Potential Rent and Overcapacity in the Swedish Baltic Sea Trawl Fishery

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Abstract

Many EU fisheries have problems with depleted stocks and fleet overcapacity following from regulated open access regimes. Some EU countries have introduced Individual Vessel Quotas (IVQs), which can stop the race to catch and provide the fishers with incentives to minimize costs for a given catch. We model an IVQ fishery using a cost function approach and apply the methodology to the Swedish cod fishery in the Baltic Sea. We estimate a translog cost function for a data set of Swedish trawlers and assess the potential gains from a structural adjustment of the fleet. Results suggest potential cost savings of SEK 140 millions and a desirable fleet reduction of 25% for the Swedish Baltic Sea cod fishery.

Keywords: cost function, efficiency gains, individual vessel quotas, Swedish fisheries.

JEL classification: D24, Q22

1. Introduction

Global marine capture fishery production has been declining since 1988 (Watson and Pauly, 2001) [1], and several important commercial stocks are severely depleted. During the same period technical improvements have increased the fishing power of most vessels. This has contributed to the overcapacity that is still a major problem afflicting marine fisheries (Kirkley and Squires, 1999). The fundamental underlying reason for these problems is the lack of well-defined property rights for marine fisheries (Gordon, 1954; Ostrom, 1990). Among economists, individual transferable quotas (ITQs) are generally seen as the most promising approach to handle these problems (Wilen, 2000). However, ITQs have met considerable resistance when introduced in e.g. USA and Iceland (Matulich and Sever, 1999; Matthiasson, 1997). Countries in the European Union (EU) have been reluctant to introduce ITQs.[2] A compromise is the use of individual vessel quotas (IVQs) where each fisher in a fishery gets the right to catch a share of the total allowable catch (TAC) but cannot buy or sell these shares. IVQs in various forms are now used inter alia in Norway, Sweden, Denmark and UK for certain species. The major contribution from IVQs is that the traditional incentive to 'race for catch' is altered and fishers can focus on minimizing costs for a given catch. But the IVQ system, unlike a successful ITQ system, does not imply capacity adjustment, which in the long run is necessary to handle the general problem of overcapacity. In traditionally managed fisheries with regulated- or unregulated open-access conditions each fisher can choose the size of their landings by increasing (decreasing) effort or changing various vessel characteristics to increase (reduce) fishing capacity. In principle, the same applies for an efficiently functioning ITQ fishery, where the only additional feature is that the fisher has to buy (sell) ITQ shares. The modeling implication of open-access and ITQ regimes is to use a profit function approach (e.g. Squires 1987 a, b and c) or a restricted profit function in case of

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[1] Excluding Peruvian anchoveta and adjusting for Chinese misreporting.
[2] The Netherlands is the only EU country, which uses ITQs to a greater extent.

input restrictions (Dupont, 1990 and 1991).[3] Choosing the output level is not an option for an individual fisher in an IVQ fishery, since the TAC share is given and cannot be changed. Fishers will focus on the cost in an IVQ regime and given that they are profit maximizers, we can expect them to minimize costs. Hence, we assume that fishers can choose input levels (endogenous variables), but face given input prices and output levels (exogenous variables). The appropriate modeling approach for an IVQ fishery is then a cost function (Christensen and Greene, 1976; for fisheries e.g. Bjørndal and Gordon, 2000; Asche, Bjørndal and Gordon, 2003).

In this paper we use a cost function approach to model the production technology of an IVQ regulated fishery. We apply the methodology to the Swedish cod fishery in the Baltic Sea and estimate a translog cost function for a data set of Swedish trawlers operating in 2001. The resulting estimates are then used to determine the optimal catch per vessel for this particular fishery and to assess the potential gains from carrying out the optimal fleet reduction after replacing all vessels by optimal ones. We also discuss an efficient fleet operating with an optimally managed cod stock for the Baltic Sea. The results indicate substantial scale economies at low levels of output and then fairly constant average costs for higher levels of output. Further, we note that there is significant overcapacity in the fishery and find that substantial gains can be made from down sizing and adjusting the fleet to optimal size vessels.

2. The Baltic Sea cod fishery

The Baltic Sea cod stock[4] was for a long period among the most productive in the world and during 1980-85 landings were more than 300 000 tons annually, which at that time constituted

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[3] See Jensen (2002) for an overview of applications of dual theory in fisheries.

[4] Biologists usually refer to two stocks in the Baltic, one west of the Bornholm Island and the other east. During the highly productive years, 1978-1986, the total stock was completely dominated by the eastern stock. For simplicity, we refer to these two stocks as one stock through out this paper.

more than 10% of global cod landings. After this period with severely high fishing mortality levels, the stock started to decline drastically and from 1993 landings have been around or below 100 000 tons (see fig 1 and 2).

[Fig 1 about here]

Today, the spawning stock biomass is judged to be outside safe limits and a four months moratorium was imposed during 2003 in order to restore the stock (Anon, 2003). The Baltic Sea fisheries are managed by The International Baltic Sea Fishery Commission (IBSFC), which was established in 1973. The IBSFC started to set TACs for the cod fishery in 1974, but due to disagreement on jurisdiction of the Baltic Sea there was no functioning TAC during the period 1982-88.

[Fig 2 about here]

The cod fishery has been subject to various measures and in the early 1990ies, when the spawning stock biomass (SSB) was estimated to be below safe limits, i.e. 240 000 tons, a temporary moratorium was imposed. The Swedish cod fishery in the Baltic Sea is carried out with fixed gear, i.e. mostly gill net, and with moving gear, i.e. mostly trawl. Landings with fixed gears amount to roughly 70%, while the remaining 30% is caught with moving gear. In 1995 a regulation was introduced for the Swedish cod fishery in the Baltic Sea, which resembles an IVQ system. All vessels are granted a weekly quantity of cod, which is increasing in vessel length. This system has been in place ever since, but the authorities have both increased and reduced the original rations during 1995-2003. In table I, we report the weekly rations for the Swedish vessels during 2001 where vessels below 9 meters length were allowed to catch 6.4 tons, vessels above 9 meters but below 21 gross registered tons (GRT) could catch 9.6 tons and so on.

[Tab I about here]

3. Modeling the Structure of Production in an IVQ Fishery

From a biological perspective changes in a fish stock depend on initial stock size, recruitment, growth, and catch. The proportionate relation between catch and stock is called fishing mortality, F, and the link to economics is often provided by an simple relation between F and the composite measure fishing effort, E. In a Gordon-Schaefer bioeconomic model the profit maximization problem for the fishing firm can be expressed as:

$$\Pi\ (y, E) = py - c\ (E) \qquad (1)$$

where p is the exogenously given price of fish and y is the output. The standard assumption is to assume a homogenous fleet implying a cost expression cE, i.e. constant marginal cost of effort, which is depicted as the straight total cost line in figure 3.

[Fig 3 about here]

If we relax the assumption of a homogeneous fleet, the various vessels could be illustrated by the piece wise linear curve, which still ends in point a) where total profits equal total benefits. A standardized unit of fishing effort employed on a given stock size leads to a given amount of catch, but the cost of producing this unit is lower the lower angle to the horizontal axis. The best practice is shown by the first segment of the piece wise linear curve, if all other vessels are replaced by such optimal ones, the total cost curve would be the dotted line which intersects the total revenue curve at c. In an open-access fishery, using optimal vessels would lead to equilibrium in c where all rents are dissipated as in a, but for an IVQ fishery each vessel has a given output and if all other vessels are replaced by optimal ones, there is a potential long run equilibrium which is shown by the intersection denoted b. An IVQ fishery with optimal vessels in equilibrium b, implies that a standard unit of fishing effort is produced at the minimum average cost but also by fewer vessels. The figure shows a measure of the partly restored resource rent as the vertical distance from a to b, while the fleet reduction is indicated by a shorter line but cannot be measured in size from the figure.[5] As noted earlier, we assume that the price p cannot be influenced by an individual fisher and the output y is exogenously given by the IVQ, which corresponds to a given level of fishing effort. Hence, a profit maximizing fisher is trying to produce the given amount of fishing effort at minimum cost, where we assume that fishing effort is a function of labor, capital and fuel[6] consumption. From duality theory we know that given certain regularity conditions, there exist cost and production functions which are dual to each other. Estimation of the cost function is more attractive when the level of output is exogenous as it is with a quota regulation (Christensen and Greene, 1976). Our objective is to estimate the minimum of a cost function C(y, **w**) where **w** is a vector of input prices.

3.1 Econometric Specification

We use a translog cost function, which is specified as follows:

$$\ln C = \alpha_0 + \Sigma_i \alpha_i \ln w_i + 0.5\Sigma_i\Sigma_j \alpha_{ij} \ln w_i \ln w_j + \alpha_y \ln y + 0.5\alpha_{yy}(\ln y)^2 + \Sigma_i \alpha_{iy} \ln w_i \ln y + u, \qquad (1)$$

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[5] For instance, if an optimal vessel equals the catch of two ordinary vessels at half of their total cost, the total cost line is 20% shorter for the optimal vessel but the actual fleet reduction is 50%.

[6] Fuel also include other consumable supplies like ice etc.

where C is the total cost, w_i is the price of input i (i = Fuel, Labor, Capital) and y is the level of output. By differentiating equation (1) with respect to the input prices and using Shephard's lemma, the set of cost-minimizing factor cost shares can be derived, given by

$$S_i = \alpha_i + \Sigma_j \alpha_{ij} \ln w_j + \alpha_{iy} \ln y + v, \tag{2}$$

where S_i is the cost share of the ith input, given by $w_i x_i / C$, and v is an error term. To improve the efficiency of the parameter estimates the cost function is estimated together with the cost share equations using Zellner's seemingly unrelated regression technique (Zellner, 1962).[7] Symmetry and homogeneity of degree one in factor prices are also imposed on the parameters. Input prices and output were normalized to their sample mean values prior to estimation.

From the cost function one can derive the returns to scale, which are defined as $\varepsilon_y = 1/(\partial \ln C / \partial \ln y)$. The conditional own price elasticity of demand for input i is defined as $\varepsilon_i = (\alpha_{ii} + S_i^2 - S_i)/S_i$ (Binswanger, 1974).

The marginal cost function of the translog model is:

$$MC = \partial C / \partial y = \exp(\ln C)\,(\alpha_y / y + \alpha_{yy} \cdot \ln y / y + \Sigma_i \alpha_{yi} \cdot \ln w_i / y) \tag{3}$$

3. 2 Data and variable construction

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[7] One of the share equations has to be deleted to obtain a nonsingular covariance matrix. The estimates are then asymptotically equivalent to maximum likelihood estimates and invariant to which equation is deleted (Barten, 1969).

The Swedish National Board of Fisheries collected the data used in this study. The log book database identifies vessel, including various vessel characteristics, fishing effort, gear type and landing date on a per trip basis. Economic data comes from a sample of vessels' tax reports for the year 2001, which include gross revenues, expenditure data on fuel, maintenance, insurance, labor costs, crew size, ice and product fees. The merged data set from these two data sets provides information on annual fishing effort, gross revenues and total costs. The total sample of observations was 37 vessels but due various missing items, the final analysis was carried out on 30 observations.[8] We report mean values for the sample vessels in table II with corresponding figures for all 37 vessels in brackets and note that the sample is representative for the population.

[Table II about here]

Total costs are divided into three components, capital costs, fuel and other operating costs, and labor costs. Capital cost is defined as the sum of depreciation costs and opportunity cost. Several vessels in the sample are old and there is a general tendency among fishers to invest surpluses from successful years in equipment, e.g. reducing mortgages on the vessel. The result is that recorded depreciation and interest costs are low, the annual average is 6% of the total capital value, and would lead to downward biased estimates of the capital cost. We add a social user cost of capital changing the average price of capital to 12% of the total capital, which is more in line with previous studies (e.g. Squires, 1987a). The price of capital (w_1) is defined as the capital cost divided by total capital, where total capital is measured by the insurance value. The composite price of fuel and other inputs (w_2) is calculated using monthly prices on fuel from IEA and monthly prices on materials and services from Statistics Sweden.

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[8] All costs, output, and revenue data are confidential at the level of the individual firm.

We calculate the average annual fuel price for each vessel by using the number of trips per month as weights in the Divisia index. The price of labor (w_3) is defined as recorded labor costs divided by crew size. Output (y) is measured by harvest in kilos.

4. Empirical Results

In table III, we report the descriptive statistics for the sample variables used in the estimation.

[Table III about here]

The estimated parameters are provided in table IV. The R-square statistics for the cost function is 0.999, while the corresponding figures for the two share equations, capital and fuel costs, were 0.855 and 0.962 indicating a good fit of the data.

[Table IV about here]

The parameters of flexible functions are difficult to interpret. We provide the own price elasticities, which are significant at the 1% level, in table V. All the elasticities have the expected negative sign and we see for instance that the $\varepsilon_{capital}$ = - 0.63. All else equal, this indicates that a 1% increase in capital costs will lead to a capital reduction of 0.63%. Returns to scale is derived at the mean prices and output level and found to be 1.43, which indicates substantial economies to scale.

[Table V about here]

In figure 4, we plot the estimated marginal and average cost curves. The optimal catch, given the prevailing regulation, was 880 tons during 2001. We note the large reductions in unit costs for annual landings up to around 400 tons, while landings above that level do not enjoy scale economies to any larger extent and as noted above, scale diseconomies occur for landings above 880 tons.

[Fig 4 about here]

The optimal annual catch of 880 tons is based on estimates where we have added a 6% user cost of capital to adjust for the low mortgage loans. In table VI we report the optimal catch levels depending on the assumed additional user cost.

[Table VI about here]

The optimal catch when the additional user cost is excluded and only the actual capital figures are used is way above the highest catch recorded. This is likely a reflection of the regulated open-access regime (Homans and Wilen, 1997) of all Swedish fisheries before 1995. All vessels in the sample are constructed before 1992, with one exception of a mid size vessel built in 1999.

The overall picture is that this industry has the often found L-shaped average cost curve (e.g. Robidoux and J. Lester, 1992) with large returns to scale in the lower interval and then a flat AC curve. The flat AC curve is the reason for the sensitivity of the optimal catch level. We also note that the suggested optimal levels are above the actual landing figures, where the maximum was about 400 tons. As a consequence and to get a conservative estimate, we assume that the optimal landing level is in the range 300-400 tons. If the sampled vessels were replaced by vessels landing 300-400 tons the cost reduction would be almost 40% and about ten vessels of the larger size from the sample instead of 30 could have harvested the same amount of fish, which corresponds to a reduction in GRT of about 25%. Further, assuming that our sample was representative of the Swedish cod trawler fleet in the Baltic Sea at that time and that the trawlers have an equal or better performance than the vessels using fixed gear, the optimal size vessels could have replaced the gill net fishers and landed all of the Swedish quota of cod, which in 2001 was almost 18 000 tons. The gains from landing at a unit cost of SEK 12.50 instead of SEK 20 would lead to a total profit of about SEK 140 millions, which corresponds to almost 40% of the total landing value in 2001, SEK 370 millions.

5. Policy Implications and Conclusions

In this paper we model an IVQ fishery by assuming that fishers aim at minimizing cost, and apply the model to the Swedish cod fishery in the Baltic Sea. The results indicate an L-shaped average cost curve with considerable scale economies at low levels of output but exhausted economies of scale at output levels of the larger vessels in the fleet. We find that there are substantial gains to be made from adjusting the fleet to enjoy scale economies. It is interesting to note that the larger vessels on average are more profitable despite the prevailing regulation where the weekly allocation system is designed in favor of the smaller vessels. The estimated optimal landing level is sensitive to the chosen additional user cost of capital, but the initial cost reductions from increasing landings from the lower landing intervals are robust. However, the additional user cost is not perceived by individual fishers and the estimates then confirm how regulated open access leads to overcapacity, which has not yet been reduced in the Swedish fishery. Our study indicates cost savings of SEK 140 millions and capacity reductions of about 25% for the given stock level. Recalling the current poor state of the Baltic Sea cod stock it is plausible that the potential rent from a cost minimizing industry exploiting a recovered cod stock are substantially larger. A recovery to what biologists recommend, i.e. 240000 tons, implies an increase of roughly three times the 2001 level. Doubling the stock level for a uniformly distributed species like cod implies a doubling of landings from the same amount of effort. However, a substantial stock recovery should rather be accompanied with further effort reduction, i.e., fleet reduction. The EU has aimed at structural adjustment for more than 20 years through the multiannual guidance programmes, but overcapacity is still a major problem for European fisheries. According to recent estimates there is more than 40 per cent overcapacity in the total EU fleet (DG Fish, 2000). The estimated 25% reduction is for the given stock level, but a recovered stock implies further fleet reduction. In terms of rent, such stock improvements may lead to increased landings and some price reductions, but a moderate assessment of the potential rent for the Swedish part of the cod fishery in the Baltic Sea is in the range SEK 300-400 millions and the corresponding figure for the total cod fishery in the Baltic Sea is then SEK 1000-2000 millions.

An additional feature of a regulated open access, which applies for most Swedish fisheries, is the general uncertainty of a seasonal closure. Most Swedish fishers tend to be risk averse (Eggert and Tveterås, 2004) and the more risk averse they are the more they support the introduction of IVQs (Eggert and Martinsson, 2004). Swedish taxation is asymmetric in the sense that profits are taxed while investments are deductible. The overall outcome of these conditions is that the stochastic nature of fisheries with some very profitable years leads to fishers reinvesting heavily, which often means reducing mortgages, instead of consuming profits. An article in a daily Swedish paper sheds some light on this issue:

> *"The two brothers bought the vessel in 1997 and paid half of the total 14 millions cash. They got an interest free loan of 3 millions from the EU, which is depreciated by 10% annually, and the remaining 4 millions from the bank are*

> *completely repaid today. The Sorensson brothers do not have any interest to worry about"* (Göteborgs Posten, 2004)

Given our conservative estimate of the optimal landing size a 25% fleet reduction is desirable and the potential rent from such reduction could be 40% of the total landing value in 2001. These figures may seem high to fisheries managers, but are low or in line with the few similar studies of this area. Dupont (1990, 1991) estimates the potential rent to 42% for the British Columbia salmon fishery and hold that the fleet should be reduced by 50%. Weninger (1998) estimates the optimal fleet reduction to 80% for the Mid-Atlantic surf clam and ocean quahog fishery, but does not provide a measure of potential rent. Asche et al (2003) estimate the potential rent in Norwegian fisheries to 60-70% of the landing values given that the fleet is reduced by 70%. Weninger and Waters (2003) study the reef fishery of the Northern Gulf of Mexico and hold that an optimal fleet reduction should exceed 80%. Given the regulated open access nature of Swedish fisheries we note that fishers whenever they find it suitable can target other fisheries elsewhere than the Baltic Sea cod fishery. We could also identify such behavior to some extent in our data sample. On average 20% of the trips had destinations outside the Baltic Sea, which also reflects the over capacity. The structural adjustment programs have at best reduced overcapacity with less than 10%, but mostly served as an income transfer to the remaining vessel owners (Weninger and McConnell, 2000). This study clearly indicates that fleet reduction has to be substantially larger than what has been done within these programs.

Our results indicate that the rent for the Swedish part implies SEK 100-200 millions. The potential gains are of course larger, firstly a build up of the cod stock to three times of the 2001 level would lead to substantial increases. Secondly, the Swedish system uses weekly rations, which means that fishers cannot optimally allocate their trips but are forced to make at least a trip per week to enjoy all possible catch. This is a drawback of this system, which may have other benefits. One potential benefit, not explored in this paper, is a higher level of compliance. Monitoring and enforcement activities in this system induce higher risk of detection, compared to an annual IVQ system, for those who try to exceed their quota allocation. Overall, our assessment is that the Swedish weekly rationing system has mitigated the depletion of the Baltic cod stock, but has not been successful in generating rent. A first step towards such a development would be to explicitly allocate IVQs in all Swedish fisheries and eliminate the incentive to first catch your IVQ and then target non-IVQ species, which is possible behavior today. The greatest merit of the prevailing regulation is probably that it paves the way for necessary changes in Swedish fishery regulation. These changes include a more complete use of IVQs and the introduction of ITQs for some segments of the fishery to facilitate some of the necessary capacity reduction.

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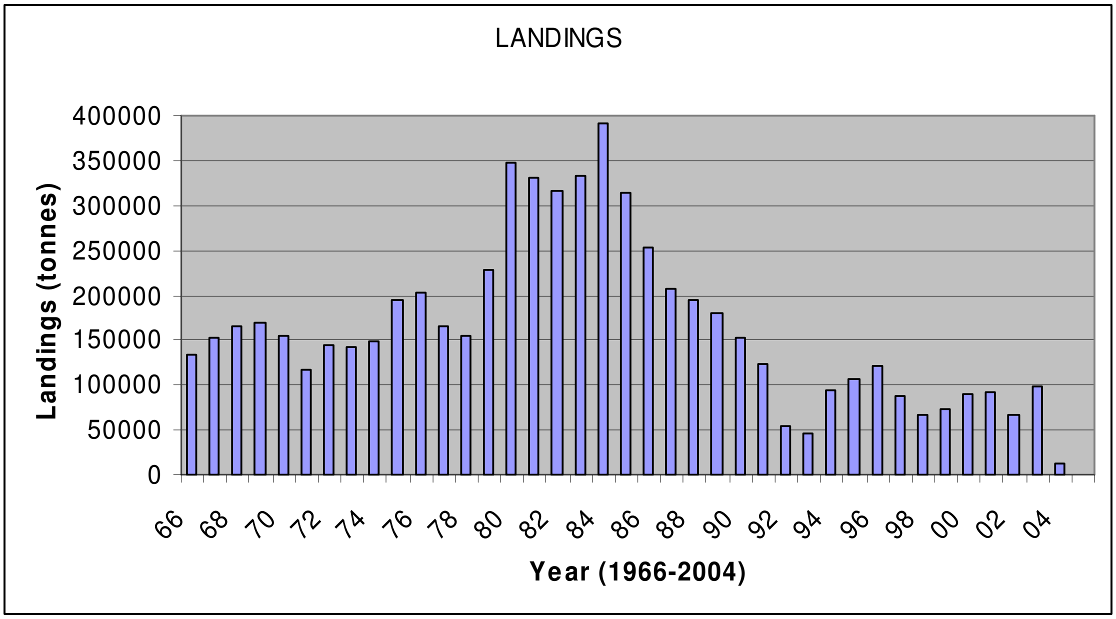
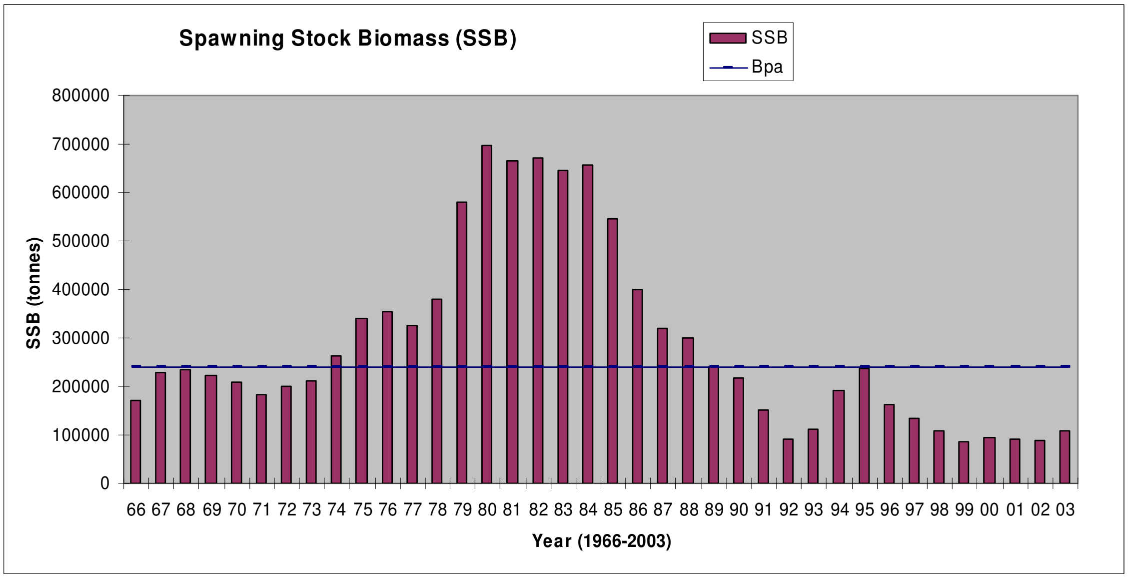
Figure 1. Annual landings of cod in the Baltic Sea, 1996-2004



Figures for 2003-04 are predicted values, given that the recovery plan is carried out (Anon, 2003)

Figure 2. Spawning Stock Biomass of cod, Baltic Sea, 1966-2003.



Figures for 2003-04 are predicted values, given that the recovery plan is carried out (Anon, 2003)

Figure 3. Open-access and Individual Quota regulation with heterogeneous costs

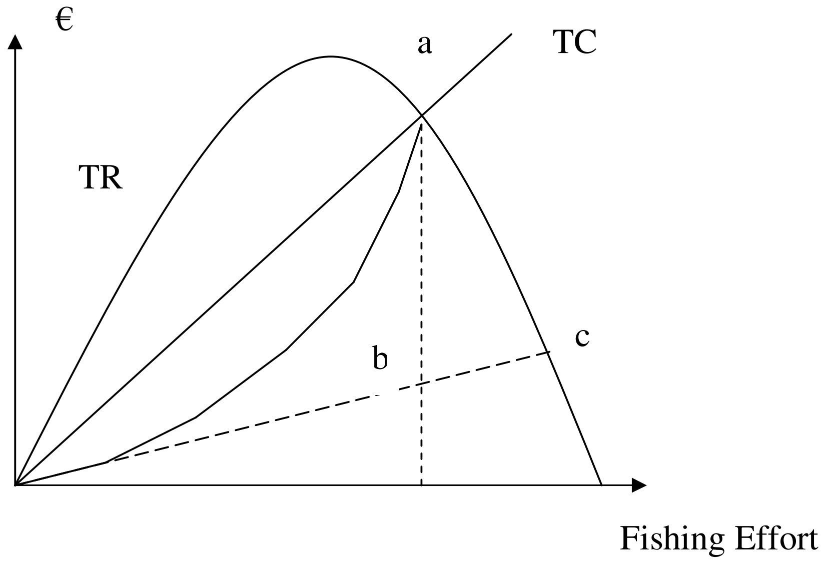
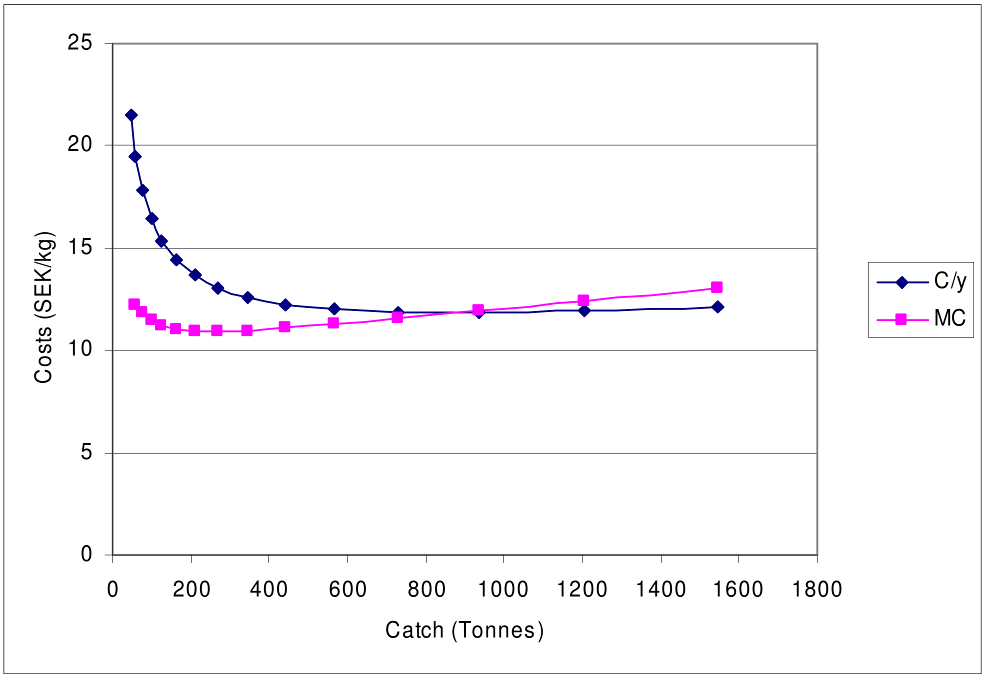


Figure 4. Predicted Cost Function for Sample Average Vessel



Optimal catch = 880 tons

Table I. Swedish weekly rations of cod in the Baltic Sea, 2001.

Vessel length (GRT)	≤9 meters	>9 m & < 21 GRT	21-40	40-55	55-80	80-106	106-131	131-161	>161
Weekly ration (tons guttered cod)	6.4	9.6	12.8	16.0	19.2	22.4	25.6	28.8	32.0

Table II. Key characteristics of the Baltic Sea cod trawlers, mean values.

	No of obs	Vessel size (GRT)	Crew	Vessel value (SEK 10^6)[9]	Revenue (SEK 10^6)	Costs (SEK 10^6)
Swedish Baltic Sea cod trawlers	30	113	3,2	4.5	2.4	2.4
	(37)	(114)	(3,2)	(4.6)	(2.4)	(2.4)

€ 1 = SEK 9.0, November, 2004.

Table III. Sample Descriptive Statistics

Variable	Mean	Std. Dev.
Cost (SEK)	2425904	1911283
Share1 (capital)	0.240	0.133
Share2 (Divisia fuel)	0.573	0.138
Share3 (labor)	0.187	0.151
Price of capital (w_1)	0.124	0.052
Divisia fuel price (w_2)	1.108	0.010
Labor cost(w_3)	148136	147596
Catch (kg)	141157	111745

Table IV. Translog SURE Cost Function Estimates

Variables	Coef.	Prob.val.
Const.	17.036	0.00
αy	-1.023	0.21
αy2	0.138	0.08
α1	0.885	0.00
α2	0.306	0.14
α3	-0.191	0.31
α11	0.031	0.46
α12	-0.027	0.51
α13	-0.004	0.52
α22	0.055	0.17
α23	-0.028	0.00
α33	0.032	0.00
αy1	-0.047	0.01
αy2	0.043	0.01
αy3	0.004	0.82

Table V. Estimated Elasticities*

	Mean	St.error	T-value
ε_y	1.425	0.173	8.22
$\varepsilon_{Capital}$	-0.632	0.179	-3.54
ε_{Fuel}	-0.330	0.072	-4.61
ε_{Labor}	-0.640	0.029	-21.92

* $\varepsilon_i = (\alpha_{ii} + S_i^2 - S_i)/S_i$ where i = Capital, Fuel, Labor, $\varepsilon_y = 1/(\partial \ln C/\partial \ln y)$

Table VI. The optimal annual catch depending on additional user cost of capital.

Additional user cost of capital	0%	3%	6%	9%	12%
Optimal catch (tons)	6000	1700	880	670	570