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Capacity and Efficiency in Swedish Pelagic Fisheries

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Abstract

The aim of this study is to estimate capacity utilization and efficiency for Swedish vessels fishing in the pelagic segment in the period 1995-2002. The Swedish pelagic fishery is the largest fishery in Sweden both in terms of total landings and the value of the landings. Capacity utilization is estimated to 74 % using Data Envelopment Analysis (DEA). The development of the fleet is towards larger vessels, which indicates that larger vessels are preferred in the fishery. In the efficiency analysis, large vessels were found to be more efficient than small vessels on average. Also, newer vessels were found to be more efficient than older ones.

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1. Introduction

According to economic theory, the problem with over-fishing is caused by the absence of well-defined property rights for the marine resources (Gordon (1954)). Without the possibility to claim a property right for the fish, investments in a larger fish stock will not be beneficial for the individual fisherman, since possible returns will be shared with others participating in the fishery. Rather, as long as the fishery is profitable, the competition for the "free" resource gives incentives for investments in larger vessels and for new fishermen to enter. This so-called "race for the fish" results in diminishing fish stocks and a fleet with excess fishing capacity.

To regulate the fishery, the access to fisheries may be limited by licences, catches may be limited by total allowable catches (TAC) per year, and how and where to fish may be regulated by restrictions in the number of fishing days, mesh sizes, closed areas etc. Such regulations may not necessarily change the driving forces that exist in an unregulated fishery, and despite the implementation of such regulations, European fisheries show many symptoms that are characteristic for an unregulated fishery. The most obvious result is that many commercially important fish stocks are over fished. This does not only have biological consequences, but also economic and social. The European Commission writes in its Green Paper that "The fisheries sector is characterised by economic fragility resulting from over investment, rapidly rising costs and a shrinking resource base: this is reflected in poor profitability and steadily declining employment."

Although the fish stocks form the base for fisheries, the economic performance of the fishing fleet is not only dependent on the status of the fish stocks, but also on an efficient fleet. The aim of the structural policy within EU's Common Fisheries Policy (CFP) is to modernize the European fishing fleets, and subsidies are given both to modernizing vessels and to the decommissioning of old vessels. However, subsidies may increase the fleets' capacity, and another issue in focus of the CFP is the relationship between the fishing capacity and the size of the fish stocks. Until 2002 the fleet was regulated through Multi Annual Guidance Programs (MAGPs), but since 2003 the size of the fleet is to a larger extent and issue for the individual member states.

Swedish fisheries management is part of the CFP. The Swedish management does not define strong property-rights to the resource, so economic theory predicts that excess capacity might be a problem. However, the empirical knowledge about the topic is limited. The aim of the study is to estimate capacity utilization and efficiency in the Swedish pelagic segment. Pelagic fishing is the largest fishing in Sweden both in terms of weight and catch value. The vessels in the pelagic segment mainly target herring, mackerel and industrial species. Efficiency and capacity are estimated using Data Envelopment Analysis (DEA). DEA is well suited for modelling a sector with multiple outputs, such as vessels targeting more than one species.

The paper continues with an introduction to Swedish fisheries in chapter 2, where details of the pelagic fishery are presented. Chapter 3 contains a discussion of the DEA method and how it is used for estimating capacity utilization and efficiency. Empirical models and data are presented in chapter 4. Chapter 5 contains the result concerning capacity utilization and chapter 6 contains the results concerning efficiency. The results are summarized and discussed in chapter 7.

2. Swedish Fisheries

The Swedish fishery sector employs approximately 2200 licensed fishermen. The major part of Swedish fishing takes place in marine waters, employing 2000 fishermen. The most important fishing areas are the Baltic Sea, the North Sea, the North Atlantic, the Skagerrak and the Kattegatt. In 2002, the total catch of marine species was 284 773 tons. In table 2.1 the catch of different marine species is presented.

Table 2.1 Swedish Fish Landings in Tons

Species	**Tons**
Eel	531
Salmon	264
Cod	15 115
Saithe	1 583
Herring	62 586
Mackerel	5 090
Industrial species	167 393
Norwegian lobster	1 008
Shrimps	2 151
Other	29 052
Total	**284 773**

Source: National Board of Fisheries Sweden

The major fisheries are for cod and for pelagic species such as herring, mackerel and industrial species. Cod is primarily caught in the Baltic Sea, while herring, mackerel and industrial species are caught in large volumes both in the Baltic Sea and in other fishing areas. Herring and industrial species have the largest total landings. The landings of herring had a value of 198 million Swedish crowns (SEK) and industrial species 211 million SEK. The cod fishery has the highest economic value, 256 million SEK in 2002. (National Board of Fisheries Sweden (2003a)).

2.1 Swedish Fisheries Management[1]

Since 1995 Swedish fisheries is managed as a part of EU's common fisheries policy (CFP). Within the CFP, the regulations concerning the size of the fleet are managed in the structural policy. Until 2002 this was done through four development programs, MAGP I – MAGP IV. Subsidies for vessel decommissioning were given in these programs, but in the CFP subsidies were also given for modernization and construction. MAGP IV covered the period 1997-2002 and is the development program that has been in force most of the time of the Swedish EU membership. In 2003 the CFP was reformed in favour of a more long-term management of fish stocks, and today there are no investment subsidies for construction and the subsidies for modernization have been more restrictive.

To protect the fish stocks from over-fishing, there are regulations concerning how fishing is allowed. One such regulation is the amount of fish allowed to be caught during the year, the Total Allowable Catch (TAC). Most, but not all, species have a TAC. The member states decide how to divide the national TAC between fishermen within the country. Many Swedish TACs are divided into weekly vessel-quotas. The purpose is to prevent the fishermen from taking all the allowable catches at the beginning of the year. The weekly quotas are based on the vessels' size. Swedish fishing is also regulated by technical restrictions such as closed fishing areas, temporary closing of specific fisheries and minimum mesh sizes. The access to the fishery is restricted and it is not possible to become a fisherman without a license from the National Board of Fisheries Sweden.

2.2 Segments

Swedish vessels are classified into five segments depending on the type of fishery. The segments are:

- The coastal segment. The vessels have passive gear and are less than 12 meters. In 2002 there were 309 active vessels.

[1] The section is based on National Board of Fisheries Sweden (2003b).

- The shrimp segment. The vessels are used for shrimp trawling. In 2002 there were 56 active vessels.
- The pelagic segment. The vessels are used for targeting herring, mackerel and industrial species. In 2002 there were 124 active vessels.
- Demersal segment. The vessels are used for targeting cod and Norwegian lobster. In 2002 there were 180 active vessels.
- Vessels over 12 meters with passive gear. In 2002 there were 48 active vessels.

For the purpose of economic analyses, the segments are further divided (Economic Assessment of European fisheries (2002)). The pelagic segment is divided into vessels that are less than 24 meters and vessels that are 24 meters and over. The focus of the remainder of the paper will be on the pelagic segment with vessels 24 m and over.

2.3 The Pelagic Segment, 24 m and over

The pelagic segment is the most significant Swedish fleet segment in terms of capacity, volume and value of landings.[2] Primarily pelagic and industrial species like herring, sprat, mackerel, sand eel and blue whiting are targeted. The segment is defined as vessels that are at least 24 meters. Vessels in the segment primarily use trawling, but also purse seines.[3] In 2002 Sweden had 58 active such vessels. The aggregate capacity was 21.9 thousand gross tonnes (GT), or defined as engine power, 65.6 thousand kW. Employment on board amounted to about 350 people. The total landings in 2002 were 247.8 thousand tonnes. Fishing takes place in the Baltic Sea, the North Sea, the North Atlantic, the Skagerrack and the Kattegatt.

2.3.1 Fleet Development over Time

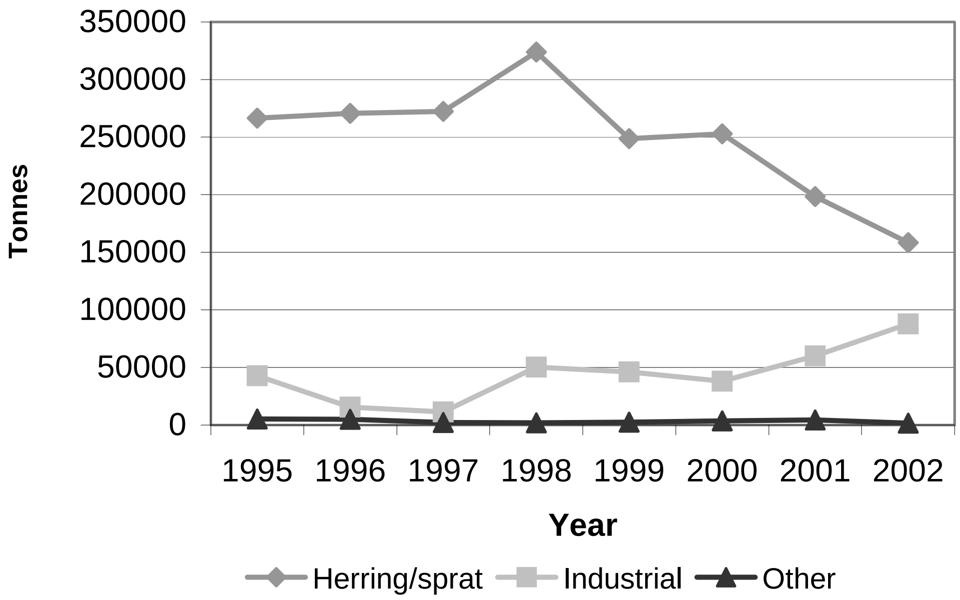
The pelagic fleet has changed during the period 1995-2002 both in the fleet structure and in catches and catch composition. The total tonnage has increased by approximately 20%, at the same time as mean tonnage per

[2] The section is based on National Board of Fisheries Sweden (2005).
[3] A purse seiner puts a net in a circle around a school of fish and closes the lower end of the net to capture the entire school.

vessel has increased by about 40% from 271 gross tonnes to 393 gross tonnes.

During the period 1995-2002 total available quotas decreased by approximately 25% (available quotas are in general caught). Some reallocation between species has occurred where e.g. traditional fishing in the Baltic Sea and the Skagerrak/Kattegatt has decreased, while new fishing for sand eel, capelin and North Atlantic herring have been introduced. Figure 2.1 shows the development for the three fish categories analysed in this paper, herring/sprat, industrial species and other species.

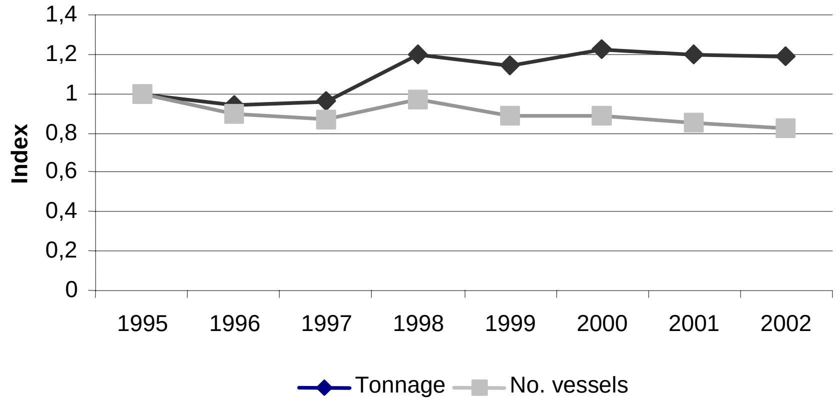
Figure 2.1 Catch composition



As can bee seen from figure 2.1, herring and sprat are the dominating species in Swedish pelagic fisheries. However, catches have declined rapidly since 1998 while at the same time catches of industrial species have increased. Other species are caught in very small quantities, although they are important for individual vessels.

During 1995-2002 the number of vessels decreased from 65 to 58 while the capacity in terms of both total gross tonnage and engine power increased. In figure 2.2 the development of the number of vessels and total tonnage is shown as an index with the year of 1995 having a value of 1.

Figure 2.2 Fleet development



Total tonnage increased in 1998 and has since been stable at about 20% over the 1995 level. The number of vessels has decreased continuously, except for 1998. In 2002 the total gross tonnage had increased by 18% compared to 1995 and the number of vessels had decreased by approximately the same.

2.3.2 Management of the pelagic segment

The management of quotas is important for over capacity since ill-defined property-rights to the quotas will cause over investments in the fishery. Dividing the TAC into vessel specific quotas is a system with stronger property-rights than a system with free fishing until the entire TAC is caught. The management of quotas differs in this respect between the target species. The fishing for e.g. sand eel is free until the total Swedish TAC is caught, while the majority of the herring and sprat quotas are formally divided into two weeks quotas for each vessel depending on the size of the vessel since 2002. The two weeks quota must be caught within the period and can thus not be saved for future fishing. Before 2002 the fisheries organization rationed the quota in a similar way. A few smaller quotas for herring and the quota for mackerel are vessel specific, but not transferable.

3. Data Envelopment Analysis (DEA)

Efficiency and capacity are estimated using Data Envelopment Analysis (DEA). In DEA, each production unit is compared with the best performing units in a linear programming problem. Applied on fisheries, the idea is to estimate the share of potential catches that a vessel has actually caught, where potential catches are the catches observed for the best performing vessels having the same (or less) inputs (e.g. tonnage, engine power, etc). Efficiency and details of DEA modelling are discussed in section 3.1, and capacity together with the relation between efficiency and capacity in section 3.2.

3.1 Efficiency

DEA is a linear programming technique that is used to compare a vessel's in- and outputs with a *best practice* front. The best practice front constitutes the maximum obtainable output for a vessel with a fixed amount of inputs (this is called an output oriented approach). In the paper a vessel's *efficiency index* is defined as the vessel's share of obtainable output.[4]

In DEA, the best practice front is spanned by the observations having most outputs using a fixed amount of inputs. We do not know whether these best performing vessels also are as efficient as they could be, i.e. if they are efficient compared to a "true" front. It is possible that they too could increase catches, although we have not observed any vessel having higher catches given the observed input quantities. Efficiency in relation to a best practice front and to a true front is illustrated in Figure 3.1.[5]

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[4] This is the reciprocal of the output oriented efficiency score defined in e.g. Färe et al (1994).

[5] Figure 1 illustrates what is called an output-oriented measure, where efficiency is estimated as the maximum possible expansion of outputs. Alternatively, efficiency may be estimated using input orientation, i.e. the maximum possible decrease in inputs. Which approach to use depends on what is the main objective of the fisherman, to increase outputs or decrease inputs. In the empirical application output orientation is used since it is assumed that the main objective of the fishermen is to maximize catches using available resources.

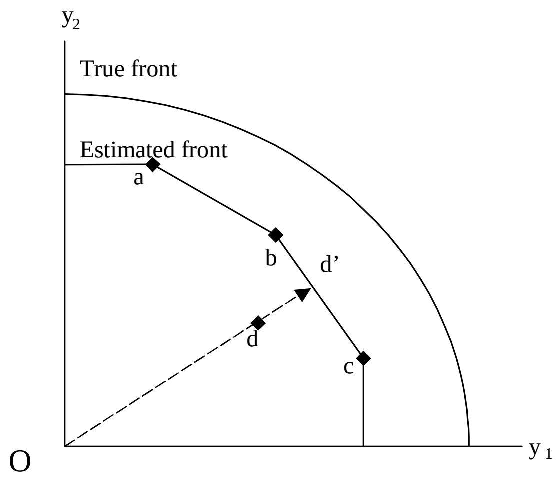


Figure 3.1. Efficiency

In figure 3.1 four vessels are shown, *a*, *b*, *c*, and *d*. All vessels are assumed to have the same inputs (i.e. identical vessels fishing the same number of days). Each vessel produces two outputs (y_1 and y_2), e.g. two different target species. Vessels *a*, *b*, and *c* are defined as efficient since none of the other vessels is observed to catch more of both species. These vessels span the best practice front, which is defined as the observed vessels and the straight lines connecting them (linear combinations) as illustrated in the figure. Vessel *d* is inefficient since it would be possible for it to catch more of both species. The efficiency index is defined as the ratio Od/Od'. This ratio is always less or equal to one, where efficient vessels obtain a value of one.

Although vessels *a*, *b*, and *c* are defined as efficient in a DEA estimate (they cannot expand outputs and thus have an efficiency score of one), they are not on the true frontier. If the true production possibilities were known these vessels would also be defined as inefficient. However, the true front is not known, and thus efficiency estimated with DEA is used as an estimate of true efficiency.

The example in figure 3.1 illustrates a two-output case, but the idea may be generalized to N inputs and M outputs. The efficiency index is estimated in the following linear programming problem for a unit *l*:

$$
\begin{aligned}
1/Effindex^{l} &= \max_{z,\lambda} \lambda \\
\sum_{k=1}^{K} z_k y_{km} &\geq \lambda y_{lm}, \quad m = 1,\ldots,M \\
\sum_{k=1}^{K} z_k x_{kn} &\leq x_{\ln}, \quad n = 1,\ldots,N \\
z_k &\geq 0, \quad k = 1,\ldots,K
\end{aligned} \qquad (1)
$$

X are the N inputs, y are the M outputs and z is a vector of activity variables. K are the production units. Following this notation, y_{km} is the m:th output for production unit k, and x_{kn} is the n:th input for production unit k. Efficiency is estimated using constant returns to scale (CRS) in equation 1. A variable returns to scale (VRS) front is estimated by including the constraint that the z-variables sum to one in the linear programming problem. References to DEA literature are Coelli, Rao and Battese (2001) and Färe, Grosskopf and Lovell (1994).

The efficient vessels span the production front to which inefficient vessels are compared. Each point to which an inefficient vessel is compared is thus a combination of some specific efficient vessels. These vessels are called *peers* to the inefficient vessel. It is possible to identify which vessels are used as peers for each inefficient vessel. This information may be used to compare inputs and outputs of the evaluated vessels and their peers, but is also useful for further analysis of vessel characteristics such as organization and management. The number of times an efficient vessel serves as peer for other vessels provides interesting information, since it tells us something about how important the efficient vessel is for the efficiency scores of inefficient vessels. So e.g. some efficient vessels are so-called "self evaluators", i.e. no other vessel is using them as peer. Removing such a vessel from the sample will not affect the efficiency scores of other vessels. In figure 3.1, vessel *a* is a self evaluator since it is not used as peer by any of the other vessels. Vessels *b* and *c* are used as peers by vessel *d*.

3.2 Capacity Utilization

The definition of capacity used here is the one adopted by FAO (1998), where capacity is defined as “the maximum amount of fish over a period of time that can be produced by a fishing fleet if fully utilised, given the biomass and age structure of the fish stock and the present state of the technology”. The capacity utilization is the share of the maximum potential catches that is actually caught.

The linear programming approach for estimating capacity is similar to that for estimating efficiency. The difference is that when estimating capacity, the variable factors of production are allowed to vary freely. The production frontier in the capacity estimation is spanned by vessels that may have used more variable inputs than the vessel under evaluation. As a consequence of this, the difference between a vessel’s observed and obtainable output is not only due to inefficiency, but also to the fact that the evaluated vessel has used less variable inputs. Capacity utilization is estimated in a DEA model as the ‘efficiency’ of a unit in relation to the production frontier where variable inputs are unrestricted. In this paper, this is referred to as CU_1. If the fixed factors of production are x^f and the variable factors are x^v, the linear programming problem for estimating CU_1 for vessel *l* is

$$
\begin{aligned}
& 1/CU_1^l = \max_{z,\lambda} \lambda \\
& \sum_{k=1}^{K} z_k y_{km} \geq \lambda y_{lm}, \quad m = 1,\dots,M \\
& \sum_{k=1}^{K} z_k x_{kn} \leq x_{\ln}^f, \quad n = 1,\dots,N \qquad (2) \\
& z_k \geq 0, \quad k = 1,\dots,K \\
& \sum_{k=1}^{K} z_k = 1, \quad k = 1,\dots,K
\end{aligned}
$$

In equation 2 the variable factors of production are left out, since they do not constrain capacity output.[6] By imposing the restriction that the z-variables sum to one, the model is estimated with a variable returns to scale technology.

Färe et al (1989) argue that the CU_1 measure may be downward biased since outputs may be produced inefficiently. They propose a measure where a technically efficient production is compared to the production frontier. This measure, CU_2, is calculated as CU_1/Efficiency-index. The relation between CU_1, CU_2 and the efficiency index is illustrated in figure 3.2 (following Färe et al (1989))

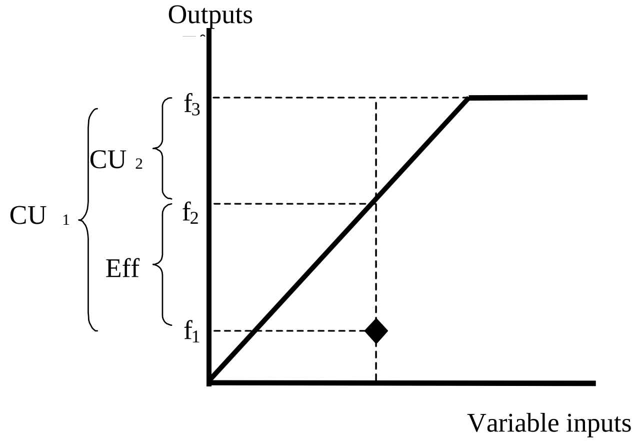


Figure 3.2 Capacity and Efficiency

In the figure the obtainable output for vessels with the same amount of fixed inputs is shown. By increasing the variable inputs, the obtainable output is increased up to the f_3-level, which is the largest observed catch. F_3 is the obtainable catch when estimating capacity utilization. Assume that an observed vessel, *a*, has an output of f_1. CU_1 is then the ratio f_1/f_3, i.e. the ratio between observed and obtainable catches. The efficiency index is estimated as f_1/f_2, i.e. the ratio between observed catches and the catches that are obtainable without increasing the variable inputs. CU_2 is estimated as f_2/f_3.

[6] The variable inputs may be included in the linear programming problem to estimate optimal usage, see e.g. Färe et al (1989).

4. Empirical Models and Data

Modelling Fisheries

When estimating efficiency with DEA no a priori assumption about the functional form of the relationship between inputs and outputs is necessary. The flexibility of the production relationships and the multiple input and multiple output technology are the advantages of DEA. The drawback is that DEA is not based on statistical theory, but is deterministic. The lack of an error term may be problematic if there is a large random component in the production. In fisheries there is clearly a component of luck, especially if production is measured per trip. However, in the long run, luck will even out but differences in managerial skill will persist. The importance of luck and skill is discussed e.g. by Álvarez et al (2003).

Modelling production in a fishery requires that a number of considerations are made concerning the production process and the production possibilities of the individual vessels. One issue is how to deal with the catch of multiple species (see Álvarez (2001)). Two species may be considered as different outputs when they are targeted e.g. on different trips or with different gears. On the other hand some species may to a large extent be caught in the same fishing effort. Such species are not separable as different outputs. So e.g. the by-catch of herring is large when targeting sprat.

DEA is well suited for a multi species characterization of the production process. Efficiency is always estimated in relation to a point on the production frontier that has the same catch composition as the vessel under evaluation. That is, if a vessel primarily targets herring, its efficiency will be evaluated in relation to other vessels primarily targeting herring. The drawback with modelling a multi species production process is that when the number of different outputs becomes larger, efficiency will tend to increase due to characteristics of the DEA model. *In this paper three output dimensions are used: Herring/sprat, industrial species and other species*. Herring and sprat are aggregated to one output since it is not possible to target the two species separately. Industrial species, such as sand eel and blue whiting, are species that are targeted for reduction purposes. They are primarily targeted in the North Sea. Vessels in the pelagic segment to a minor extent also target other species. Species that are not pelagic or targeted for industrial purposes are defined as a separate output.

On the input side, the fixed inputs gross tonnage and weight are used to represent the size of the vessel. Engine power is important e.g. for trawlers, which use their ability to move fast when fishing. Size statistics for the vessels are used as standard within the CFP. Electronic equipment is not shown in the vessel statistics, but is a potentially important tool to identify where the fish is located. It will decrease search time and may thus increase estimated efficiency if it is not accounted for as an input. Also, we do not have access to variable inputs such as labour and fuel. The variable inputs will vary with the number of fishing days and thus we use days at sea as a proxy for them. *Thus, in this paper three inputs are used: Tonnage, engine power and days at sea*.

As is the case in other industries that are based on renewable resources, fishing is dependent on the size of the stock. When fish is abundant, catches will be larger given the same effort. If not taken into account, fish abundance will be included as a part of the estimated inefficiency. Including stock estimates in the efficiency models is important when vessels face different fish abundance. Many studies in fisheries include observations from different periods of time, e.g. each month of the year. Here the fish stocks are important because stock abundance changes between periods[7] e.g. by seasonal behaviour. In the case of Swedish pelagic fisheries, we estimate efficiency separately for each year. Thus, we do not compare observations from different periods of time. In this sense, all observations have the same stock. What is more problematic is the heterogeneity of the fleet. Some vessels only target herring and sprat, while others catch a large share of industrial species. Vessels are also used for targeting the same species in

[7] One reason for including different periods is to increase the number of observations when the number of vessels is small.

different fishing areas. This implies that the vessels face different stocks and that the stocks are difficult to compare. One way of getting around this problem is to use only a sub sample consisting of more homogeneous vessels. This approach is used by e.g. Kirkley et al (1995), at the expense of having only few vessels included. In the present study the entire Swedish pelagic fishery is in focus and therefore all vessels are included.

Data

All data is administrated by the National Board of Fisheries Sweden. Catches are estimated on board the vessel (reported in the vessel's logbook) and aggregated to total catches per vessel and year in the empirical application. Data on tonnage, engine power and fishing days are used for management purposes in the CFP. Data is available since the EU membership in 1995 and the period studied is from 1995 to 2002. Data is available for all vessels in the segment except a few (in 2002 e.g. three vessels were discarded). The statistics for the pelagic segment below will therefore be based on vessels used in the empirical analysis.

Descriptive statistics for inputs and outputs are presented in table 4.1.

Table 4.1 Descriptive Statistics for Inputs and Outputs 1995-2002

	INPUTS			OUTPUTS		
	Variable	Fixed				
Mean values	**Days at Sea**	**Engine Power**	**Tonnage**	**Herring/sprat**	**Industrial**	**Other**
1995	163,2	850,3	271,0	4094,9	853, 9	89,2
1996	192,2	885,6	287,2	4740,4	399,4	109,3
1997	198,6	922,3	298,6	4694,1	293,9	63,8
1998	186,5	958,7	336,4	5060,8	1093,5	47,4
1999	216,9	989,8	351,3	4438,1	1044,9	41,5
2000	209,5	1094,3	376,1	4286,6	864,3	84,0
2001	228,8	1143,9	383,8	3554,3	1338,5	114,7
2002	200,8	1165,5	393,0	2870,8	1952,8	57,9

The vessel size is increasing over the years. Measured as tonnage the mean vessel has increased from 271 tonnes to 393 tonnes. The catch of herring and sprat has been declining while industrial species have increased on average. Days at sea have increased from 163.2 in 1995 to 200.8 in 2002. The number of vessels varies between 53 in 2001 and 65 in 1995. A vessel may be part of the segment for a number of years, leave for some other fishery and then return to the pelagic segment again. 96 vessels are used in the estimations but only 25 vessels have been part of the segment for the entire period.

Age Distribution of the Fleet

The vessels in the segment differ in characteristics like age, size and catches. A description of differences between vessels with different characteristics may therefore give useful information about the structure of the segment. Also, the relation between vessel characteristics and the efficiency results will be analysed in section 6.

The vessels are classified into three age categories, vessels built before 1970, vessels built from 1970 to 1994 and vessels built 1995-2002. Statistics are presented in table 4.2 for the 55 vessels used in the empirical analysis for 2002.

Table 4.2. Summary Statistics for Age Groups

	No. Vessels	Mean tonnage	Mean das	Mean catch/year (ton)
1995-2002	9	689	234	8 740
1970-1994	24	419	224	5 226
-1969	22	244	162	1 966

Nine vessels that were fishing in 2002 have been built after the Swedish EU membership in 1995. These vessels are significantly larger than the vessels from other age groups, and their mean catches are also higher. The oldest vessels are the smallest on average, they fish fewer days and also have the smallest mean catch. The vessels built between 1970 and 1994 are the second largest on average and they fish approximately the same number of days as the most recently built vessels. The age classification is based on the construction year of the vessel and modernizations may have taken place over the years.

The catch composition differs somewhat between the age groups. In table 4.3 the catch composition for 2002 is presented. All groups of vessels have herring/sprat as the largest share of the catch and very small catches of “other species”. Industrial species constitutes 43% of the catch for the vessels built 1995-2002, which is the largest share for the three groups. For the vessels built 1970-1994, the industrial species are 38% of the catch and for vessels built before 1970 industrial species constitutes only 16% of the total catches.

Table 4.3 Catch Compositions for Age Groups

	1995-2002	1970-1994	-1969
Herring/sprat	57%	62%	83%
Industrial	43%	38%	16%
Other	0%	1%	1%

Differences in catch composition between the age groups reflect the geographical location of the vessels. The most recently built vessels are located on the Swedish west coast, which is closer to the fishing areas where industrial species are caught. A larger share of the older vessels is located on the south coast, where mainly herring and sprat are targeted.

5. Capacity Utilization

Capacity utilization has been estimated for each vessel for 2002. The mean values are presented in table 5.1. Recall from figure 3.2 that CU_1 is the entire difference between actual catches and potential catches, while CU_2 is the difference net of estimated inefficiency.

Tabell 5.1 Capacity utilization

	Mean
CU_1	0,743
CU_2	0,878

The mean value for CU_1 is 0.74, which implies that the catches of the vessels were on average 74% of potential catches. 55 vessels were active in the segment. Twelve of these utilized their full capacity. Among the vessels with full capacity utilization vessels from both the south coast and the west coast are represented, as well as both large and small vessels. 15 vessels had capacity utilization (CU_1) of less than 60%. Also among these there are both large and small vessels represented and vessels both from the south and west coasts of Sweden.

CU_2 is 0.88. In the CU_2 measure, the efficiency index is not part of the capacity utilization. Instead, a low CU_2 value depends only on the use of variable inputs. Thus, capacity utilization estimated as CU_2 is always larger than if estimated as CU_1.

The total capacity of the segment is the sum of the capacity of each vessel in the segment. If all vessels were fully efficient and used their entire capacity, they would be able to catch 325 100 tonnes, which can be compared with the actual catches of 247 800 tonnes. The excess capacity is thus 77 300 tonnes, which is approximately 31% of actual catches or 24% of the capacity.

The analysis shows that the catches in 2002 could have been made with considerably fewer vessels, if these vessels hade used their full capacity.

One example of such a decrease in capacity could be if the vessels with the highest efficiency index had stayed in the segment. To generate the catches for 2002, it would have been sufficient for the segment to operate with 41 vessels. These correspond to approximately 75% of the number of vessels in the segment in 2002.

Excess capacity is not limited to fisheries but is found in most industries. The demand for products tends to vary during the business cycle and it may be profitable for a company to have excess capacity to meet an increase in demand. The fisheries sector, however, is different since the fish is a common resource. The open access problem leads to excess capacity which is too large.[8] On the other hand it may be rational to have some excess capacity in order to adjust fishing to biological fluctuations in the fish stocks. It may also be rational to have high capacity in the short run if actions are taken to increase the stocks, and thus more capacity may be needed in the future.

However, the general problem is that too much fishing capacity is in use. The European commission states in the Green Paper that "the available fishing capacity of the Community fleets far exceeds that required to harvest fish in a sustainable manner".

International Comparisons

Comparing the results with studies from other fisheries must be interpreted with caution since these are calculated under different resource conditions and different regulatory systems. Lindebo, Hoff and Vestergaard (Lindebo (2004, chapter 2)) have estimated the capacity utilization for Danish North Sea trawlers in 1999. These are used for targeting cod, herring/mackerel and industrial species. They find a CU_1 value of 0.81 and a CU_2 value of 0.94. The capacity utilization is thus somewhat higher in this case compared to Swedish pelagic fisheries. Lindebo (2004, chapter 4) analyses the flatfish fishery in the North Sea for vessels from Denmark, France, the Netherlands,

[8] See e.g. Brady (2004).

and the United Kingdom. Capacity utilization is estimated to be 77% for the entire fishery, but it varies substantially between the countries. Vestergaard et al (2003) estimate capacity utilization for Danish gill-netters in the North Sea and the Skagerrak. They find CU_1 to be 0.88 and CU_2 to be 0.92. Dupont, Grafton, Kirkley and Squires (2002) estimate a capacity model where it is possible for the vessels to make non-radial increases in the catches. The fishery studied takes place in Canada with active gears for e.g. cod and haddock. Capacity utilization varies from 0.64 in 1990 to 0.72 in 1998. Compared to these studies, the capacity utilization in the Swedish pelagic segment is approximately the same as for other fleets, although the Danish studies show somewhat higher capacity utilization for both the CU_1 and CU_2 measures.

Studies not using the DEA approach are Bjørndal and Gordon (2000) who only find a small over capacity in Norwegian pelagic fisheries in 1994-96 and Nøstbakken (2005) who find considerable over capacity in the same segment for the period 1998-2000. Eggert and Tveterås (2004) studies the Swedish trawl fishery for cod in the Baltic Sea. They estimate over capacity, given the small fish stocks, to approximately 25 %. They also find economics of scale in the segment and that a structural adjustment of the fleet could cause cost savings of about 40%. The over capacity for Swedish cod trawlers is about the same as is estimated in the CU_1 measure for the pelagic segment.

6. Efficiency Results

In section 6 the efficiency scores are presented for efficiency estimated both under VRS (6.1) and CRS (6.2) assumptions. In sections 6.3 to 6.5 an analysis of efficiency differences between vessels is performed. The analysis deals with size differences, age differences and vessel decommissioning.

6.1 Variable Returns to Scale

Estimated mean efficiency ranges from 0.80 in 1995 to 0.89 in 2001. In table 6.1 the efficiency scores are presented for the entire period 1995-2002.

Table 6.1 Summary Statistics for Efficiency Scores (VRS)

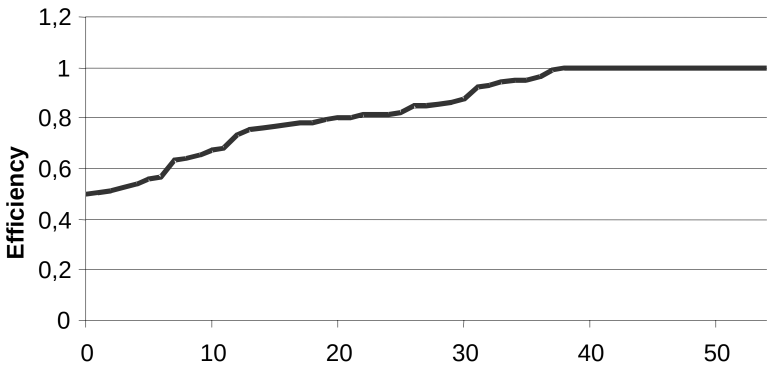
	Min	Max	Mean	Std. dev	No. vessels
1995	0,36	1,00	0,80	0,19	65
1996	0,25	1,00	0,81	0,21	57
1997	0,45	1,00	0,82	0,20	58
1998	0,37	1,00	0,81	0,22	64
1999	0,30	1,00	0,83	0,21	56
2000	0,36	1,00	0,87	0,18	59
2001	0,39	1,00	0,89	0,16	53
2002	0,50	1,00	0,84	0,16	55

The interpretation of the result for 2002, where mean efficiency is 0.84, is that the vessels on average caught 84% of potential catches.[9]

Examining the individual vessels further, we find that in 2002 the efficiency ranges from 0.5 to 1. In figure 6.1 the vessels are arranged according to the estimated efficiency. The least efficient vessel is located to the left in the figure and the fully efficient vessels to the right.

[9] Eggert (2001) estimates efficiency for Swedish Nephrops trawlers using a stochastic production function and data per fishing trip. Mean efficiency is 66% in his study.

Figur 6.1 Efficiency (VRS) 2002



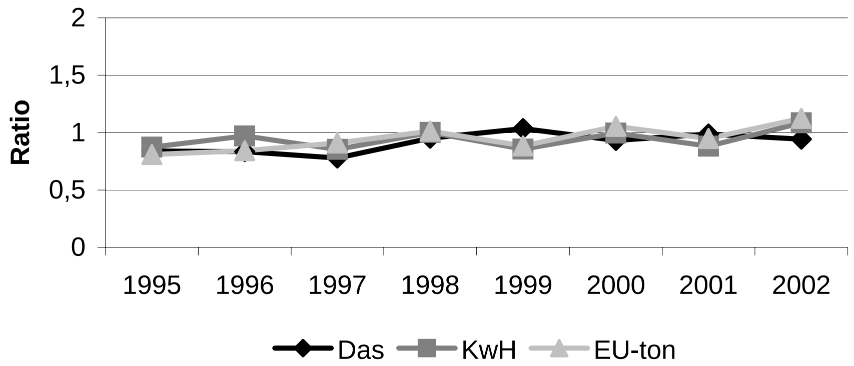
17 vessels are defined as efficient. The other vessels are inefficient and could thus increase catches without increasing resources. 12 vessels have an efficiency score below 0.75.

A problem in DEA estimations is that the model does not take technological differences into account. Thus, part of the efficiency index may be due to the fact that the vessels have different technology. As shown in table 4.2, there is a clear correlation between the age and the size of the vessels. It is reasonable to think that newer vessels have more advanced technology than older, although investments may have been made to adapt older vessels to modern fishing. Since differences in scale are taken into account in the VRS estimations, technological differences may also be taken into account to some extent.

6.1.1 Peer vessels

The efficiency index is always estimated in relation to one or more peer vessels. An analysis of the peer vessels may give useful information for instance on the comparability between a vessel and its peers, or it may show if a large number of the peer vessels have certain characteristics in common. Here, the analysis is restricted to a comparison of inputs between peer vessels and other vessels. Mean values for inputs are calculated for peer vessels and other vessels separately. For each input a ratio is calculated as the mean value of the peer vessels divided by the mean value of the other vessels. So for tonnage e.g., a value larger than one implies that the peer vessels are on average larger than the other vessels. The ratios for the inputs days at sea (das), engine power (kwH) and tonnage (EU-ton) are presented in figure 6.2

Figure 6.2 Differences between peer vessels and other vessels (VRS)



The results show that the peer vessels are approximately the same size or somewhat smaller than the other vessels, as the ratios are below or approximately equal to one. The interpretation is that on average the vessels are not compared with larger vessels in the estimations. This is an advantage if the fishing possibilities (such as the length of fishing trips or sensibility to weather conditions) are different for small and large vessels.

6.2 Constant Returns to Scale

Summary statistics for efficiency estimated using CRS is presented in table 6.2

Table 6.2 Summary Statistics for Efficiency Scores (CRS)

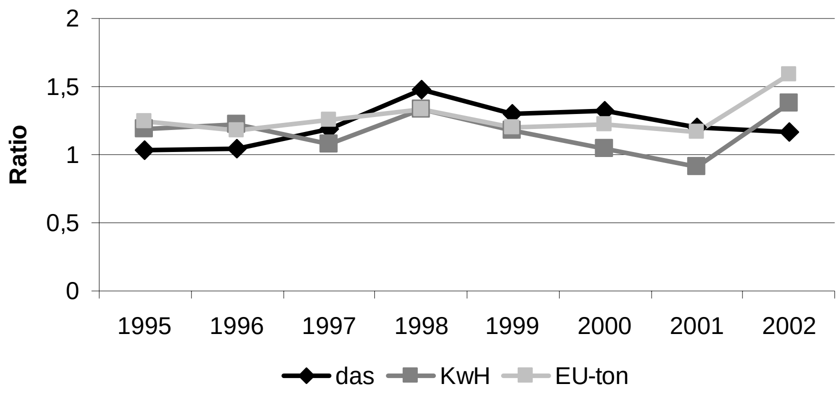
	Min	Max	Mean	Std. dev.	No. vessels
1995	0,29	1,00	0,72	0,21	65
1996	0,25	1,00	0,69	0,24	57
1997	0,21	1,00	0,68	0,25	58
1998	0,17	1,00	0,63	0,26	64
1999	0,27	1,00	0,75	0,23	56
2000	0,20	1,00	0,75	0,24	59
2001	0,35	1,00	0,80	0,19	53
2002	0,21	1,00	0,72	0,21	55

Mean efficiency for 2002 is 0.72. The interpretation is that vessels on average catch 72% of potential catches. Observe that the mean efficiency scores are lower for the CRS estimates than for the VRS estimates in each of the years. Mean efficiency shows a development similar to that in the VRS case, although the differences between the years are larger. The distinct decline in 1998 is of special interest. It does not occur in the VRS estimates, although the mean efficiency score is the smallest also for the VRS case in 1998. We also note that to a large extent efficiency follows the development of herring and sprat catches with a peak in 1998 followed by a decline in the coming years. In 1998 Sweden also gained access to a sand eel quota in the North Sea.

6.2.1 Peer Vessels

The relations of the input resources for peer vessels and other vessels are presented in figure 6.3.

Figure 6.3 Differences between peer vessels and other vessels (CRS)



As can be seen in figure 6.3, the peer vessels were larger all the years, but in 2001 the engine power of the peer vessels was less than that of the others (the ratio is less than one). The general picture though is that peer vessels are larger on average.

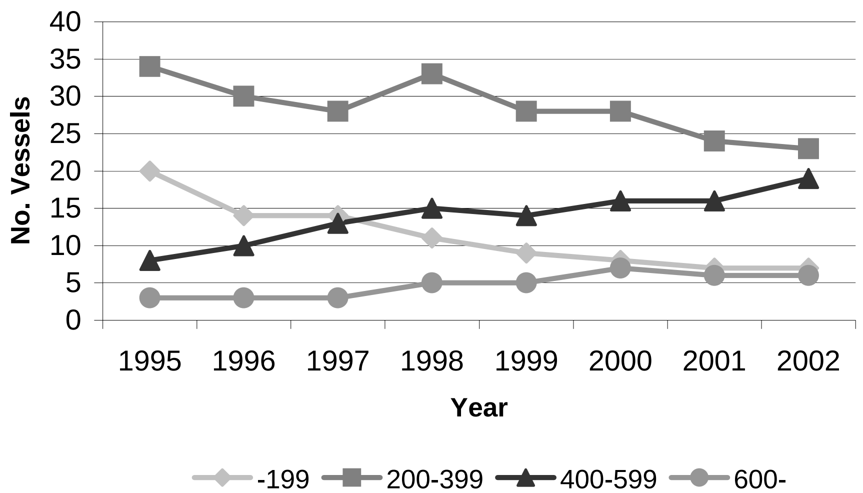
In 1998, when CRS efficiency had a peak, the ratios for all inputs are high. With the exception of 2002, the differences between peers and other vessels are at their largest this year. This might be explained by the fact that larger vessels were able to better utilize the increased fishing possibilities. When estimating efficiency assuming CRS, the scale of operation is not taken into account. Thus, small vessels may be compared to a point on the frontier that is a down-scaling of the production of a large vessel. Low efficiency may in the CRS case stem from an inefficient scale of operation. The relation between vessel size and efficiency is analyzed in section 6.3.

6.3 Size and Efficiency

The peer vessels are on average larger than other vessels when the efficiency index is estimated by using constant returns to scale. This indicates that it is an advantage to use larger vessels. An interesting question is therefore if large vessels systematically have higher efficiency indices than smaller vessels. If vessels of a certain size have higher efficiency indices than others, there could be a reason for analysing if they are better suited for pelagic fishing.

The vessels are divided into four size categories: Vessels less than 200 tonnes, vessels 200-399 tonnes, vessels 400-599 tonnes and vessels larger than 600 tonnes. The development from smaller to larger vessels during the period 1995-2002 is clear from figure 6.4.

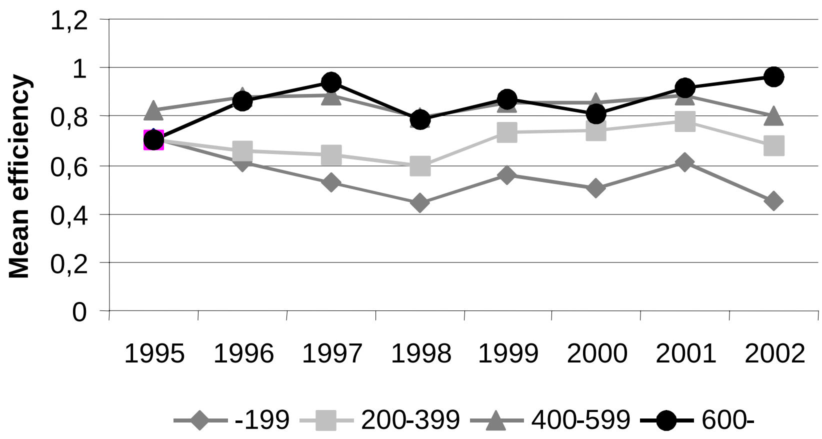
Figure 6.4. Number of Vessels in Size Classes



The number of vessels in the two smallest size classes has decreased during the period, while the number of vessels in the two largest size classes has increased. In 1995, 20 vessels under 200 tonnes operated in the segment, whereas in 2002 only 7 such vessels were left. The number of vessels between 200 and 399 tonnes decreased from 34 to 23, while the number of vessels between 400 and 599 tonnes increased from 8 to 19. Only few vessels are larger than 600 tonnes, 3 in 1995 and 6 in 2002.

Estimated mean efficiency using a CRS technology for the four size classes is presented for the period 1995-2002 in figure 6.5.

Figure 6.5 Efficiency (CRS) for size classes



It is clear from the figure that the two smallest classes have lower efficiency indices than the two largest. The size differences indicate that larger vessels are preferred from an efficiency perspective. When interpreting the results it is important to note that the development of the sector towards larger vessels implies that larger vessels will tend to be newer. Thus, the high efficiency scores for small vessels may to some extent be due to old fishing techniques that have not been taken into account in the efficiency model.

6.4 Age and Efficiency

Vessels built between 1995 and 2002 can be expected to function as peer vessels in the analysis because it has been possible to adapt the size and engine power of these vessels in accordance with the fishing opportunities that existed in the segment during the studied period. The vessels are e.g. larger than older vessels as discussed in section 4. Newer vessels may also to a larger extent fit modern fishing techniques. 11 vessels were built during the period 1995-2002 (9 vessels were active in the segment in 2002). In this section for the sake of simplicity we classify vessels built in 1995-2002 as modern, although of course other vessels also may have modern equipment. This, however, cannot be deduced from available data. The hypothesis is that modern vessels have higher efficiency indices than older vessels and that the modern vessels define the technological front with which others are compared.

The first year analysed is 1998. Three modern vessels were built before 1998 and two during that year. The constant returns to scale model is used since the question studied is caused by long-term decisions made by the fishermen. When investing in new vessels, decisions concerning size, engine power, etc, are choice variables and investments that are not on an optimal scale are defined as inefficiency in the CRS model. The same models as in section 6.2 are used, but the results are divided into vessels built before 1995 and vessels built in 1995-2002.

Results from the efficiency analysis are presented in table 6.3. The third column shows the total number of vessels in each age category. The fourth column shows the mean efficiency of these vessels. The number of vessels defined as efficient and how often these are used as peers for others is presented in the two last columns.

Table 6.3 Efficiency for Vessels Built Before 1995 and Vessels Built 1995-2002

Year	Age Category	No. Vessels	Mean efficiency	No. Efficient	Serves as Peers
1998	1995-2002	5	0,73	1	2
	-1995	59	0,62	10	131
1999	1995-2002	5	0,93	3	26
	-1995	51	0,73	8	121
2000	1995-2002	8	0,75	1	14
	-1995	51	0,75	14	118
2001	1995-2002	8	0,87	1	16
	-1995	45	0,79	10	108
2002	1995-2002	9	0,93	3	37
	-1995	46	0,68	5	87

The first observation is that the vessels built in 1995-2002 on average have higher efficiency indices in each of the studied years, except for 2000.[10] The number of peer vessels, however, is comparatively low for all the years, and the peer vessels are not used as peers for many other vessels either. So e.g. only one modern vessel functioned as a peer vessel in 1998, and this only twice. The other ten peer vessels in 1998 were older vessels. The interpretation is that many of the older vessels also have large catches in relation to the resources used. During the entire period 1995-2002, the modern vessels are high-performing but do not constitute a predominant part of the segment in terms of being peers to others. A possible explanation is that the modern vessels to some extent are used for targeting other species than older vessels.

6.5 Were Scrapped Vessels Less Efficient?

A crucial part of the CFP is to decrease the size of the fleet in order to achieve a balance between fish stocks and fishing capacity. Subsidies are granted for the decommissioning of vessels. It may be assumed that it is predominantly vessels with low efficiency scores that are decommissioned

[10] The result is in line with Andersen (2002b) who finds older Danish trawlers to be less efficient than newer.

(Vestergaard et al (2003)), since these vessels achieve lower catches with the same use of resources.

Data is available for vessels that have been decommissioned with financial support from the CFP. During the period 1995-2002, there were four such vessels. Data is available for the last year these vessels were active in the pelagic segment, but the vessels may have been active in other segments before being decommissioned.

The efficiency analysis shows that two of the decommissioned vessels had an efficiency index that was distinctly lower than average for both constant and variable returns to scale. The other two had average performance, which indicates that it is not necessarily only low-performing vessels that are decommissioned with subsidies from the CFP. However, with only four decommissioned vessels during the entire period it is not possible to draw any general conclusions.

7. Summary and Discussion

The importance of well-defined property rights in fisheries is strongly emphasized in economic theory. In an unregulated fishery, the theory predicts excess capacity, over-fishing, and low profitability. The symptoms are well known, and fishing fleets around the world have long been regulated by governments in order to deal with the problems. Examples of this are the management plans for fishing capacity in the EU, and FAO's international plan of action for fishing capacity. The future of the fishing sector is dependent on a balance between fleet capacity and biological resources. However, the long term economic development is also dependent on an efficient fleet where the fish is caught by using a minimum of resources. In this paper capacity and efficiency are analysed for Swedish vessels fishing in the pelagic segment between 1995 and 2002. The pelagic segment is the most important segment in Swedish fisheries both in terms of volume and value of landings. Vessels in the pelagic segment are primarily used for targeting herring, sprat, mackerel, and industrial species.

The present management of the pelagic fleet does not affect the basic features concerning property rights in the fishery. The pelagic species are regulated by free fishing under the TAC, two-week rations, and vessel specific quotas (these are only smaller quotas). A majority of Swedish fishermen are allowed to fish for pelagic species, so there is a potential for an increase in the number of vessels if the segment becomes more profitable.

The results of the empirical analysis show that the average capacity utilisation was 74 % in 2002. Both large and small vessels as well as vessels from the south and west coasts of Sweden are represented among vessels with both high and low capacity utilization. Calculating capacity utilisation as the number of vessels, it can be shown that the 41 vessels with highest technical efficiency would be able to generate the observed catches for 2002 if they were to utilize their capacity fully. 55 vessels were part of the pelagic segment in 2002.

Excess capacity is not a phenomenon that is unique to the fishing industry. In most industries the demand varies over time, and having excess capacity will enable a firm to increase its production when demand is high. In fisheries the stocks and thereby the fishing opportunities may vary considerably due to biological conditions. Some excess capacity may thus be profitable in the long run so that the fisherman can take advantage of periods with good fishing. However, the fishing sector is different from many other sectors because of the common ownership of the fish resources, and economic theory predicts an excess capacity that is not motivated by changes in fishing possibilities.

The efficiency of the vessels is studied in the paper with regard to the trend in the segment that newer vessels are larger than older. Investments have been made in large vessels, which indicate that larger vessels are better suited for pelagic fishing. The empirical results show that larger vessels in general have higher efficiency than smaller ones in the period studied. This confirms the hypothesis that there is economics of scale in the segment. The size difference between old and new vessels is especially manifest for vessels built before and after Sweden became a member of the EU in 1995. The newer vessels are considerably larger than the older and are expected to be more efficient since they are built to utilize the fishing possibilities optimally during the period studied. The analysis also shows that the modern vessels are more efficient on average. Thus, the general trend is towards larger vessels, and the high efficiency of these does not indicate any changes in this trend. However, a change of the regulations may also change the optimal size of a vessel.

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