all years in the analysis. However on average the fleet could increase production by about 13% if the capacity utilization is maximized. About 1% of the capacity utilization inefficiency is caused by idle/excess capacity. The remaining 12% can be attributed to economic capacity inefficiency and technical inefficiency (4%).

It is optimal to leave about 1% of the fleet capacity idle. This very low percentage indicates that there are few indivisibilities in the input (i.e. fixed variables) for the Dutch beam trawl and demersal fleet. Based on short term profit maximization it is clear that it is optimal to make as much use of the available capital as possible. It also shows that the capacity of the fleet is almost fully used in 2005 and it can be expected that a reduction of capacity will have an immediate effect on the output of the sector.

The economic capital utilization can be used to predict investments. Results show that vessels with a low capital utilization are more likely to disinvest than vessels with a high capital utilization. Vessels with a capital utilization that is higher than unity almost always will choose to invest.

While it is difficult to provide real quantitative investment decisions based on a data envelopment analysis, this study has shown that data envelopment analysis can be a useful tool in estimating potential investment opportunities in the fishing sector. The substantial differences between efficiency levels of vessels and difference in the optimal levels of idleness demonstrate to amount of information that can be generated by using data envelopment analyses in this field.

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