Technical efficiency in the Swedish trawl fishery for Norway lobster

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Abstract

Reducing fleet capacity in European fisheries is an important objective of the European Union's Common Fisheries Policy. The success of such programmes depends both on the variation and the level of efficiency within the fishing fleets. If vessels with significantly lower than average efficiency levels are decommissioned, the actual reduction in fishing capacity will be less than expected. Further, if the remaining vessels are not operating at an efficient level after a decommissioning program, future improvement in efficiency may even further offset the effects of the decommissioning program. This paper examines the level and determinants of technical efficiency for a sample of Swedish demersal trawlers, which mainly target Norway lobster but also shrimp and demersal fish, in 1995. The data on per-trip gross revenues, fishing effort, gear choice, month of fishing and vessel attributes are analyzed using a translog stochastic production frontier, including a model for vessel-specific technical inefficiencies. Output elasticities and returns to scale are also examined. The technical inefficiency effects are found to be highly significant in explaining the levels and variation in vessel revenues. The mean efficiency for the sample vessels is estimated to be 66%. The inefficiency model indicates that efficiency decreases with total annual effort, and the same applies with vessel size in Gross Registered Tonnage. Further, it is found that older vessels are less efficient.

Keywords: stochastic production frontier, Swedish fisheries, technical efficiency

JEL classification: C23; Q22

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Introduction

Declining fishery resources and excessive economic waste have become of increasing global concern. The fishing nations within the European Union (EU) are no exception. EU's Common Fisheries Policy (CFP) is a multi-objective policy, consisting of four principal components (Rodgers and Valatin, 1995). These four components can be characterized as a conservation policy, a structural policy, a market policy, and finally, third-country agreements and international conventions. A crucial element within the structural policy is the Multi-Annual Guidance Programme (MAGP), which seeks to reduce fleets to an appropriate size given the available fishing opportunities. Standard bioeconomic models usually assume a homogenous fishing fleet, but the existence of heterogeneous fleets have long been identified, modeled (e.g. Copes, 1972, Anderson, 1982), and confirmed by several empirical studies (e.g. Dupont, 1990). Hence, a crudely designed decommissioning program aimed at reducing of overall Gross Registered Tonnage (GRT) for instance, may not achieve the desired reduction in fishing capacity. Further, if the remaining vessels after a decommissioning program are not operating at an efficient level, future improvement in efficiency may even further offset the effects of the decommissioning program. A potential outcome is a failure to ensure sustainable fisheries along with increased social costs.

From a fishery manager's perspective, knowledge of the efficiency level at both the firm and fleet level and its determinant factors would be valuable information for coming to grips with the problems of overfishing. Ideally, such information would include measures of total economic efficiency, but given the lack of appropriate data, estimates of technical efficiency can be a valuable substitute. Technical efficiency can be measured by different techniques (e.g. Färe, Grosskopf and Lovell, 1994), but given the stochastic nature of fishing, the stochastic frontier approach (Meusen and van den Broeck, 1977, and Aigner, Lovell and Schmidt, 1977) has so far been advocated in the literature (Kirkley, Squires and Strand, 1995).[2]

Despite the rapid development and widespread use of stochastic frontier approaches in assessing efficiency in many industries, such studies of commercial fisheries are scant. So far, there are only four published studies using the stochastic

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[2] Kirkley and Squires (1998) hold that the criticism of non stochasticity of the DEA approach can be overcome through the use of bootstrapping DEA (Data Envelope Analysis).

frontier approach (Kirkley, Squires and Strand, 1995, Kirkley, Squires and Strand, 1998, Sharma and Leung, 1998, and Campbell and Hand, 1998).[3] This is probably not only due to the complexity of marine fisheries leading to problems of providing necessary data, but also to the traditional focus on biological objectives among fisheries managers. The traditional single focus on biological aspects is gradually changing within the EU, and it is now accepted that successful fisheries management systems must foster economic efficiency (Rodgers and Valatin, 1995).

In this study, the stochastic frontier approach is applied to a sample of Swedish demersal trawlers, which target Norway lobsters but in some cases also other species like shrimp and cod. The Battese and Coelli (1995) model is used on data including effort and gross revenues collected on a per-trip basis during 1995. Technical efficiency is estimated together with determinants of the technical efficiency at the vessel level, and we also explore output elasticities and returns to scale.

The Swedish trawl fishery for Norway lobster

The Norway lobster (*Nephrops* norvegicus), also known as the Dublin Bay prawn, is a crustacean landed from 18 major stocks by fishers from 14 European countries. Total landings in 1995 were 50 000 tons with an ex-vessel value of almost Euro 200 million, which makes it the most valuable crustacean in European fisheries. The Swedish trawl fishery for *Nephrops* exploits the Scandinavian stock together with Danish and Norwegian fishers, and in 1995 Swedish trawl landings exceeded 800 tons corresponding to a value of almost Euro 7 million[4] (Eggert and Ulmestrand, 1999).

The Swedish West Coast demersal trawl fleet targets several species of which *Nephrops*, shrimp and cod are the most important. Each commercially important species has an overall total allowable catch (TAC) quota and a specific gear regulation. The gear regulations include different minimum sizes of the trawl mesh and a general upper limit of 70% by-catch of other species. *Nephrops* are caught mainly with *Nephrops* trawls, but also with creels and as by-catches in shrimp and demersal fish trawls. In

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[3] Coglan, Pascoe and Harris (1998) is a fifth paper, discussing the EU related topic in this paper.

[4] Euro 1 = SEK 9.00 (March, 2001)

1995, approximately 200 trawlers recorded landings of *Nephrops*, but 73 of these accounted for more than 70% of total landings. Forty percent of these vessels have Göteborg, the second largest city in Sweden, as their home port. The other vessels have home ports at a distance of 100-300 km away from Göteborg, where alternative job opportunities for fishers are more scarce. *Nephrops* live on specific bottoms and do not undertake extensive migrations, i.e. emigration and immigration between sub-areas are zero, but the eggs are pelagic and can move long distances with currents. The latter implies a possible stock-recruitment relationship referring to the major stock, but such a relationship is at present unknown (Anon., 1997).

Swedish *Nephrops* fishery is managed under the Council of the EU, but the Swedish Board of Fisheries and the Swedish Coastguard carry out the monitoring and enforcement. A TAC of 3500 tons for the Scandinavian stock was agreed upon in 1992, but was increased to 4800 tons in 1995, and has so far not been restrictive for any given year. Sweden joined the EU on January 1, 1995, which implies that the overall GRT restriction merely functioned as an upper limit in 1995. Commercial fishing requires a vessel license, which in turn requires a personal license held by a minimum of one crew member. The enforced and supposedly restrictive regulations are; a) the maximum 70% by-catch rule, b) the minimum landing size of 40 mm carapace length (The size of the “head” of the creature, measured from the rear eye socket to the distal edge of the carapace, which corresponds approximately to a full length of 13 cm or an age of 5 to 8 years) and c) the minimum trawl mesh size of 70 mm. The overall impression is that Swedish *Nephrops* fishery in 1995 could be characterized as an open access fishery (Eggert and Ulmestrand, 1999).

Data and variables

The Swedish Board of Fisheries collected the data used in this study, where the two most important sources are the log book database and the sales book database. The log book database identifies vessel, fishing effort, gear type and landing date on a per-trip basis, while the sales book database contains vessel, landing date and gross revenue.[5] A total of 73 demersal trawlers, which landed more than 5 tons of *Nephrops* during 1995, were selected. Some vessels were dropped due to missing information, and some trips with stationary gear where the effort variable has a different meaning than for trawling, were excluded. The final data set is an unbalanced panel of 5644 observations from 61 vessels. Descriptive statistics are presented in Table 1. The different trawls are labeled Shrimp, Single, Twin, and Fish, which represents shrimp trawl, single *Nephrops* trawl, twin *Nephrops* trawl, and demersal fish trawl, respectively. We define dummy variables for each trawl. Table 1 shows that almost 90% of the trips targeted *Nephrops*. The variable *YEAREFFORT* is the total effort hours during 1995 for each vessel. Stock index is a constructed proxy for stock abundance and price paid on a monthly basis (see also next section).

Table 1. Summary statistics for 5644 trip observations on 61 fishing vessels in Swedish demersal trawlers, targeting *Nephrops*, during 1995

Variable	Sample mean	Standard deviation	Maximum	
	Minimum			
Trips per vessel	92.52	28.5	152	36
Output (SEK)	10740	9801	124500	24
Effort (hours)	11.33	7.5	110	1
GRT (tons)	44.58	21.87	120	11
LOA (meters)	16.28	3.17	22.84	11.67
Engine power (kW)	244.4	62.75	400	110
Age (years)	28.5	20.9	66	4
SHRIMP dummy	0.07	0.26	1	0
SINGLE dummy	0.41	0.49	1	0
TWIN dummy	0.45	0.50	1	0
FISH dummy	0.07	0.25	1	0
YEAREFFORT (h)	1058	405.5	2564	299
Stock index	3.92	0.10	4.04	3.74

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[5] The link between the two databases is the landing date, which unfortunately does not provide a perfect match. Corrections for mis-fitting landing dates were done manually, and a potential risk of changing the data characteristics cannot be disregarded.

Measuring capital in fisheries is often problematic. Though the standard approach is to focus on different vessel attributes such as length, width, GRT, etc. (Carlson, 1973), some attempts have been made to find more economic-related measures like insurance value (Frost et al, 1995) or cost of capital invested in equipment (Hannesson, 1987). For this study, insurance values for a minor group of vessels were available but did not offer any promising results in terms of measuring capacity. A Swedish insurance company, specializing in fishing vessels, confirmed the lack of correlation between insurance value and capacity (Bengt Schröder, personal communication). Investment figures were not available, which left us with the vessel attributes approach. Pascoe and Robinson (1998) constructed a composite measure of length and width, which proved superior to GRT in their study. In the MAGPs, capacity is a function of vessel attributes, notably vessel size and engine power. Given the available attributes and the correlation figures (Table 2), an attempt with GRT, age, and kW was made, while length overall (LOA) was dropped to avoid multicollinearity problems.[6]

Table 2. Correlation matrix of vessel attributes

	LOA	GRT	KW	AGE
LOA	1			
GRT	0.88634	1		
KW	0.476254	0.599341	1	
AGE	0.551067	0.31195	0.004342	1

The Stochastic Frontier model

The original stochastic frontier approach was further developed in a paper by Jondrow et al. (1982), which shows how to estimate the level of technical efficiency for each observation in the sample. Battese and Coelli (1988) developed a random effects model

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[6] In the analysis, the chosen model failed to converge when kW was included. This led to a stochastic model with GRT and age.

for estimating firm-specific levels of technical efficiency using panel data. A general frontier model can be given by,

$$Y_{it} = \boldsymbol{\beta}\mathbf{x}_{it} + \varepsilon_{it}$$

where Y_{it} denotes the output for the i*th* firm in the t*th* period, $\mathbf{x}_{it}$ is a vector of explanatory variables, $\boldsymbol{\beta}$ is a vector of unknown parameters to be estimated, and the error term is made up of two independent components, $\varepsilon_{it} = V_{it} - U_{it}$. V_{it} is assumed to be a standard symmetric independent and identically distributed (i.i.d.) error term as $N(0, \sigma_v^2)$, while U_{it} is the non-negative variable representing inefficiency. Estimation of the model only yields estimates of ε_{it}, but Jondrow et al. (1982) derived the expected value of U_{it} conditional upon the residual ε_{it}, using an additional distributional assumption for U_{it}.

Once technical efficiency is estimated, the search for explanatory variables is a natural step. Early empirical studies (e.g. Pitt and Lee, 1981) investigated the determinants of technical inefficiencies among firms in an industry by regressing the predicted inefficiency effects, obtained from an estimated stochastic frontier, upon a vector of firm specific factors. This two-stage approach is problematic as the inefficiency effects are assumed to be independent and identically distributed (i.i.d.) in the first stage, while in the second stage the predicted inefficiency effects are assumed to be a function of a number of firm-specific factors. The latter implies that the firm-specific factors are not identically distributed, unless all the coefficients of the factors are simultaneously equal to zero. This inconcistency was identified by Reifschneider and Stevenson (1991), and by Kumbakhar, Ghosh and McGuckin (1991). As a further development Battese and Coelli (1995) presented an approach where the technical inefficiency effects in the stochastic frontier are assumed to be independently, but not identically distributed non-negative random variables.

To investigate the relationship between technical efficiency and input variables like fishing effort, vessel size, and type of gear, a stochastic frontier production function of the type proposed by Battese and Coelli (1995) is employed. In their model, a production frontier is specified which defines output as a function of a given set of inputs, together with technical inefficiency effects, which define the degree to which firms fail to reach the frontier because of technical inefficiencies of production. The model specifies that these inefficiency effects are modeled in terms of other observable explanatory variables and all parameters are estimated simultaneously.

We assume that the frontier technology of the fishing vessels can be represented by a translogarithmic production function. The parameters are estimated using data from individual fishing trips of 61 Swedish West Coast demersal trawlers operating during 1995

The Battese and Coelli (1995) model is estimated with the following specification of the production frontier:

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\begin{aligned}
(1)\ \ln \mathrm{Y}_{it} &= f(\mathbf{x}_{kit}, \mathrm{AGE}_{i}, \mathrm{SHRIMP}_{it}, \mathrm{SINGLE}_{it}, \mathrm{FISH}_{it}, \mathrm{PORT}_{i}) \\
&\quad + (V_{it} - U_{it}) \\
&= \beta_0 + \beta_H \ln x_{HOURSit} + \beta_G \ln x_{GRTi} + \beta_S \ln x_{STOCKt} + \beta_{HH}(\ln x_{HOURSit})^2 + \beta_{GG}(\ln x_{GRTi})^2 \\
&\quad + \beta_{SS}(\ln x_{STOCKt})^2 + \beta_{HG}\ln x_{HOURSit}\cdot\ln x_{GRTi} + \beta_{HS}\ln x_{HOURSit}\cdot\ln x_{STOCKt} + \beta_{GS}\cdot\ln x_{GRTi} \\
&\quad \ln x_{STOCKt} + \beta_A lnAGE_i + \beta_{AA}(lnAGE_i)^2 + \beta_{SHRIMP}SHRIMP_{it} + \beta_{SINGLE}SINGLE_{it} + \\
&\quad \beta_{FISH}FISH_{it} + \beta_{PORT}PORT_i + (V_{it} - U_{it}), \qquad k = HOURS,\ GRT,\ STOCK, \\
&\quad i=1,\ldots,61,\ t=1,\ldots,T_i,
\end{aligned}
$$

where $\ln \mathrm{Y}_{it}$ is the logarithm of harvest value by the *i*th vessel per *t*th trip[7], x_{HOURS} is the number of hours fished[8], x_{GRT} is the vessel's gross registered tonnage, and x_{STOCK} is a proxy for stock abundance. All inputs are assumed to be exogenous.[9] *AGE* is the vessel's age in years, and the dummy variables *SHRIMP*, *SINGLE*, and *FISH* take on the value 1 for shrimp trawl, single *Nephrops* trawl, and demersal fish trawl, respectively. The twin *Nephrops* trawl dummy was omitted to avoid exact multicollinearity, the so-called dummy variable trap, and acts as a reference for the other trawls. Stock abundance is an important input in fishery production. In this study we focus on output during one year, where the output is a multiple product measured as

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[7] Defining the production variable as the total value of output is standard practice in empirical work involving multi-product firms, but leads to a specified frontier that is not truly a production frontier. As noted by Coelli, Rao and Battese (1998), this implies that the inefficiency effect, μ_{it}, accounts for any factors associated with inefficiency of production, including technical efficiency.

[8] The fishers report the number of hours that the trawl is in the water, i.e., steaming time is not included.

[9] We assume that the fishers attempt to maximize expected profit rather than actual profit to avoid the problem of simultaneous equations bias (Zellner, Kmenta and Drèze 1966)

its total sales value. A correct stock measure would require stock estimates for each species on a monthly basis, species composition on a per-trip basis, and prices for each species on a per-trip basis. These requirements could not be met and instead a proxy for stock abundance and price variations was constructed. x_{STOCK} is a proxy which is constructed by calculating the overall average landing value per unit effort on a monthly basis. The variable *PORT* is a dummy variable taking on the value 1 if the homeport of the vessel is Göteborg and zero otherwise. It was included to test if there is a difference between Göteborg vessels and the others, which for example could be due to a higher opportunity cost of labor or higher motivation among Göteborg skippers. The V_{it}s are assumed to be i.i.d. normal random variables with mean zero and constant variance, σ_v^2 , and the U_{it}s are non-negative variables, which were assumed to be independently distributed, such that U_{it} is the truncation at zero of the normal distribution with mean, μ_{it}, and variance, σ^2, where μ_{it} is defined by

$$(2)\ \mu_{it} = \delta_0 + \delta_H \ln YEAREFFORT_i + \delta_G \ln x_{GRTi} + \delta_A lnAGE_i + \delta_P PORT_i,$$

where ln*YEAREFFORT* is the natural logarithm of annual effort hours.

Deviations from the production function are captured in the two error terms. The random error, *V*, accounts for measurement errors, potential effects from misspecification in the production technology, and stochastic production shocks in the fishery, while *U* is associated with technical inefficiency of production.

The technical efficiency of production for the *i*th firm at the *t*th observation is defined by equation (3),

$$(3) \qquad TE_{it} = \exp\,(-U_{it})$$

The prediction of the technical efficiencies is based on its conditional expectation, given the model assumptions. Technical efficiency is equal to one if a firm has an inefficiency effect equal to zero and is less than one otherwise.

Maximum-likelihood estimates of the parameters of the model defined by (1) and (2) are obtained using the computer program FRONTIER 4.1 (Coelli, 1996).

The variance parameters are estimated by FRONTIER in terms of $\sigma^2 = \sigma_v^2 + \sigma_u^2$ and $\gamma = \sigma_u^2 / \sigma^2$.

Various tests of hypotheses of the parameters in the frontier function and in the inefficiency model can be performed using the generalized likelihood-ratio test statistic, λ, given by,

$$(4) \qquad \lambda = -2\,[\lambda(H_0) - \lambda(H_1)]$$

where $\lambda(H_0)$ and $\lambda(H_1)$ denote the value of likelihood function under the null (H_0) and alternative (H_1) hypotheses, respectively. This test statistic has approximately a chi-square or a mixed chi-square distribution with degrees of freedom equal to the difference between the parameters involved in the null and alternative hypotheses.

If the inefficiency effects are absent from the model, as specified by the null hypothesis H_0: $\gamma = \delta_0 = \ldots = \delta_4 = 0$, then the statistic, λ, is approximately distributed according to a mixed chi-square distribution. In this case, critical values for the generalised likelihood-ratio test are obtained from Table 1 in Kodde and Palm (1986). If this null hypothesis is true, the production function is equivalent to the traditional average response function, which can be efficiently estimated by ordinary least-squares regression.

The estimated coefficients of the translog stochastic production frontier, equation (1), do not have a straightforward interpretation. Since the input variable *GRT is* included in the inefficiency model (2), the output elasticity with respect to this input variable is a function of the value of the input in both the frontier and the inefficiency models. Following Battese and Broca (1997), the elasticity of mean output with respect to the *k*th input for vessel i at time t can be derived as,

$$(5) \qquad \frac{\delta \ln E(Y_{it})}{\delta x_k} = \left[\beta_k + 2\beta_{kk} x_{kit} + \sum_{j \neq k}^{3} \beta_{kj} x_{jit}\right] - C_{it}\left[\frac{\delta \mu_{it}}{\delta x_k}\right]$$

where

$$C_{it} = 1 - \frac{1}{\sigma}\left[\frac{\phi\left(\frac{\mu_{it}}{\sigma} - \sigma\right)}{\Phi\left(\frac{\mu_{it}}{\sigma} - -\sigma\right)} - \frac{\phi\left(\frac{\mu_{it}}{\sigma}\right)}{\Phi\left(\frac{\mu_{it}}{\sigma}\right)}\right] \tag{6}$$

and ϕ and Φ represent the density and the distribution functions of the standard normal random variable, respectively. The elasticity of mean output with respect to the *k*th input variable in equation (5) has two components. The first component within brackets is the traditional elasticity, here referred to as the elasticity of frontier output, and the second is referred to as the elasticity of technical efficiency with respect to the *k*th input variable. The variables *AGE* and *PORT* are also included in both models and the total effect of these variables has to be evaluated in a similar manner.

Empirical Results

The parameter estimates of the stochastic production frontier model (1) and the technical inefficiency model (2) are presented in Table 3. All coefficients, except when indicated, are significant at the 1% level.

Table 3. Parameter Estimates of Stochastic Production Frontier and Technical Inefficiency Models

	Coefficient	T-ratio
Stochastic production frontier		
Constant	-13.81	-13.49
HOURS	1.51	2.34
GRT	-3.32	-5.00
STOCK	13.28	16.94
HOURS^2	0.05	2.39
GRT^2	0.52	19.76
STOCK^2	-1.54	-8.84
HOURSGRT	0.07	2.44
HOURSSTOCK	-0.36	-2.24
GRTSTOCK	-0.06	-0.38*
AGE	0.07	-0.64*
AGE^2	-0.03	-1.64*
SHRIMP	0.23	6.57
SINGLE	-0.05	-2.93
FISH	0.02	0.47*
PORT	-0.12	-5.37
Technical inefficiency model		
Constant	-30.30	-7.56
YEAREFFORT	1.33	6.61
GRT	0.26	-2.84
AGE	0.60	6.70
PORT	-7.55	-7.96
σ^2	11.64	8.27
γ	0.98	478
Log likelihood function	-5540	
Mean Technical efficiency	0.66	

* Insignificant variable at the 1% level.

The input coefficients in the frontier model presented in Table 3 do not have a straightforward interpretation, and are discussed later in conjunction with the reported output elasticities.

The estimates of the explanatory variables in the technical inefficiency model are also presented in Table 3. All of the five variables are significant at the 1% level. The coefficients *YEAREFFORT* and *GRT* are positive, which indicate that efficiency decreases with total annual effort, and with vessel size. The *AGE* coefficient is positive, which implies lower efficiency with increasing age. The dummy variable *PORT* is negative, which implies that vessels with home port Göteborg on average are closer to the frontier. However, note that Göteborg vessels are on a slightly lower frontier according to the associated coefficient in the frontier function.

Generalized likelihood-ratio tests of three null hypotheses are presented in Table 4. All postulated null hypotheses are rejected at the 1% level. The first null hypothesis, that the age variables could be dropped, is rejected. The second null hypothesis which tests the possibility that the traditional Cobb-Douglas production is preferable, is rejected. The final null hypothesis concerns whether inefficiency effects are non-stochastic and whether technical inefficiency effects are absent, but is again rejected. Hence, the traditional average production function (OLS) is not an adequate representation of the data. This is also confirmed by the value of γ, which is significantly different from zero and indicates that the inefficiency effect, U, explains most of the deviations from the frontier output.

Table 4. Generalized likelihood-ratio tests of hypotheses for parameters of the stochastic production frontier and technical inefficiency models for the Swedish Norway lobster fishery

Null hypothesis	Log-likelihood value	Test statistic (λ)	Critical value
$H_0 : \beta_A = \beta_{AA} = 0$ (No age effects)	-5565	50.1	9.21
$H_0 : \beta_{HH} = \beta_{GG} = \ldots = \beta_{GS} = 0$ (Cobb-Douglas)	-5801	522	18.5
$H_0 : \gamma = \delta_0 = \delta_Y = \ldots = \delta_P = 0$ (No inefficiency effects)	6038	996	16.1

All values statistically significant at the 0.01 level. The correct critical values for the hypothesis involving γ=0 are taken from Table 1 in Kodde and Palm (1986, p.1246).

Elasticities of mean output with respect to three input variables, fishing effort, GRT, and stock, are estimated in Table 5 at the mean values of the variables involved. It should be noted that fishing effort is a flow input variable while GRT is a stock input variable, which excludes the possibility of direct comparison. Returns to scale are estimated to 1.08 when stock input is included. When stock is excluded returns to scale are 0.95, which is almost identical to the estimate of 0.96 in Campbell and Hand (1998). Sharma and Leung (1998) have a corresponding estimate of 1.86, while the estimated returns to scale for Kirkley, Squires and Strand (1995) are 1.6.[10]

Table 5. Output elasticities for the Swedish Norway lobster fishery estimated at the mean of the input levels

Variable	Mean	Std. Dev.
HOURS	0.554	0.071
GRT	0.398	0.574
STOCK	0.132	0.335
Returns to scale	1.084	0.669

The total effect of the variable *AGE* is -0.116 (0.052), which confirms a significant decreasing effect on output the older the vessel. The corresponding figures for *PORT* are -0.004 (0.031), which rejects the hypothesis of a significant difference between vessels from Göteborg and vessels from outside Göteborg.

The dummy variables in Table 3 have a more direct interpretation. Of the four different trawls, the shrimp trawl gives the highest return while a single *Nephrops* trawl has the lowest. Choosing the single *Nephrops* trawl instead of the twin *Nephrops* trawl leads to a reduction in expected returns of 5%. The result that shrimp trawls yield higher returns for the fishers, who mainly target *Nephrops* may seem puzzling. A potential explanation is that the fishers only go for shrimp when they know that abundance and/or prices are high for this species, but target *Nephrops* even if conditions are moderately worse than average.

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[10] Sharma and Leung (1998) calculated the returns to scale (RTS) from Kirkley, Squires and Strand's (1995) estimated model. They also calculated RTS including stock variable, and found that they exceeded 2.

The overall mean technical efficiency (TE) was estimated to 0.66. The majority of the vessels have a mean TE in the range 0.6-0.7, but a group of approximately 20% is in the range of 0.51-0.6 while the highest mean efficiency was 0.78.

Discussion and Conclusion

This paper provides an assessment of technical efficiency for a sample of Swedish demersal trawlers, which mainly target Norway lobster, based on their 1995 fishing effort, vessel characteristics, and landings data. The performance of these vessels is analyzed by estimating a translog stochastic frontier production function. Explanatory variables of technical inefficiency are estimated simultaneously, and output elasticities and returns to scale are also explored. Our results predict that technical inefficiency effects are significant in explaining the level and variation in per-trip vessel revenues. The mean technical efficiency level is estimated to be 66%. The inefficiency model indicates that fishers are less efficient the more hours they fish, the larger their vessels, and the older their vessels.

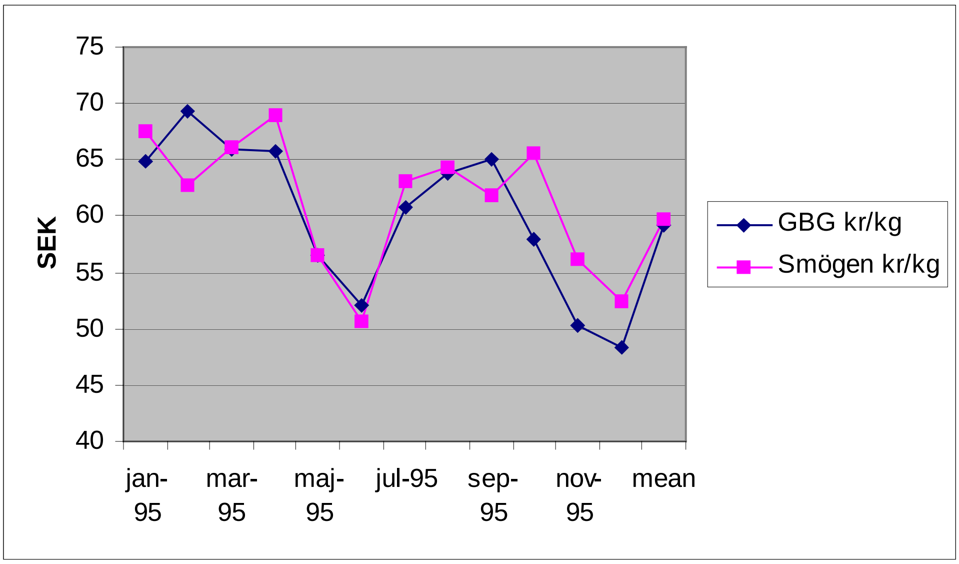

Figure 1. 1995 Prices for *Nephrops*, monthly averages and annual mean, at the Göteborg and Smögen fish auctions

Finally, the results indicate that there is no significant difference between Göteborg vessels and non-Göteborg vessels. However, differences in landing prices at different ports pose a potential problem, as the output is measured as landing value. The major part (in the range 70-90%) of the landing values comes from *Nephrops*. A comparison of monthly average prices paid in Göteborg and Smögen, the major landing port outside Göteborg, shows no trend in differences and the annual mean prices are almost identical (Figure 1). Overall, our conclusion is that there are no significant differences between vessels from Göteborg and outlying areas.

The input elasticity estimates for this study lead to a returns to scale estimate below unity when the stock input is disregarded. This is close to the result of Campbell and Hand (1998) and, despite the occurrence of insignificant elasticity estimates in both studies, future studies will likely indicate at least more moderate returns to scale in fisheries than the results of Kirkley et al. (1995) and Sharma and Leung (1998).

The report on MAGPs (Lassen et al., 1996), to the European Commission recommended fleet reductions of 40-50%. Via the political process, including handling by the European Commission, the decision by the European Council stopped at a 20% reduction (personal communication Tore Gustavsson, Swedish National Board of Fisheries). If 20% of the vessels with the lowest mean technical efficiency level in our sample are decommissioned, the reduction in fishing power would be only about 15%. If the remaining vessels manage to improve their mean efficiency from the current level of 0.67 to 0.8, which is just above the level of the best performing vessel, the effects of the decommissioning would be completely offset.

Longer time series data for this study would have given the opportunity to test the hypothesis of a positive time trend, as outlined in Campbell and Hand (1998). Despite the importance of allocative efficiency, this study deals only with technical efficiency due to data constraints. Further data collection of economic variables in European fisheries would facilitate improved studies following the methods outlined here. The gear choice among the demersal trawlers in this study has a significant result both in output and explaining efficiency. Due to the focus on Norway lobster in the data set, further aspects of different gears could not be analyzed. A future study with vessels focusing on shrimp, demersal fish, Norway lobster, or a mix of two or three of these, together with price data could analyze the decision-making process of gear choice and estimate separate production frontiers for each target.

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