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COST STRUCTURE AND CAPACITY IN THE NORWEGIAN PELAGIC FISHERIES

by

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Abstract:

The parameters of the short-run cost function are estimated for three vessel types taking part in the Norwegian pelagic fisheries: purse seine vessels, trawlers, and coastal vessels. The generalised translog functional form is used. Estimates of returns to scale are calculated and the results indicate that there are substantial economies of scale in all vessel classes. We further investigate whether overcapacity varies with vessel size and age. The analysis suggests increased quotas per vessel to avoid rent dissipation. With the total allowable catch given, the number of participating vessels must be reduced.

1. Introduction

The broad opinion in the Norwegian fishing industry is that there is considerable overcapacity in the pelagic fisheries. Three vessel types participate in these fisheries; coastal vessels, trawlers, and purse seine vessels. However, in a study of the fisheries using data for 1994-96, Bjørndal and Gordon (2000) did not find evidence of large economies of scale. They conclude that most of the returns from scale effects have already been captured, and that only coastal vessels have more to gain by taking advantage of increasing returns to scale. The purpose of this study is to reconsider the issue of returns to scale and overcapitalisation in the Norwegian pelagic fisheries using newly available data for the years 1998-2000. Multi-output cost functions are estimated for each of the three vessel classes. Based on the results, returns to scale can be computed for each class of vessels. If there are returns to scale (RTS), the production structure is suboptimal and rent is dissipated in the fishery.

The aim of the study is to gain empirical knowledge of the production and cost structure of the fishery and to use this knowledge to evaluate the question of overcapacity. Despite the results of Bjørndal and Gordon (2000), we expect to find evidence of returns to scale in the fishery in question. Since the fishing fleet is constantly being renewed, returns to scale might change with vessel age. The continuous renewal of the fleet can also explain a possible change in returns to scale since Bjørndal and Gordon’s study. If new vessels are larger than the ones they replace, overall returns to scale will be affected. We will therefore investigate if and how returns to scale vary with vessel age and size in each vessel class. This aspect has not been considered by Bjørndal and Gordon (2000) and might give further insight into the overcapitalisation issue. An understanding of how returns to scale vary between different segments of the fleet can be used to determine how best to allocate quotas among fleet segments, and to choose which vessels, if any, should be withdrawn from the fishery.

The pelagic fisheries are regulated with catch quotas and effort regulations. Total allowable catches (TACs) are set annually for commercial species and are then distributed as 'group quotas' among three classes of vessels. The further distribution of group quotas among vessels within a group differs depending on species and vessel class. The purse seine vessels are provided individual vessel quotas (IVQs) in all their fisheries. IVQs are allocated to trawlers in their main fisheries (primarily demersal species). For other species, trawlers are allowed to fish within maximum quotas. Under a maximum quota there is an upper limit to a vessel's total catch of a species. The sum of maximum quotas is larger than the group quota and the fishery is therefore closed before all vessels have landed their maximum quotas.[1] Maximum quotas are employed in all of the coastal vessels' fisheries.

A quota-transfer system called the unit quota system was introduced in the trawler and purse seine fleets in the early 2000 by the Norwegian government to address the overcapacity problem (Norwegian Ministry of Fisheries 2004). Under the unit quota system, the number of assigned (unit) quotas is larger than the number of participating vessels. If a vessel with unit quotas is withdrawn from the fishery, its quotas, reduced by 20% (redistributed among all remaining vessels in the fishery), can be transferred to and used by other vessels for 13 to 18 years.

Gordon (1954) identified how overcapitalisation and overfishing would be a problem in an open-access fishery. Under open access, fishing effort increases and the fish stock is depleted until fishing is no longer viable. Although the Norwegian pelagic fisheries are no longer open access, the regulatory regime has not eliminated the incentive to race for fish for every vessel in the fishery. Trawlers and coastal vessels still have to deal with maximum quotas in some or all of their fisheries. As long as all fishing vessels do not have a guaranteed share of the total quota, these vessels will have incentives to overcapitalise. To deal with such problems, fishery managers have typically imposed regulations to restrict fishing effort, but numerous examples show how difficult this is. Munro and Scott (1985) identify the problem of overcapacity in regulated fisheries,

[1] See Aarland and Bjørndal (2002) on fisheries management in Norway.

which they refer to as class II open access. Homans and Wilen (1997) illustrate how regulated open-access fisheries can have very high overcapacity. The introduction of individual transferable quotas (ITQs), an approach based on assigning property rights to the fish stocks, is a solution which has been proposed to address these problems (see e.g. Grafton 1996). Individual vessel quotas are similar to ITQs but cannot be transferred between vessels. An IVQ system will all the same reduce the incentives to overcapitalise since every vessel is provided a guaranteed share of the TAC and therefore does not need to race for fish. Economies of scale can be a sign of overcapacity in a fishery.

The use of maximum quotas to regulate the coastal vessel's total harvest gives these vessels incentives to overcapitalise. We therefore expect to find evidence of increasing returns to scale in the coastal fleet. Trawlers largely operate under maximum quotas in the pelagic fisheries. These quotas are, however, mainly by-catch quotas to restrict by-catch in the trawlers' main fisheries, which primarily are demersal fisheries wherein trawlers are assigned IVQs. If the main fisheries determine the degree of capitalisation, there should be less overcapitalisation in the trawler fleet than in the coastal fleet. Overcapitalisation and scale economies might, however, still be present both in the trawl and the purse seine fisheries, as the introduction of IVQs in these fisheries happened in 2000[2]. If there was overcapacity in the fisheries when the IVQ system was introduced, there might still be overcapacity if the vessels have not had strong enough incentives to reduce capacity. The IVQ system eliminates the incentive to race for fish. Vessel owners have, however, no incentive to withdraw vessels from the fishery, as they are not allowed to transfer or allocate the withdrawn vessels' quotas among other vessels. This changes if quotas are made transferable as under the individual transferable quota system or, to some degree, under the Norwegian unit quota system.

The rest of the paper is organised as follows. In the next section, the data set and the Norwegian pelagic fisheries are described. The third section presents the model and

[2] IVQs have been used in some fisheries on a temporary basis prior to 2000. The introduction of IVQs in 2000 was however permanent (Norwegian Ministry of Fisheries 2004).

estimation results. The production structure of the fishery and policy implications are analysed in the fourth section. The final section summarises and concludes.

2. The Norwegian Pelagic Fisheries

The data for the empirical analysis have been made available by the Norwegian Directorate of Fisheries, which gathers data on a random sample of vessels annually. The data include information on expenditures, revenues, catches, and vessel specifications for vessels which are 13 metres overall length and above.

Three vessel types are defined in the data set: purse seine, trawl, and coastal vessels. The definitions are based on the technologies employed. Purse seine vessels use a purse seine net to catch schools of fish. After locating a school of fish, the vessel sails around it and surrounds the fish with a wall of net. By closing the bottom of the seine, a purse is formed. When the seine is pulled, the top of the purse is drawn closed and the fish are trapped in the net purse. The purse seine is very effective when it comes to harvesting pelagic schooling species like herring and mackerel.

Trawlers use a cone-shaped net (trawl) to harvest fish. By pulling the net through deep water (pelagic trawl) or across the bottom (bottom trawl), fish are scooped into the trawl. The trawlers operate mainly in the North Sea.

Vessels in the coastal fleet are not as homogenous as vessels in the two other vessel classes. Common factors for our observations on coastal vessels are an overall vessel length of 27 metres or less and a harvest of 50 tonnes or more of Norwegian spring-spawning herring. Apart from this, the coastal fleet constitutes a diverse group of fishing vessels including vessels employing the following fishing gear: gill net, hand line, long line, Danish seine, trawl, *etc*. Most coastal vessels operate close to the coast although this depends on among other things the fishing gear employed.

The data set covers the three-year period 1998-2000. Table 1 gives the number of observations per year. For each vessel, data are available on the following expenditures: fuel, product fees, bait etc., social costs, insurance (vessel and other), maintenance (vessel and gear), miscellaneous, labour, and depreciation based on historical cost. The catch and revenues data consist of quantity (kg) and value in Norwegian Kroner (NOK) of Norwegian spring-spawning herring, North Sea herring, mackerel, blue whiting, capelin, sandeel, and 'other species'. The following information is available on vessels: vessel type (purse seine, trawler or coastal vessel), length of vessel, gross registered tonnage, tonnage units, licensed capacity, and age.

All fish species specified in the data set are pelagic with the exception of sandeel and 'other species'. Sandeel is a demersal species but it alternates between staying on or close to the bottom and swimming in schools in the water column. Blue whiting belongs to the cod family, but is nevertheless considered a pelagic species. Blue whiting is normally harvested at 300-400 meters depth. Norwegian spring-spawning herring, North Sea herring, and mackerel are schooling species most often found and harvested close to the surface. Capelin, a member of the salmon family, is also a pelagic species found in schools. While the other fish species mentioned here are caught along the Norwegian cost, in the North Sea, in the Norwegian Sea, and/or in the West-Atlantic, the capelin fishery takes place far north; from Spitzbergen in the west and eastward in the Barents Sea.

As can be seen in Table 1, the data set consists of 222 observations on purse seine vessels. In terms of revenues, Norwegian spring-spawning herring is most important for purse seine vessels followed by mackerel, blue whiting, and North Sea herring (Table 2). Measured by volume, we can see from Table 2 that blue whiting is the largest species. However, not all purse seine vessels harvest blue whiting, capelin, and sandeel. Data on trawlers are available for vessels that have caught more than 50 tonnes of Norwegian spring-spawning herring. The data set includes a total of 84 observations on trawlers (Table 1). As can be seen in Table 2, sandeel brings in the highest revenues for the average trawler followed by Norwegian spring-spawning herring, blue whiting, and mackerel. We have 175 observations on coastal vessels. All of these vessels have harvested more than 50 tonnes of Norwegian spring-spawning herring. The data set shows that coastal vessels do not participate in the blue whiting or sandeel fisheries (Table 2). The Norwegian spring-spawning herring fishery generates the largest share of revenues for the average coastal vessel, which is also largest in terms of quantity.

Landings of all pelagic species can be reduced to fish oil and fish meal. While landings of herring and mackerel are also delivered for human consumption, capelin and blue whiting are almost exclusively used in the production of fish meal and fish oil. A higher price is typically obtained for landings delivered for human consumption and, as a result, high quality herring and mackerel are normally delivered for human consumption. Both harvesting method and the way fish are stored vary between the fleets, affecting the quality and consequently the price of landed fish.

Average first-hand prices of harvest, measured in 2000 NOK, by fleet and species are presented in Table 2. The table confirms that prices depend on vessel type. Purse seine vessels obtain the highest price for almost every species. The exception is capelin for which coastal vessels obtain the highest price. Trawlers obtain the lowest prices for all species. Note that average price of ‘other species’ is not comparable between vessel classes. For coastal vessels, other species are seen to be very valuable. As some of these vessels utilise fishing gear which makes it possible to harvest and land valuable fish of very high quality, the high price obtained for these catches raises the average price of ‘other species’.

The vessels range in age from less than one year to 62 (purse seine), 51 (trawlers), and 111 years (coastal vessels). The average vessel in the data set is 23 years old. The trawlers are on average the oldest fleet segment, followed by purse seine and coastal vessels. Table 3 shows upper limits for capacity and age quartiles by vessel group. Tonnage units, a measure of vessel size, are used as measure of vessel capacity for purse seine vessels and trawlers, whereas gross registered tonnage (GRT) are used as the capacity measure for coastal vessels. The available data do not allow us to use the same capacity measure for all three vessel types. For the vast majority of coastal vessels, data are available on GRT and not on tonnage units, for most trawlers and purse seine vessels, on the other hand, only data on tonnage units are available.

3. Empirical Specification and Estimation

The duality approach offers a framework for analysing the harvesting technology and cost structure of the fishing firms. Empirical knowledge of the relationship between input factors and outputs can be used to analyse returns to scale in the fishery. The purpose of this section is to gain the necessary empirical knowledge of the cost structure of harvesting for the three vessel types in the Norwegian pelagic fisheries. We start out by specifying the empirical model.

The quantity landed by a vessel is given by the vessels' quotas if the quota constraints are binding.[3] The rational fishermen then minimise costs given their quota restrictions, rather than maximise profits. Harvest can in this case be explained by a harvest or production function $Y = f(X, K)$, where Y is an output vector, K is capacity or capital (assumed fixed), and X is an input vector. The fishermen's cost minimisation problem can thus be written as:

$$VC\left(W, Y, K\right) = \min_{X \geq 0} \left\{W \cdot X : f(X, K) = Y\right\}, \tag{1}$$

where W is a vector of input prices (variable inputs).

The vessels' variable costs are mainly wages, fuel, and vessel and gear maintenance. As crew remuneration is a given fraction of the vessel's catch value, we disregard wages. The data are therefore used to define two price indices. First, a price index for fuel w_f that measures the cost of purchasing fuel. The data set does not include information on the quantity of fuel used or purchased. Following Bjørndal and Gordon (2000), a proxy variable for fuel quantity is calculated based on a Cobb-Douglas aggregator function. Equal weight is given to vessel length and total catch quantity in the aggregator function

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[3] We assume that vessels for which the quota constraints are not binding also minimise costs.

and the price index of fuel is defined as expenditure on fuel divided by the proxy variable. Second, we define the vessel-price index w_v as expenditure on insurance (vessel and other), maintenance (vessel and gear), bait etc., and 'other costs' divided by the vessel's total catch quantity. The vessel-price index is an aggregate index measuring the cost of maintenance of vessel and gear and the insurance cost.

Summary statistics for price indices can be found in Table 4. While the fuel price index has been increasing significantly over the period, the vessel price index is seen to be more stable. The increase in the fuel-price index is likely to reflect the corresponding increase in the price of oil. The coastal vessels have the lowest price index of fuel and the highest price of maintaining vessel and gear. The difference in fuel prices between purse seine vessels and trawlers is seen to be small whereas the vessel price index is higher for purse seine vessels than for trawlers.

The generalised translog functional form (Caves *et al.* 1980) is used to specify the cost function:

$$\begin{aligned} \ln VC_t &= \alpha + \sum_i \alpha_i \ln w_i + \frac{1}{2}\sum_i \sum_j \beta_{ij} \ln w_i \ln w_j + \sum_m \alpha_m y_m^{(\lambda)} \\ &+ \frac{1}{2}\sum_m \sum_n \beta_{mn} y_m^{(\lambda)} y_n^{(\lambda)} + \sum_i \sum_m \beta_{im} \ln w_i y_m^{(\lambda)} + \alpha_K \ln K \quad , \\ &+ \frac{1}{2}\beta_{KK} (\ln K)^2 + \sum_i \beta_{iK} \ln w_i \ln K + \sum_m \beta_{mK} y_m^{(\lambda)} \ln K + \alpha_t D_t + e \end{aligned} \tag{2}$$

where VC_t is the sum of variable costs in period t, D_t is a year dummy,[4] e is an error term, i, j are input factors (fuel and vessel, as defined above) and m,n are outputs. The superscript in parentheses represents the Box-Cox transformation of outputs: $y^{(\lambda)} \equiv \left(y^{\lambda} - 1\right)/\lambda$, where λ is a transformation parameter. $y^{(\lambda)} \to \ln y$ as $\lambda \to 0$, thus with $\lambda = 0$ the model reduces to the standard translog function.

[4] As an alternative to additively including dummy variables for year like we have done here, terms in the cost equation could have been multiplied by the dummy variables, giving us the opportunity to analyse if and how different parameters change from year to year.

As we are dealing with multi-product firms for which zero-output observations may occur, it is inappropriate to use the ordinary translog functional form. The generalised translog function allows for zero-output observations and is therefore preferred. Several other functional forms have been suggested for estimating cost functions for multi-product firms, including Pulley and Braunstein's (1992) composite cost function. Pulley and Braunstein found that when the generalised translog function is a close approximation to the standard translog function, *i.e.*, for small values of λ, the generalised translog might cause problems when estimating economies of scope. The generalised translog functional form is used in the current analysis despite the reported shortcomings.

By applying Shephard's Lemma, the cost share equations associated with equation (2) can be written as:

$$s_i = \frac{\partial \ln VC_t}{\partial \ln w_i} = \alpha_i + \sum\nolimits_j \beta_{ij} \ln w_j + \sum\nolimits_m \beta_{im} \ln y_m^{(\lambda)} + \beta_{iK} \ln K + u \,, \qquad (3)$$

where s_i is a cost share, and u is an error term. Equation (2) and the share equation for fuel (s_f) are estimated using iterative Seemingly Unrelated Regression (SUR). By dropping one of the share equations from the system, the singularity problem, arising from the fact that the cost shares sum to one, is avoided. The iterative procedure converges to the maximum-likelihood results. Maximum-likelihood estimates of the cost function and share equations are invariant to which equation is dropped (Barten 1969). The following estimation routine is used: The system of equations is estimated for different values of the Box-Cox transformation parameter, $0 < \lambda < 1$. Estimation results and $\hat{\lambda}$ are reported for the regression that yields the highest log-likelihood value.[5]

For the cost function to be well behaved, it must satisfy homogeneity of degree one, monotonicity, and convexity in factor prices (Diewert 1974). Linear homogeneity can be

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[5] As a consequence of the estimation procedure, λ is taken as given when the other parameters of the cost function are estimated. The reported standard errors are therefore lower than they would be if all parameters, including the Box-Cox transformation parameter, λ, were estimated simultaneously.

imposed by adding linear parametric restrictions on the estimated cost function.[6] Monotonicity and convexity in prices can be tested after estimation and are satisfied if the fitted cost shares are positive and the Hessian matrix of the cost function with respect to factor prices is negative semi-definite.

An indicator of returns to scale for a multi-product firm with a fixed factor is given by:

$$RTS = \left(1 - \frac{\partial \ln VC}{\partial \ln K}\right)\left(\sum_n \frac{\partial \ln VC}{\left[\partial y_n^{(\lambda)}\right]} y_n^{\lambda}\right)^{-1}, \tag{4}$$

where RTS greater (less) than one means increasing (decreasing) returns to scale (cf. Caves *et al*. 1981, and Panzar and Willig 1977). By taking partial derivatives of the cost function given by equation (2), we get the following expression for returns to scale:

$$RTS = \frac{1 - \left(\alpha_K + \beta_{KK} \ln K + \sum_i \beta_{iK} \ln w_i + \sum_m \beta_{mK} \frac{y_m^{\lambda} - 1}{\lambda}\right)}{\sum_n \left[\left(\alpha_n + \sum_m \beta_{mn} \frac{y_m^{\lambda} - 1}{\lambda} + \sum_i \beta_{in} \ln w_i + \beta_{nK} \ln K\right) y_n^{\lambda}\right]} \tag{5}$$

We now turn to the estimation of cost functions for the pelagic fisheries. There has been no significant change in the technology employed in these fisheries over the three-year period in question. There has, on the other hand, been a slight change in the size of the fish stocks. To find out if this has any effect on the estimated cost parameters, tests using dummy variables for year were carried out (cf. equation (2)). The results did not show any significant change in costs. The annual data are therefore pooled. All right-hand side variables are centred on the mean of the variable in the data set for estimation.

Different vessel types take part in different fisheries. This is reflected in the output definitions of the estimated cost functions; the same outputs are not defined for the three vessel types as can be seen in Table 5. Based on prior knowledge of the fisheries, cost functions were estimated for each vessel type with alternative output definitions. The

[6] Homogeneity imposes the following restrictions:
$\sum_i \beta_i = 1,\ i = f, v.\ \sum_i \beta_{if} = \sum_i \beta_{iv} = \sum_i \beta_{iK} = \sum_i \beta_{im} = 0,\ i = f, v$, must hold for all m.

output definitions that scored highest on number of significant variables, adjusted R-squared, *etc*. when estimating the cost functions were chosen. Notice how the defined outputs reflect similarities among species in terms of behaviour as well as other factors like distance from shore to fishing areas, if the species for the most part are delivered for human consumption or for reduction, *etc*.

Estimation results are shown in Table 6. For all vessel classes, the estimated cost functions explain approximately 95% of the variation in the underlying data. Tests of regularity conditions were carried out and the results imply that monotonicity and convexity in prices are satisfied. Most of the estimated parameters are significant at the 5% level. The fit of the models are therefore reasonable.

For coastal vessels, three outputs - herring (y_A), capelin (y_B), and other species (y_{ot}) - are defined. As Table 2 shows, the average annual harvest of capelin per coastal vessel is small. Capelin was nevertheless defined as an output, based on estimation results that showed that including capelin as a separate product improved the fit of the model significantly. Of the 175 observations on coastal vessels, only 32 have positive quantities of capelin. The average harvest of capelin per vessel participating in the capelin fishery is thus much higher than indicated by Table 2.

The nature of the capelin fishery gives us reason to believe that coastal vessels taking part in this fishery to some extent differs from the majority of coastal vessels. If the cost structure of coastal vessels harvesting capelin differs from that of other coastal vessels, the difference will be reflected in the estimated parameters related to the production of capelin (y_B). The estimation results in Table 6 strengthen this suspicion. Both parameters α_B and β_{BB} are negative for coastal vessels. This suggests that capelin is harvested at a negative cost. It is, however, more likely that the parameter values of α_B and β_{BB} reflect lower variable costs for coastal vessels participating in the capelin fishery relative to other coastal vessels. Estimating the cost function with dummy variables for different vessel types in the coastal fleet could be one way to correct for this, but as the focus of the current analysis is on overall returns to scale within this particular group, further empirical analysis is not carried out. This could, however, be an interesting question for future research.

Having established and estimated the model, we now turn to the analysis of production structure and implications for regulation of the fishery.

4. Production Structure and Policy Implications

Before we can say anything about policy implications we need to characterise the structure of the production processes. The main purpose is to analyse returns to scale in different vessel classes to establish if overcapacity is present and, if so, to what extent. We start by looking at measures of elasticity.

Table 7 shows returns to scale (equation (5)) and input-price elasticities calculated for each vessel type and evaluated at mean levels. The reported own-price elasticities are all significant at a 5% level, negative, and indicate that the response to price changes is rather inelastic. Purse seine vessels seem to have a more inelastic response to changes in both of the two input prices than the other vessel types. Bjørndal and Gordon (2000), who used the same price indices in their analysis, also report inelastic factor demand. In his study of the ITQ regulated surf clam and ocean quahog fishery, Weninger (1998) reports inelastic input-price responses. Dupont (1991) estimates a normalised quadratic restricted profit function for the British Columbia salmon fishery, which is regulated by input restrictions. Her empirical analysis shows that the elasticities of the unrestricted inputs are inelastic. Other studies in the fisheries economics literature report elastic factor demand. Most of the fisheries analysed in these studies are, however, subject to other regulatory regimes.

We now turn to the question of whether there is overcapacity in the Norwegian pelagic fleet. The estimates of returns to scale reported in Table 7 are significant at a 5% level, and they indicate substantial economies of scale in every vessel class. Recall that we used measures of vessel size to measure capacity: tonnage units measure the capacity of purse seine vessels and trawlers, and GRT measures the capacity of coastal vessels. For purse seine vessels and trawlers, the estimates are significantly larger than two at the 5% level. This strongly implies that there is considerable overcapacity in these fisheries. Estimated RTS are high for coastal vessels as well, but the standard error for this estimate is large and we cannot verify that RTS are above one for coastal vessels at the 5% significance level. Bjørndal and Gordon (2000) found evidence of returns to scale in their analysis of the fishery. Their estimates of RTS are, however, much smaller than the ones reported in Table 7.

The difference in estimated returns to scale between Bjørndal and Gordon (2000) study and this study can be due to changes in vessel quotas. If vessel quotas were much higher in the period for which Bjørndal and Gordon did their study, this can explain why the degree of returns to scale has increased in the meantime. The capelin fishery was closed from 1994 through 1998, a period that covers the entire data set used by Bjørndal and Gordon (the years 1994-96). Capelin is, on the other hand, an important source of income for some of the vessels in our data set. The quotas of Norwegian spring-spawning herring have also increased, while quotas of North Sea herring and mackerel, with the exception of the coastal fleet's mackerel quota, have been reduced. The total quotas of herring, the commercially most important pelagic species, have however increased rather than decreased. The difference in quotas per vessel does therefore not seem to explain the relatively large difference in estimated returns to scale between Bjørndal and Gordon's (2000) study and our study. As we are dealing with pelagic fisheries for which the stock-output elasticity is expected to be small (c.f. Bjørndal's 1987 study of herring), changes in stock should not affect estimated cost parameters very much.

Several other studies in the fisheries economics literature deal with the question of returns to scale. Asche *et al*. (2002) find evidence of substantial scale economies for Norwegian cod trawlers operating under an IVQ system. Increasing RTS are also reported in other studies of fisheries, e.g. by Weninger (1998) in his analysis of the surf clam and ocean quahog fishery. As Asche *et al*. (2002) note, most of the RTS estimates in the fisheries economics literature show decreasing returns to scale (e.g. Alam *et al.* 2002, Squires 1987 and 1987b, Squires and Kirkley 1991). The regulatory regime in fisheries where one finds decreasing RTS is typically different from that of the fisheries with increasing RTS.

The fact that regulations have been changing over the years might suggest that returns to scale vary with vessel age. This could be the case if the current regulatory regime is taken into account when investments in vessels are made. It seems most likely to find evidence of such change in the purse seine fleet, where an IVQ system was introduced in the late 1980s. If vessels built after the introduction of the IVQ system have lower RTS than other purse seine vessels, this could indicate that the introduction of IVQs in the purse seine fleet has helped reduce overcapacity and consequently reduced rent dissipation in the fishery. The overcapacity problem will then become smaller as time passes by. It might also be useful to investigate how and whether returns to scale change with vessel capacity within vessel classes. Such variations would have implications for how quotas should be reallocated to take advantage of scale effects. Fishing vessels are provided quotas depending on, *inter alia*, the size of the vessel and size could therefore matter. It has also been suggested that the smaller vessels have been provided relatively large shares of the TAC (Aarland and Bjørndal 2002). If this is true, we should find lower returns to scale for smaller vessels.

To find out whether returns to scale vary with vessel capacity or vessel age, RTS are calculated for the average vessel in every capacity and age quartile. Capacity and age ranges for the quartiles can be found in Table 3. Results with standard errors are reported in Tables 8 and 9. Table 8 shows returns to scale for the average vessel by vessel-age quartile. The results do not show significant differences between age quartiles in any vessel class at the 5% significance level. We nevertheless find that the point estimate of RTS for purse seine vessels is increasing with vessels age, as we expected. The point estimate of RTS for the youngest purse seine vessels (≤ 10.75 years of age) are 2.93, while the same estimate for the oldest vessels are 3.61. Although not statistically significant, this indicates that the IVQ regime can have helped reduce overcapacity in the fishery. For trawlers and coastal vessels the point estimates of RTS are seen to be lowest for the two age quartiles in the middle but for coastal vessels the four point estimates are almost identical.

Returns to scale for the average vessel by vessel-capacity quartile are reported in Table 9. Looking only at the point estimates, the results suggest that RTS in the trawler fleet are increasing with capacity, and the largest trawlers seem to have very high returns to scale. In the coastal fleet, on the other hand, the smallest vessels seem to have very high scale returns. There is, on the other hand, little or no difference in the point estimates of RTS among purse seine vessels of different sizes. At the 5 % significant level, however, we cannot state that there are significant differences in RTS between vessels of different size (capacity) in any vessel class. This study therefore does not find statistical support for the hypothesis that the degree of overcapacity in the fishery depends on vessel size.

The fact that we did not find significant differences between age and capacity quartiles for any vessel class suggests that the problem of overcapacity is present in a large part of the pelagic fleet. As seen in Tables 8 and 9, nearly all estimates of the RTS indicator for the purse seine and trawler fleets are significantly larger than two. The exceptions are the two estimates for capacity quartiles Q4. For trawlers, the standard error associated with this estimate is very large, whereas we only have statistical support to say that RTS are significantly larger than 1.87 not 2.00 for capacity quartile Q4 of the purse seine fleet. None of the estimates of RTS in the coastal fleet, as presented in Table 8 and Table 9, are significantly larger than one.

The estimated indicator of RTS can be used to analyse how quotas should be reallocated for the fleet to capture the full cost advantage of scale effects. As the vessels are producing several outputs, there is more than one way to capture the scale benefits, as many different output combinations result in $RTS = 1$. Making the standard assumption that a manager wants to maximise net revenues from the fishery, estimates of cost functions can be used to suggest how quotas should be optimally redistributed both within and between vessel classes. Our data set contains information on vessels participating in the pelagic fisheries. This means that we have data on all purse seine vessels but only on distinct groups of vessels from the coastal and trawler fleets. The full production structure of the fleets should be taken into account when analysing the optimal reallocation of quotas between vessel classes. This question will therefore not be addressed in the current analysis.

5. Concluding Remarks

We set out to estimate cost functions for the different vessel groups taking part in the Norwegian pelagic fisheries. The purpose was to measure scale economies in the fishing fleet. Cost functions were estimated for coastal vessels, trawlers, and purse seine vessels using annual data covering the period 1998-2000. In a similar analysis, but using data for the years 1994-96, Bjørndal and Gordon (2000) estimated returns to scale to be increasing but close to one. According to their results, only slight reductions in average cost can be gained by taking advantage of scale effects in the fishery. Despite Bjørndal and Gordon’s (2000) findings, the common opinion in the industry has been that there is substantial overcapacity in the pelagic fishery. This discrepancy and the availability of new data was what motivated us to do the current analysis.

We find evidence of substantial returns to scale in the Norwegian pelagic fisheries. Our estimates of returns to scale in the trawl and purse seine fleets seem robust and suggest that large scale economies are present. Estimated returns to scale for coastal vessels are also substantial but the estimates are not significantly different from one. It should be noted that the measure of returns to scale used in the analysis is only an indicator of the actual scale economies of the fishing fleet. Nevertheless, the results give support to the industry opinion of large overcapacity in the pelagic fleet. The results are also in accordance with the economic literature on regulated open-access fisheries.

We have looked at several explanations for why we find large returns to scale in the Norwegian pelagic fishery, while Bjørndal and Gordon (2000) only found evidence of minor returns to scale. First, a decrease in quotas was suggested as a possible explanation. However, when looking at data on annual quotas we could not find support for this hypothesis; quota differences alone would not be enough to explain the difference in returns to scale. Second, the fleet is constantly being renewed and the fleet studied by Bjørndal and Gordon is not the same as the fleet in our data set. To see if this could explain the difference in RTS we tested if the degree of returns to scale varies with vessel age. We did not find strong evidence for this either.

Overcapacity seems to be present in all vessel classes, and we find the degree of overcapacity within each vessel class to be independent of vessel age and size. This suggests that quotas per vessel should be increased in every segment of the fleet. From an economic perspective, overcapacity should be dealt with by withdrawing the least effective vessel from the fishery until there no longer is any overcapacity. Subsequently, catch quotas should be reallocated both within and between vessel classes to take advantage of scale effects. The largest gain (measured in cost reductions) is obviously realised by reallocating quotas to the vessels with the highest returns to scale. Our analysis does not point towards an unambiguous solution to the problem of how best to reduce fishing capacity and reallocate quotas. To better answer these questions, further analysis of the cost and harvest structure of the Norwegian fishing fleet is required.

Until recently, there have been few incentives to reduce capacity in the pelagic fleet. The recent introduction of a unit quota system in the purse seine and trawl fisheries has changed this. The analysis suggests that quotas per vessel should be increased considerably to take advantage of scale effects. As the total allowable catch in the fishery is given, increased vessel quotas can only be realised by withdrawing vessels from the fishery. The unit quota system has the potential of making such capacity reduction achievable. It will be interesting to see if the incentives provided by the unit quota system are strong enough to reduce the overcapacity in the fishery.

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Table 1. Observations per Vessel Type per Year

	Purse seine	Trawler	Coastal vessel
1998	78	30	51
1999	65	25	55
2000	79	29	69
Total	222	84	175

Table 2. Average Harvest, Value and Price per Vessel, 1998-2000, by Vessel Type (Harvest in Tonnes, Value in Thousand 2000 NOK, Price in Norwegian Kroner/kg)

	Species	Quantity	Value	Price
Purse Seine	Herring	4,904	9,244	1.885
	Mackerel	1,198	6,921	5.778
	Blue whiting	5,638	3,805	0.675
	Capelin	1,746	1,943	1.113
	Sandeel	304	229	0.753
	Other species	498	1,038	2.083
	Total	14,287	23,179	1.622
Trawl	Herring	1,138	1,545	1.357
	Mackerel	55	243	4.437
	Blue whiting	1,082	713	0.659
	Capelin	216	201	0.931
	Sandeel	3,046	2,272	0.746
	Other species	949	2,275	2.396
	Total	6,486	7,249	1.118
Coastal Vessel	Herring	1,160	1,669	1.439
	Mackerel	141	713	5.074
	Blue whiting	1	0	-
	Capelin	61	103	1.676
	Sandeel	0	0	-
	Other species	406	2,602	6.404
	Total	1,768	5,087	2.877

Table 3. Upper Limits for Capacity and Age Quartiles (Capacity in Tonnage Units, T, or Gross Registered Tonnage, GRT, Age in Years)

	Vessel Capacity			**Vessel Age**		
	Purse Seine (T)	Trawl (T)	Coastal (GRT)	Purse Seine	Trawl	Coastal
Q1	654	265	57	11	19	11
Q2	983	308	93	21	24	16
Q3	1,567	402	133	33	36	30

Table 4. Factor Price Indices by Vessel Type, 1998-2000 (Standard Errors in Parentheses)

		w_f		w_v	
Purse Seine	1998	51.36	(13.68)	26,179.55	(12,914.62)
	1999	61.66	(17.72)	23,201.57	(12,069.91)
	2000	96.96	(31.05)	24,040.51	(11,055.89)
Trawler	1998	49.06	(22.72)	8,490.27	(4,562.29)
	1999	62.83	(20.59)	6,960.80	(3,226.28)
	2000	108.90	(41.30)	6,882.66	(2,707.91)
Coastal Vessel	1998	33.79	(15.37)	5,454.68	(3,051.37)
	1999	38.38	(16.74)	5,235.02	(2,361.58)
	2000	57.87	(21.61)	5,528.79	(2,646.39)

Table 5. Output Definitions

	Output A	**Output B**	**Output C**	**Output Others**
Purse Seine	Herring	Mackerel Capelin	Blue Whiting Sandeel	Other species
Trawl	Herring Mackerel Capelin	Sandeel	-	Blue Whiting Other species
Coastal Vessel	Herring	Capelin	-	Mackerel Blue Whiting Sandeel Other species

Table 6. Generalised Translog Cost Function, Estimates with Standard Errors: Purse Seine, Trawl, and Coastal Vessel

	Purse Seine		Trawl		Coastal vessel	
Parameter	**Estimate**	**Std. Err.**	**Estimate**	**Std. Err.**	**Estimate**	**Std. Err.**
λ	0.5886		0.6506		0.0725	
α_f	0.240**	0.002	0.340**	0.004	0.185**	0.007
α_v	0.760**	0.002	0.660**	0.004	0.815**	0.007
α_{ff}	0.171**	0.002	0.199**	0.004	0.121**	0.003
α_{vv}	0.171**	0.002	0.199**	0.004	0.121**	0.003
α_{fv}	-0.171**	0.002	-0.199**	0.004	-0.121**	0.003
α_A	0.157**	0.052	0.136**	0.044	0.275**	0.134
α_B	0.056**	0.017	0.063**	0.013	-0.028	0.028
α_C	0.083**	0.009				
α_{ot}	0.025**	0.006	0.065**	0.016	0.074	0.067
β_{AA}	-0.418*	0.241	-0.118	0.083	0.148**	0.069
β_{BB}	0.098**	0.034	-0.012	0.015	-0.005	0.004
β_{CC}	0.019*	0.011				
β_{otot}	0.007	0.008	-0.015	0.021	0.178**	0.057
β_{AB}	-0.036	0.059	0.005	0.040	0.016	0.010
β_{AC}	-0.007	0.031				
β_{Aot}	0.015	0.024	-0.027	0.032	-0.109**	0.049
β_{BC}	-0.002	0.010				
β_{Bot}	-0.001	0.010	-0.046**	0.014	0.005	0.005
β_{Cot}	-0.005	0.004				
β_{fA}	0.039**	0.013	0.007	0.012	0.056**	0.006
β_{vA}	-0.039**	0.013	-0.007	0.012	-0.056**	0.006
β_{fB}	0.014**	0.004	0.047**	0.005	0.000	0.001
β_{vB}	-0.014**	0.004	-0.047**	0.005	0.000	0.001
β_{fC}	0.023**	0.002				
β_{vC}	-0.023**	0.002				
β_{fot}	-0.006**	0.002	0.032**	0.006	0.025**	0.005
β_{vot}	0.006**	0.002	-0.032**	0.006	-0.025**	0.005
α_K	-0.047*	0.028	-0.069	0.060	-0.057	0.131
β_{KK}	0.022	0.080	0.461*	0.266	-0.044	0.097

β_{fK}	0.040**	0.007	0.087**	0.020	-0.003	0.006
β_{vK}	-0.040**	0.007	-0.087**	0.020	0.003	0.006
β_{AK}	0.035	0.125	-0.046	0.104	0.027	0.066
β_{BK}	-0.060	0.039	-0.092	0.057	-0.006	0.009
β_{CK}	-0.021	0.019				
β_{otK}	-0.010	0.013	-0.067	0.066	-0.077	0.063
α_0	16.014**	0.012	15.049**	0.013	14.337**	0.064

* Statistically significant at the 10% level.
** Statistically significant at the 5% level.

Table 7. Returns to Scale and Input Price Elasticities with Standard Errors: Purse Seine, Trawl, and Coastal Vessel

		Coeffisient	Standard Error
Purse Seine	RTS	3.252	0.494
	Fuel	-0.046	0.012
	Vessel	-0.014	0.004
Trawl	RTS	4.037	0.640
	Fuel	-0.076	0.013
	Vessel	-0.039	0.007
Coastal Vessel	RTS	3.292	1.308
	Fuel	-0.163	0.023
	Vessel	-0.037	0.006

Table 8. RTS by Vessel Age with Standard Errors. RTS for Average Vessel in Quartile Reported.

	Purse Seine	Trawl	Coastal
Q1	2.932 (0.444)	4.470 (0.939)	3.332 (1.334)
Q2	3.204 (0.590)	3.757 (0.508)	3.165 (1.225)
Q3	3.430 (0.544)	3.719 (0.528)	3.239 (1.292)
Q4	3.607 (0.565)	4.511 (0.862)	3.594 (1.453)

Table 9. RTS by Vessel Capacity with Standard Errors. RTS for Average Vessel in Quartile Reported.

	Purse Seine	Trawl	Coastal
Q1	3.047 (0.472)	3.213 (0.321)	17.009 (15.448)
Q2	3.570 (0.558)	3.724 (0.524)	19.213 (17.170)
Q3	3.469 (0.604)	5.087 (1.273)	3.537 (1.396)
Q4	3.245 (0.699)	18.657 (26.540)	3.463 (1.391)