ECONOMIES OF SCALE, EXCESS CAPACITY AND POTENTIAL RENT IN UK DEMERSAL WHITEFISH TRAWL FISHERIES

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ABSTRACT

In the UK, individual quotas are imposed on the demersal whitefish trawl fleet. Many of the key whitefish stocks are at historically low levels, and there is pressure on the industry to adjust to remove the current excess capacity. Adjustment in the fishery is likely to favour vessels that are operating closer to the 'optimal' scale, and the fleet structure is likely to move in this direction. In this paper, a translog cost function is used to estimate the returns to scale and 'optimal' scale for the UK demersal whitefish trawlers operating in 2001. Data Envelopment Analysis (DEA) is also used to provide estimates of technical efficiency and capacity utilisation that are used in the development of the long run cost function. The results of both analyses suggest that there is substantial overcapacity in the fishery. The results suggest that adjusting for capacity utilisation and inefficiency results in more robust estimates of optimal scale.

Keywords: cost function; DEA; excess capacity; scale economies; fisheries

INTRODUCTION

The UK demersal trawl fleet consists of three main activities – otter trawling, danish seining and Nephrops trawl. Otter trawlers and danish seiners both target similar whitefish species, but using different types of trawl gear, while Nephrops trawlers target primarily Nephrops (also known as scampi, langoustine and Dublin Bay prawns). The fleet is regulated through a series of input and output controls. Licence limitations restrict entry to the fishery, while a unitisation system restrictions boat replacement. Many of the main species caught by the sector are managed through quotas. Aggregate total allowable catches are set at the European level for each stock of the key species and distributed to the individual Member States in relatively fixed proportion. In the UK, these are further distributed to individual vessels greater than 10m in length in the form of fixed quota allocations. Although termed “fixed”, the quotas are transferable on an annual basis through quota leasing. Permanent quota transfers can also be arranged, although the complexity associated with this has prevented wide-scale permanent transfer of quota.

The whitefish trawlers (otter trawlers and seiners) operate primarily in the North Sea, English Channel, Celtic Sea and Irish Sea targeting cod and other whitefish species. The catch composition varies in the different areas, with the English Channel trawlers being characterised by a relatively high proportion of non-quota species in the catch. In contrast, catch in the North Sea is dominated (i.e. in excess of 90 per cent) by quota species. The Nephrops trawlers are predominantly based in Scotland, and operate in the North Sea as well as off the west coast of Scotland. Nephrops are also caught in the Irish Sea, a high proportion of which is caught by vessels moving down from the west coast of Scotland on a seasonal basis.

The whitefish trawlers have recently been adversely affected by quota cuts. Reductions in total allowable catches (TACs) in excess of 50 per cent were imposed for many North Sea whitefish stocks in 2002, with stocks in other areas subject to TAC reductions of between 10 and 30 per cent (DG Fish 2001). Further cuts in quotas of the order of between 30 and 40 per cent were made in 2003, and these lower quotas were carried through to 2004 also. In contrast, Nephrop fisheries have experienced increased stock sizes over recent years largely as a reduction in predation from the whitefish.

The objective of this paper is to examine what the UK whitefish trawl fleet may look like if vessels are able to adjust to their most efficient scale and fleets are reduced to levels that allow each vessel to be fully utilised. In addition, the economic rent that could be generated by such a fleet is examined. A combination of data envelopment analysis and a cost function approach was used to determine the optimal scale and potential rents for the UK demersal trawl fleets, and the reduction in fleet size that may be necessary to achieve these rents.

METHODOLOGY

Two approaches were used to assess capacity and optimal vessel size. Data Envelopment Analysis (DEA) was initially used to overcome some data deficiencies, but also provided useful information on returns to scale and optimal vessel size. A translog cost function analysis was also estimated in order to determine the cost-minimising level of output.

Data Envelopment Analysis

Although the estimation of capacity in fisheries using DEA is relatively new, a number of studies have already emerged (e.g. Pascoe, Coglan and Mardle, 2001; Dupont *et al.*, 2002; Feltoven, 2002; Vestergaard *et al.*, 2003; Tingley *et al.*, 2003; Kirkley *et al.*, 2003; Walden *et al.*, 2003, Reid *et al.* 2003).

Following Färe *et al.* (1992, 1994), the traditional DEA model of capacity output given current use of fixed inputs is given as:

$$Max\ \theta$$

subject to

$$\begin{aligned} &\theta_1 y_{0,m} \le \sum_k z_k y_{k,m} \quad \forall\, k \\ &\sum_k z_k x_{k,i} \le x_{0,i} \quad i \in \alpha \\ &\sum_k z_k = 1 \\ &z_k \ge 0 \end{aligned} \qquad \text{(Eq. 1)}$$

where θ_1 is a scalar denoting how much the output of the target boat (i.e. $k=0$) can be increased, where $y_{k,m}$ is the output m produced by boat k, $x_{k,i}$ is the amount of input i used by boat k and z_k are the weights that relate the target boat to the set of peers (i.e. the vessels against which it is compared). The restriction $\sum z_k = 1$ allows for variable returns to scale (VRS). In contrast, excluding this constraint implicitly imposes constant returns to scale (CRS) while $\sum z_k \le 1$ imposes non-increasing returns to scale (NIRS) (Färe *et al.*, 1994). The sum of the weights when CRS is imposed provides an indication of the returns to scale. $\sum z_k < 1$ implies the vessel is subject to increasing returns to scale while $\sum z_k > 1$ implies decreasing returns to scale. The ratio of the θ_1's with VRS and CRS imposed provides a measure of the scale efficiency (i.e. scale efficiency = $\theta_{VRS} / \theta_{CRS}$).

Inputs are divided into fixed factors, defined by the sub-set α, and variable factors defined by the sub-set $\hat{\alpha}$. For the purposes of estimating capacity, only fixed inputs are considered. The value of θ is estimated for each vessel separately (i.e. so effectively a set of θ_k are estimated), with the target boat's outputs and inputs being denoted by $y_{0,m}$ and $x_{0,i}$ respectively. (Färe *et al.*, 1994).

Capacity utilisation (*CU*) is defined as CU=1/θ. The measure of CU ranges from zero to 1, with 1 being full capacity utilisation (i.e. 100 per cent of capacity). The capacity output of each vessel is determined by $y'_{k,m} = \theta y_{k,m}$ where $y_{k,m}$ is the current catch of each species *m* made by boat *k* and $y'_{k,m}$ is the potential full capacity catch of species *m* by boat *k*.

A firm's outputs may not be produced efficiently and hence some of the apparent capacity under-utilisation may actually be due to technical inefficiency (i.e. not producing to the full potential given the level of both fixed and variable inputs) (Färe *et al.* 1994). If all inputs (both fixed and variable) are not being used efficiently, then it would be expected that output could increase even without an increase in the level of variable inputs through the more efficient use of these inputs. By comparing the capacity output to the technically efficient level of output, the effects of inefficiency can be separated from capacity under-utilisation. Further, the ratio of these measures has been found to be less susceptible to bias due to random error than the initial capacity utilisation and efficiency estimates (Holland and Lee, 2002).

The technically efficient level of output requires an estimate of technical efficiency of each firm, and requires both variable and fixed inputs to be considered. The DEA model for this is given by:

$$Max\ \theta_2$$

subject to

$$\begin{aligned} &\theta_2 y_{0,m} \le \sum_k z_k y_{k,m} \quad \forall m \\ &\sum_k z_k x_{k,i} \le x_{0,i} \quad \forall i \\ &\sum_k z_k = 1 \\ &z_k \ge 0 \end{aligned} \qquad \text{(Eq. 2)}$$

where θ_2 is a scalar outcome denoting how much the production of each firm can increase by using inputs (both fixed and variable) in a technically efficient configuration. In this case, both variable and fixed inputs are constrained to their current level and θ_2 represents the extent to which output can increase through using all inputs efficiently. The technically efficient level of output (y^*_{TE}) is defined as θ_2 multiplied by observed output (*y*). As the level of variable inputs is also constrained, $\theta_2 \le \theta_1$ and the technically efficient level of output is less than or equal to the capacity level of output (i.e. $y^*_{TE} \le y'$). The level of technical efficiency is estimated as:

$$TE = 1/\theta_2 \qquad \text{(Eq. 3)}$$

An estimate of capacity utilisation excluding efficiency effects (CU^*) is derived by:

$$CU^* = \frac{CU}{TE} = \frac{1}{\theta_1} \Big/ \frac{1}{\theta_2} = \frac{\theta_2}{\theta_1} \qquad \text{(Eq. 4)}$$

As $\theta_1 \geq \theta_2 \geq 1$, $CU \leq CU^* \leq 1$. That is, this measure of capacity utilisation is greater than the original measure (which includes efficiency effects), but less than 1. The difference between the measures reflects the degree to which random variation and technical inefficiency affect the output levels of the different firms.

Cost function approach

An implicit assumption of a primal approach such as implicit in the DEA model illustrated above and other production frontier approaches that have been applied to fisheries (e.g. Kirkley *et al.* 1995, 1998, Pascoe, Andersen and de Wilde, 2001; Pascoe and Coglan 2002) is that output can increase to the full utilisation level. Under a system of individual quotas, economic efficiency is determined by cost minimisation given the fixed quota allocation rather than output maximisation given the set of inputs available to the fisher. While the DEA model can be specified with an input orientation, and hence can provide a measure as to the extent to which input use can be reduced to achieve efficient production, this does not provide information on the capacity of the vessel. With tradeable quotas, vessels can adjust output levels, but have incentives to produce this output at the lowest cost possible. For this reason, the estimation of the cost function can be considered a more appropriate means of assessing capacity under an individual quota system. Relatively few applications of the cost function approach have been made in fisheries (see Weninger 1998, Lipton and Strand 1992, Segerson and Squires 1990, Bjørndal and Gordon 2000, Asche *et al.* 2003), largely due to difficulties in obtaining cost and revenue data for commercial fishing vessels.

The translog cost function for a single output industry[a] can be specified as

$$LnC = \beta_o + \sum_i^n \alpha_i \ln w_i + \frac{1}{2}\sum_i^n \sum_j^n \alpha_{ij} \ln w_i \ln w_j + \beta_y \ln y + \frac{1}{2}\beta_{yy} (\ln y)^2 + \sum_i^n \beta_{iy} \ln w_i \ln y + \varepsilon \qquad \text{(Eq. 5)}$$

where C is the total cost, w_i is the price of input i and y is the (aggregated) level of output. By differentiating equation 5 with respect to the input prices and using Shephard's lemma, the set of cost-minimising factor cost shares can be derived, given by

$$S_i = \alpha_i \ln w_i + \sum_j^n \alpha_{ij} \ln w_j + \beta_{iq} \ln Q + \varepsilon \qquad \text{(Eq. 6)}$$

where S_i is the cost share of the ith input, given by $w_i x_i / C$.

The cost function and the associated set of share equations need to be estimated simultaneously. As the input shares sum to 1 (one), one of the share equations needs to be excluded in order to avoid problems of singularity. A number of restrictions also need to be imposed on the system to ensure consistency with economic theory. Homogeneity in input prices and output requires $\sum_i^n \alpha_i = 1$, $\sum_i^n \alpha_{ij} = 0$, and $\sum_i^n \beta_{iy} = 0$, while symmetry in input prices requires $\alpha_{ij} = \alpha_{ji}$.

The set of coefficients from estimating the system provides additional information about the nature of the production system, including the propensity to respond to input price changes by changing input use or even substitute inputs, and the returns to scale associated with different production levels. The Allen partial elasticities of substitution between the factor inputs (σ_{ij}) are given by

$$\sigma_{ii} = (\alpha_{ii} + S_i^2 - S_i)/S_i^2,\ \sigma_{ij} = (\alpha_{ij} + S_i S_j)/S_i S_j \qquad \text{(Eq. 7)}$$

and the partial price elasticity of demand for input factor i (η_i) are given by

$$\eta_i = \sigma_{ii} S_i,\ \eta_{ij} = \sigma_{ij} S_j \qquad \text{(Eq. 8)}$$

A positive elasticity of substitution and cross price elasticity indicates substitution possibilities exist, while negative values indicate a complementary relationship.

The returns to scale of an individual vessel can be given by

$$RTS = 1/(\partial C/\partial R) = 1/(\beta_y + \beta_{yy} \ln Y + \sum_i \beta_{iy} \ln w_i) \qquad \text{(Eq. 9)}$$

The inclusion of both fixed and variable costs in the cost function implicitly assumes that the vessels are operating at their long run optimum level. However, where capital has a relatively long life, such as in the case of fishing vessels, capacity may not be fully utilised. In such a case, the fisher may be operating on the short term cost curve rather that the long term cost curve. Al-Mutairi and Burney (2002) suggest that in such cases it is more appropriate to estimate the short term cost curve (i.e. excluding fixed and capital costs) and include a variable representing the level of capacity utilisation. Further, inefficiency may exist in the industry that could result in bias in the estimated coefficients if ignored (see Kumbhaker 2001 for bias relating to the estimation of profit functions as a consequence of inefficiency). As adjustment in the fishery as a result of individual quotas is likely to result in a more efficient fleet on average, assuming current efficiency levels may not be appropriate.

Given this, three separate cost functions were estimated. The first is the standard cost function presented in equations 5 and 6. Second, the output measure was adjusted using the results of the DEA analysis to reflect the full capacity output. Costs and cost shares were similarly adjusted to represent the full capacity output. Finally, output and costs were adjusted to represent the fully efficient, full capacity level of output.

DATA

Data on costs, revenues and physical characteristics for 67 UK demersal whitefish trawlers relating to the 2001 financial year were available, representing roughly 9 per cent of the total whitefish trawl fleet. These vessels were all above 10m in length.[b] A summary of the key characteristics of the data set is presented in Table 1.

The individual cost items were aggregated into four cost categories: crew costs, running costs, capital costs and ‘other’ costs. Crew costs were the payments to crew. Running costs consisted of fuel costs, ice, box charges and food. Information on the capital value of the vessel was not provided by most skippers. However, where information on capital values was provided, this was generally based on the insurance value of the vessel. The insurance cost was therefore used as a proxy measure for capital costs. All other costs were included in the 'other' cost category.

Table 1. Key characteristics of the sample, 2001

Fleet segment	No of obs.	Average length (m)	Average engine power (kW)	Average crew number	Average revenue (£)	Average total costs (£)
Irish Sea trawlers	4	20.0	242	2.0	140005	90596
North Sea trawlers	42	23.6	439	5.4	436255	271849
English Channel trawlers	8	14.0	224	2.0	115504	61207
Seiners (NS and EC)	13	25.4	411	5.0	399941	257121
Total	67	22.6	396	4.7	373224	311015

Data on input prices were not available, but proxy measures of input prices were derived from the survey data. The crew price was derived from total crew payments divided by the number of crew. This is a potentially misleading measure, as crew are paid a share of the net revenue (i.e. revenue less running costs). As a result, a relatively high crew price does not necessarily indicate a relatively high labour productivity, but may be a consequence of 'luck' (i.e. higher than expected catches). Running costs are a function of both the amount of time fished and the size of the vessel. Information on fishing effort (e.g. days fished) was not available for most of the vessels. The input price associated with running costs was assumed to be the running cost of the vessel if it was operating at full capacity divided by the number of vessel capacity unit (VCUs).[c] The capacity utilisation was estimated using DEA. An assumption was made that running costs were proportional to the level of capacity utilisation. Hence the running cost if fully utilised was given by the observed running cost divided by the capacity utilisation rate.[d] The prices of capital and other inputs were also derived from the costs information and the physical boat characteristics. Various combinations of measures were tried. The physical measures that resulted in the lowest variance in input prices were length for 'other costs' and the VCUs for capital costs. Input prices for other costs and capital costs were therefore taken as other costs per unit length and insurance cost per VCU.

The analysis was also run assuming full capacity utilisation and full efficiency. The level of capacity utilisation and technical efficiency were derived using DEA. The revenue and running costs were scaled up by the appropriate factor for each analysis. Crew are currently paid a share of the revenue (and hence capture some of the rent). As a consequence, the price of labour and crew costs were also assumed to increase in proportion to the revenue increase.

The price and revenue values were normalised (after appropriate adjustments to account for capacity utilisation and efficiency) such that the mean values of the normalised data were 1.

EMPIRICAL RESULTS

DEA: Capacity utilisation, efficiency and returns to scale

The DEA model was run with revenue as the output measure and length and engine power as the fixed inputs. Fuel costs, which were assumed to be proportional to days fished, were included as the variable input for the purposes of estimating technical efficiency and the 'unbiased' estimate of capacity utilisation. Estimates of capacity utilisation were also obtained for the case of both constant returns to scale and variable returns to scale. The ratio of these measures provides a measure of the scale efficiency.

A summary of the DEA results is presented in Table 2. On average, the vessels were operating at around 87 per cent capacity and at around 69 per cent efficiency. If the vessels operated at both full capacity and efficiency, average output could potentially increase by 67 per cent (i.e. 1/0.6). In contrast, if the vessels were fully utilised but remained at their current (in)efficiency levels, potential output could increase by around 15 per cent on average.

Table 2. Average capacity utilisation and technical efficiency

	Otter Trawlers			Seiners	All boats
	Irish Sea	North Sea	Channel		
Fully efficient capacity utilisation	0.53	0.61	0.68	0.54	0.60
Technical efficiency	0.59	0.68	0.79	0.67	0.69
Capacity utilisation	0.88	0.89	0.86	0.82	0.87
Scale efficiency (CU)	0.71	0.88	0.46	0.94	0.83
Scale efficiency (TE)	0.83	0.92	0.70	0.96	0.90

Scale efficiency was estimated relative to both capacity utilisation and technical efficiency. The seiners and North Sea otter trawlers were, on average, closer to the ‘optimal’ scale. The optimal scale in this case is defined where constraint returns to scale exist. Both these boat groups were larger, on average, than the other two in terms of length and engine power as well as in terms of output.

A measure of returns to scale can be derived from the sum of the weights from the CRS technical efficiency model. Only four boats were found to be operating at the optimal scale, with three boats operating at above the optimal scale (and therefore subject to decreasing returns to scale). The remaining vessels were all found to be operating with increasing returns to scale. Of the four boats operating at the optimal scale, only 2 were both fully efficient and operating at full capacity. These vessels where 26m and 30m in length with respective engine powers of 750kW and 500kW, and respective revenues of £1.16 and £0.97m (an average revenue of £1.06m). While they were at the top end of the vessels in the fleet (in terms of size), they were not the largest vessels.

Cost function

The cost function was estimated excluding the crew share equation in order to avoid singularity. As mentioned above, three variants of the model were run using different manipulations of the data. The first run was assuming the industry was in a long run equilibrium. The second run took into account capacity under-utilisation and the revenue and running costs were re-estimated. The third run took into account the existence of inefficiency as well as capacity under-utilisation. In this run, revenues were increased to take into account both of these factors while running costs were increased to take into account the increased utilisation only.

The parameter estimates from the three model runs are presented in Table 3. In all three models, most parameters were significant at the 1 per cent level. The adjusted R^2 values were also reasonably high for the cost function itself, but less so for the share equations. While the adjusted R^2 values varied for the different models, these cannot be compared as the values of the dependent variable also differed in each model run.

The estimated partial own and cross price elasticity for the demand for factor *i* are presented in Table 4. As would be expected, the own price elasticity was negative for each input and the cross price elasticities were generally positive indicating the potential for substitution. The exception to this was capital and running costs, which were found to have a complementarity relationship. As running costs are a function of both the level of capital and its utilisation, an increase in capital prices would lead to lower levels of capital and, consequently, also lower running costs.

Table 3. Results from econometric analysis

	Base Run		Full capacity utilisation		Technically efficient full CU	
	Coeff	St. Err.	Coeff	St. Err.	Coeff	St. Err.
Constant	-0.023	0.020	-0.018	0.028	-0.029	0.030
Crew	0.343	0.009 ***	0.357	0.011 ***	0.429	0.014 ***
Running	0.240	0.006 ***	0.243	0.004 ***	0.196	0.005 ***
Other	0.349	0.006 ***	0.327	0.006 ***	0.278	0.005 ***
Capital	0.068	0.006 ***	0.073	0.006 ***	0.097	0.014 ***
Revenue	0.549	0.030 ***	0.630	0.050 ***	0.754	0.064 ***
Crew^2	0.003	0.013	0.024	0.010 **	0.051	0.009 ***
Running^2	0.065	0.013 ***	0.101	0.008 ***	0.096	0.008 ***
Other^2	0.100	0.014 ***	0.046	0.009 ***	0.039	0.011 ***
Capital^2	0.017	0.010 *	0.016	0.009 *	-0.003	0.019
Revenue^2	0.023	0.017	0.069	0.023 ***	0.120	0.021 ***
Crew*running	-0.019	0.022	-0.056	0.010 ***	-0.085	0.007 ***
Crew*other	-0.061	0.019 ***	-0.057	0.012 ***	-0.082	0.007 ***
Crew*capital	0.074	0.017 ***	0.066	0.010 ***	0.065	0.018 ***
Crew*revenue	0.014	0.016	0.019	0.017	0.031	0.020
Running*other	-0.070	0.018 ***	-0.042	0.012 ***	-0.021	0.014
Running*capital	-0.040	0.017 **	-0.104	0.013 ***	-0.085	0.020 ***
Running*revenue	0.053	0.013 ***	-0.002	0.010	0.001	0.011
Other*capital	-0.069	0.020 ***	0.007	0.016	0.026	0.025
Other*revenue	-0.100	0.016 ***	-0.041	0.013 ***	-0.030	0.014 **
Capital*revenue	0.033	0.013 **	0.024	0.013 *	-0.002	0.025
Irish	-0.008	0.062	-0.001	0.093	-0.092	0.087
Channel	-0.206	0.053 ***	-0.162	0.080 **	-0.079	0.077
Seine	0.042	0.034	0.001	0.050	-0.016	0.049
Adjusted R^2						
Total costs		0.969		0.934		0.901
Running share		0.573		0.723		0.505
Other share		0.380		0.562		0.561
Crew share		0.150		0.245		0.189

*** significant at 1% level; ** significant at 5% level; * significant at 10% level

Table 4. Own and cross price elasticities for demand for the factor inputs

	Crew	Running	Other	Capital
Base run				
Crew	-0.650 ***	0.177 ***	0.177 ***	0.288 ***
Running	0.260 ***	-0.489 ***	0.054	-0.104
Other	0.170 ***	0.035	-0.364 ***	-0.123 **
Capital	1.401 ***	-0.343	-0.621 **	-0.683 ***
Full CU				
Crew	-0.569 ***	0.094 ***	0.168 ***	0.243 ***
Running	0.139 ***	-0.344 ***	0.156 ***	-0.359 ***
Other	0.190 ***	0.119 ***	-0.535 ***	0.084 *
Capital	1.414 ***	-1.410 ***	0.434 *	-0.678 ***
Full TE CU				
Crew	-0.425 ***	0.024	0.098 ***	0.192 ***
Running	0.055	-0.330 ***	0.171 **	-0.359 ***
Other	0.166 ***	0.128 **	-0.583 ***	0.146
Capital	1.687 ***	-1.400 ***	0.761	-0.997 ***

*** significant at 1% level; ** significant at 5% level; * significant at 10% level

The returns to scale derived at the mean prices and output levels for each model are given in Table 5. In all three models, increasing returns were found at the mean. The optimal scale of fishing vessel can be found by solving equation (9) for the case where returns to scale are equal to 1 (one). In the base model, the optimal vessel is 17,020 times greater than the current average sized vessel. In contrast, if considering fully efficient and fully utilised vessels, the optimal scale is about 2.8 times the current average sized vessel.

Table 5. Estimated returns to scale

	Base Run			Full capacity utilisation			Technically efficient full CU		
	Coeff	St. Err.		Coeff	St. Err.		Coeff	St. Err.	
Returns to scale	1.822	0.099	***	1.588	0.126	***	1.327	0.111	***
Scale factor	17020	125869		14.599	16.321		2.793	1.178	**

*** significant at 1% level; ** significant at 5% level; * significant at 10% level

Optimal vessel size and profits

From the DEA analysis, the average of the ‘optimum’ level of output was £1.04m. The vessels from which this average was obtained were both fully efficient and operating at full capacity. From the cost function analysis, the optimal vessel size (if fully efficient and fully utilised) was 2.793 times larger than the current average vessel. Given that the average vessel if full efficient and fully utilised would produce revenue of £0.625m, the optimal vessel size would produce an output of around £1.74m.

Although the cost function estimate of optimal yield is 67 per cent greater than the DEA estimate, the lower DEA estimate of optimal output is within the 95 per cent confidence interval of the corresponding cost function estimate. Hence, the two estimates are not statistically significantly different. The DEA estimate of optimal production, by the nature of its calculation, is restricted to be within the range of the available data. Also, the DEA estimate is based on a primal output oriented function with output maximisation the implicit objective. In contrast, the cost function derived estimate of optimal production is not restricted to fall within the range of observed output levels, and the dual function has the objective of minimising costs as well as maximising output in order to maximise profits. However, extending beyond the range of the data creates problems for obtaining reliable and robust estimates. The translog function underlying the cost function is lest robust the further the variable values deviate from 1.

These difficulties in obtaining reliable estimates not withstanding, estimates of the profits associated with the “optimal” scale vessels are presented in Table 6. These are not true rents, as the non-cash capital costs (i.e. economic depreciation and opportunity cost of capital) have not been taken into account in the estimation of total costs. However, they provide an indication as to the potential increase in vessel profits that may occur through restructuring.

Table 6. Estimated revenues, costs and profits

	Current “average” vessel	DEA “optimal” vessel	Cost function “optimal” vessel
Revenue (£m)	0.373	1.065	1.747
Costs (£m)	0.311	0.633	1.182
Profits (£m)	0.062	0.431	0.565
Profits as proportion of revenue (%)	16.6	40.5	32.4
Potential fleet reduction (%)	-	65	79

From Table 6, if the vessels tend over time to move to the optimal scale identified by the DEA, then the fleet would need to reduce by nearly two thirds in order to enable the vessels to operate at full capacity (assuming also full efficiency). In contrast, if the vessels tend to increase in size over time to the optimal scale identified by the cost function, the fleet size would need to reduce by almost 80 per cent.

DISCUSSION AND CONCLUSIONS

Both the DEA and cost function approach provide useful information on the level of excess capacity in fisheries. The DEA approach is primarily a short run analysis as it assumes that fixed factors remain fixed and output is a function of their utilisation. From the DEA results, average capacity utilisation was 0.87, but average technical efficiency was 0.69. This suggests that inefficiency is a greater problem for the fleet than underutilisation. If all vessels were fully utilised and fully efficiency, then total output would be roughly two thirds greater than the current level. Given that output is currently restricted by quotas, this suggests that excess capacity is excessive in the whitefish fishery.

The cost function approach provides a longer-term perspective in that it allows for all inputs to vary. Further, when output is restricted such as through quotas, then incentives exist to minimise costs rather than maximise output. Hence, the cost function approach is theoretically more appropriate than the output oriented DEA approach. However, a difficulty arises if fixed inputs are underutilised in the short term. As seen from the econometric results, ignoring capacity under-utilisation in the estimation of the cost function results in unrealistic ‘optimal’ levels of output. Combining the results of the DEA capacity utilisation analysis into the cost function analysis overcame this problem.

The cost function approach, however, requires detailed information on factor input prices. This is a particular problem when cross sectional data are used, such as in this study. When a time series of data are available, then industry-independent price indexes can be constructed for factors such as fuel, labour (e.g. average wage) and capital (e.g. interest rate) that vary from year to year. However, within a given time period, all firms face the same set of prices, so an industry-independent set of price indexes are not appropriate. Deriving proxy measures for input prices from the available data may result in measurement error that could affect the regression results. Further, apparent differences in ‘prices’ may reflect heterogeneity in input quality. For example, in the fleet segments examined, crew costs are based on a share of the revenue less running costs. While average crew earnings can be derived as a proxy for the price of labour, price differentials most likely reflect differences in skill of the crew and skipper. Labour in such a case is not a homogeneous input. Adjusting the crew costs and labour price for differences in efficiency overcomes this problem to an extent.

Capturing the full capital cost and appropriate cost of capital in an ITQ fishery is also problematic. While interest rates can be considered an appropriate price of capital, this is common to all vessels within a given time period. The approach adopted in this study was to use the average insurance cost per unit of physical capital. Again, this is subject to measurement errors as it assumes that the insurance costs are proportional to the value of capital invested.

These problems not withstanding, the results from the cost function conformed with *a priori* expectations with respect to the signs of the derived own and cross price elasticities of demand. Further, the derived scale elasticities were consistent with the returns to scale estimated using DEA, and the ‘optimal’ scale estimated using both DEA and the cost function were not significantly different.

The results of the study suggest that the whitefish demersal fleet is likely to adjust in both scale and size to consist of fewer, but larger vessels than currently exist. This consolidation of fishing activity into fewer, larger units has been commonly observed in other fisheries subject to individual transferable quota management, and is often used as an argument by industry to prevent their implementation. In the UK, transferability is limited and involves high transactions costs. While this may slow the rate of adjustment, pressures exist for managers to reduce capacity in line with the reduction in the resource base. As a consequence, fleet sizes will, by necessity, decrease, and the social problems associated with fleet reduction (e.g. increased unemployment in rural areas), will have to be incurred. Freeing up quota transferability may facilitate this process at lower cost to the taxpayer and result in greater long run economic benefits (in terms of rent generation) than other capacity reduction management measures.

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Endnotes

[a] The cost function can also be developed for a multi-output industry. The single output case is presented for the sake of simplification.

[b] The data were collected through personal interview by the Seafish Industry Authority for the North Sea and Irish Sea, and by CEMARE for the English Channel.

[c] In the UK, VCUs are defined by length*breadth+0.45*engine power. These were found to be highly correlated with fishing capacity in trawl fisheries (see Pascoe, Coglan and Mardle 2001).

[d] This essentially assumes constant returns to fishing effort. Previous studies of revenue functions for the North Sea and English Channel demersal whitefish trawl fleet have found the production elasticity associated with days fished is around 1 (one) (see Pascoe, Tingley and Mardle 2003), suggesting that such an assumption is realistic.