Estimation of Production Functions on Fishery:

A Danish Survey*

Birgit Nahrstedt
Henning P. Jørgensen
Ayoe Hoff

August 2002

* Comments from Frank Jensen are greatly appreciated.

Editor: Eva Roth

Department of Environmental and Business Economics
IME WORKING PAPER 33/02

ISSN 1399-3224

Birgit Nahrstedt and Henning P. Jørgensen
Department of Environmental and Business Economics
University of Southern Denmark
Niels Bohrs Vej 9-10
DK-6700 Esbjerg
Tel.: +45 6550 4183 and +45 6550 4187
Fax: +45 6550 1091
E-mail: bin@sam.sdu.dk and hpj@sam.sdu.dk

Ayoe Hoff
Danish Research Institute of Food Economics
Fisheries Economics and Management Division
Rolighedsvej 25
1958 Frederiksberg C
Tel.: +45 3528 6896
Fax: +45 3528 6801
E-mail: ah@foi.dk

Abstract

The fishing fleet and the component parts of effort and production can be described and analysed in different ways. As an example, the fishing fleet can be described using a list of different production function specifications. These production functions will in this paper be estimated using data for the Danish North Sea human consumption demersal trawl fishery. Some statistical problems including multicollinearity are discussed and possible solutions and interpretations are put forward.

Keywords: Danish North Sea human consumption demersal trawl fishery, production function, multicollinearity.

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1. Introduction

The purpose of this analysis is to give a Danish contribution to estimations of different production function specifications. According to the overexploitation of the fish resources in the European Union regulation programmes have been implemented to control inputs and outputs (Jensen, 2000). One of these programmes in European Union (EU) is the Multi-Annual Guidance Programme (MAGP) of which the purpose is to control the development in capacity of the fishing fleet in each Member State. One approach of the Multi-Annual Guidance Programme to reduce the severe excess fishing capacity is the decommissioning scheme. In total, about 1,200 vessels in Denmark have received the decommissioning grant in the period 1987 – 2000 (Vestergaard et al., 2002). According to these programmes and to the general discussion of production function in fishery this analysis gives a contribution.

Within fisheries economics and management different methods of examine of the relationship between output and input can be used. The three most important methods are the Data Envelopment Analysis (DEA), stochastic frontier analysis, and regression techniques.

In this paper different production functions are estimated. Usual, production functions such as the translog production function, the CES production function, and the Cobb-Douglas production function are estimated. Also, the static Shaefer production functions as well as the dynamic Shaefer production function are estimated in what follows. The production functions will in this paper be estimated using data for the Danish North Sea human consumption demersal trawl fishery.

Econometrical problems will be analysed, too. Especially, multicollinearity will be discussed, since multicollinearity is often a problem when estimating production function ((Brown and Beattie, 1975, p. 23) and Campbell(1990)). Also, Bjorndal (Bjorndal, 1989) estimates translog and Cobb-Douglas forms of production function for the North Sea herring where multicollinearity for the trans-log function very likely exist.

After introduction of the different neo-classical production functions the paper is structured as follows. In Section 3 the methods are presented, including methods related to multicollinearity, and the collection of the Danish data are given in Section 4. The data description and the estimations are the subject of Section 5. In Section 6 the results are shown and discussed. Finally, Section 7 closes the paper with a discussion of the results in relation to multicollinearity.

2. The fishery production function

A production function describes the relationship between the physical quantity of output of goods and specific combinations of physical quantity of inputs used in a production process. Normally, the neo-classical production function is formulated as:

$$y = f(X_1, X_2, ..., X_k) \tag{1}$$

where y is the output
X_i is an input

and where the output can be produced with k different inputs.

A more simple production function is one with only two inputs; capital (K) and labour (L). In this case the production function is:

$$y = f(K, L) \tag{2}$$

where K is capital
L is labour

With production functions three elasticity aspects of production can be calculated. The elasticity of factors is the percentage change of output due to a unit percentage change of input. Returns to scale measures by how much output change if inputs varies. If the input is increased with a scale of x %, it is possible to have increasing return to scale if output increases more than x %, constant return to scale if output increases with x %, and finally, decreasing return to scale if output increases less than x %. The elasticity of substitution measures how much must other inputs have to change to produce a fixed amount of output.

The functional form of the Cobb-Douglas is:

$$y = AK^{\alpha} L^{\beta} \tag{3}$$

where A is the technology
α is the elasticity of capital
β is the elasticity of labour

The advantages using the Cobb-Douglas production function are that it is possible to calculate both the elasticity of factors and the degree of return to scale. The elasticity of substitution among the inputs is constant and equal to one.

The Constant Elasticity of Substitution (CES) function is a generalisation of the Cobb-Douglas, and the functional form of the CES function is:

$$y = A\left[\delta K^{\rho} + (1-\delta)L^{\rho}\right]^{\frac{v}{\rho}} \tag{4}$$

where δ is the distribution between the inputs
ρ is used to calculate the elasticity of substitution
v measures the returns to scale

The elasticity of substitution can be calculated as

$$\sigma\hat{} = \hat{} \frac{1}{1-\rho} \tag{5}$$

where σ is the elasticity of substitution

If $\sigma = 0$ no substitution exists at all and the function becomes a Leontief production function, where increasing one input without the others the output will not increase at all, and contrary $\sigma = \infty$ there exist perfect substitutions between the inputs (Coppola, 2001) one input can be substituted of others and the output keep constant.

When analysing a fishery production function the well-known Schaefer function[1] has often been used. The idea behind the Schaefer function is to combine biological and economic aspects within the same production function. If it is assumed that catch is a function of effort and stock, the production function ((Conrad and Clark, 1987) and (Clark, 1985)) can be formulated as:

$$Catch = f(E, S) \tag{6}$$

where E is the effort
S is the biomass stock

Substitute effort with capital and labour the bioeconomic production function is transformed to:

$$Catch = f(K, L, S) \tag{7}$$

1 The common used Schaefer function is Catch = qES, where q is constant.

In this function output can be measured by the catch of fish and capital input as the number of vessels, the length of the vessels, the insurance value of the vessels, etc. Finally, labour is defined as crew working on the vessels.

3. Methods

The estimation procedure will cover the translog production function, the CES production function, the Cobb-Douglas production function, and the Cobb-Douglas production function with constant returns to scale, the static Shaefer production function, and the dynamic Shaefer production function. The production functions will be estimated as:

The Translog model:

$$Log(\,Catch\,) = c_0 + \sum_{i=1}^{k} c_i \log X_i + \sum_{i=1}^{k}\sum_{i=1}^{k} c_{i,j} \log X_i \log X_j \tag{8}$$

The Constant Elasticity of Substitution (CES) model with several inputs:[2]

$$Log(\,Catch\,) = c_0 + \sum_{i=1}^{k} c_i \log X_i + \sum_{i=1}^{k}\ \sum_{j=i+1}^{k} c_{i,j}(\log X_i - \log X_j\,)^2 \quad where\ i \neq j$$

$$if\quad \frac{c_{ij}}{c_i c_i}\cdot \sum_{k=1}^{3} c_k = \frac{2\cdot c_{ii}}{-c_i + \dfrac{c_i^2}{\sum_{k=1}^{3} c_k}} = \frac{2\cdot c_{jj}}{-c_j + \dfrac{c_j^2}{\sum_{k=1}^{3} c_k}} = constant\ \ \forall\, i, j \tag{9}$$

2 According to the Wald tests the Translog function can be approximated to the CES function (the chi-square probabilities are 0.5450, 0.9405, and 0.4874 for the HPD/ Stock, HPD/Crew, and Stock/Crew respectively).

The Cobb-Douglas (CD) model with several inputs:

$$Log(Catch) = c_0 + \sum_{i=1}^{k} c_i \log X_i \tag{10}$$

The Cobb-Douglas (CD) model with constant return to scale:

$$Log(Catch) = c_0 + \sum_{i=1}^{k} c_i \log X_i \text{ where } \sum_{i=1}^{k} c_i = 1 \tag{11}$$

The Static Shaefer model:

$$Log(Catch) = c_0 + \sum_{i=1}^{k} c_{1,i} \log X_i + \sum_{i=1}^{k} c_{2,i} \log X_i^2 \tag{12}$$

The Dynamic Shaefer model:

$$\begin{aligned} Log(Catch_t) = c_0 &+ \sum_{i=1}^{k} c_{1,i} \log X_{t,i} + \sum_{i=1}^{k} c_{2,i} \log X_{t,i}^2 \\ &+ \sum_{i=1}^{k} \log X_{t-1,i} + \log(Catch_{t-1}) \end{aligned} \tag{13}$$

As mentioned, multicollinearity can be problematic when estimation production function. If multicollinearity exists the estimates of the structural parameters will be highly unstable. Also, if the explanatory variables are positively correlated, one implication might be that the parameter estimates are of opposite sign, and if this is the case, the expected bias in the parameters will be huge. Therefore, the possibility of multicollinearity has to be considered.

However, multicollinearity can be evaluated by using the variance-inflating factor (VIF). Variance inflation is the diagonal of $(X'X)^{-1}$ if $(X'X)$ is scaled to correlation form and thereby VIF shows how the variance of an estimator is inflated by the presence of multicollinearity. If VIF is greater than 10 then multicollinearity is strongly present in the estimation. Another measure of multicollinearity is the application of the condition index (CI) or condition number, which is defined as the square root of the ratio of the largest eigenvalue to the corresponding smallest eigenvalue. Normally, if CI is between 10 and 30, there is moderate to strong multicollinearity and if it is greater than 30 there is seriously multicollinearity present in the data (Gujarati, 1995, pp. 338 - 339).

One way to correct for multicollinearity is to calculate a weighted (WTD) estimator (Maddala, 2001, p. 288). The WTD estimator is calculated as:

$$WTD = \lambda\beta_i + (1-\lambda)\beta_i^* \tag{14}$$

where $\lambda = \dfrac{t_j^2}{1+t_j^2}$

β_i is the parameter from the equation including all variables

β_i^* is the parameter from the equation excluding variables that cause multicollinearity

t is the t-statistics from the equation including all variables

The t-statistic is calculated from the equation including all variables and it is the t-statistics from the variable that is not included in the other regression. In other words, two equations are calculated: one regression with variable j and one regression without variable j. But again, by using the WTD estimator,[3] the problems according multicollinearity still exist since the WTD estimators for crew are negatively. Therefore, the WTD estimator does not solve the problem related to multicollinearity and therefore the WTD estimator will not be shown.

A common mentioned method to solve the problem according to multicollinearity is to use Ridge regression where a constant λ (or k) is added to the variances of the explanatory variables. This is a rather arbitrary method where the estimates are somewhat suspicious and is normally not recommended.

3 See Appendix 2.

If the Cobb-Douglas production function has constant return to scale, an option is to use Constrained Least Squares where a constant λ is included as the Lagrangian multiplier. Unfortunately, constant return to scale must be rejected according to the Wald test.

Another solution according to multicollinearity is to use the Instruments Variable (IV) methods where the variable, which causes the problem will be substituted with another variable that is related to the value of the catch but less correlated to the horse power days. As possible variables to be used are the total number of vessels, total horse power, total length of the vessels, the gross tonnage, total fishing days, total income. Unfortunately, none of these variables eliminate the multicollinearity problem and the IV method will not be taken further into account.

A method often used is to omit the variable with least statistical significance. In this situation, all our variables are important but the variable total crew has the wrong sign. Therefore, our production function has been estimated with and without the total crew. But by excluding the variable the estimate for the other variables will be biased although the estimators might have smaller variance.

After a short description of the variables each of the production function will be estimated. Eleven dummy variables are included in the estimations to take care of the season fluctuations, since the estimations are done on monthly data. Dummy variables that are statistical significant on a 5 percentage level are kept within the particular specification. Again, according to the monthly data tests for higher order autocorrelations must be carried out. To test for higher order autocorrelations the Breusch-Godfrey Lagrange Multiplier test will be used, where the model is estimated including some autocorrelations. The number of autocorrelations times the resulted F-value from the regression including the autocorrelation will be the test size and will be assumed to follow a chi- square distribution with the number of autocorrelations as the degrees of freedom. If the Breusch-Godfrey Lagrange Multiplier test shows that there exist higher order autocorrelations the production function are re-estimated. Only the first and higher order auto-correlation, which are statistical significant on a 5 percentage level are included. When working with time series, heteroscedasticity might exist and in this case the AutoRegressive Conditional Heteroskedasticity (ARCH) test and the Generalised AutoRegressive Conditional Heteroscedasticity (GARCH) test can be used. The idea of an ARCH model is that the variance of the residuals can be explained by the squared residuals Again, a Lagrangian multiplier test can be used, where the number of observations (n) is multiplied with the coefficient of multiple determination (R^2) obtain from the estimation of the present estimated squared residuals on the past estimated squared residuals. This test size follows the chi-square distribution with the number of autoregressive terms as the degrees of freedom. In a GARCH model the variance of the residuals can in addition to the squared residuals also be explained by the conditional variance. The same test method as is the case for ARCH has to be used. If it shows the existence for heteroscedasticity in the data the best ARCH or GARCH model will be chosen.

Before testing for cointegration the unit test will be carried out. If the unit tests show that the variables are nonstationary cointegration relations will be estimated.

After these test have been carried out the best models will be presented.

4. Danish data

The output is the present contexts are the monthly aggregated catch values for the individual vessels. The catch values of the individual species have been indexed by the mean value during the period 1987 – 1999. As output the catch values of each species each month and year has been indexed by the mean value during the period 1987 to 1999. As input, data on vessels and crew have been used, together with data on the stocks. Data related to vessels and crew has been provided from the Danish Directorate of Fisheries.

Since the purpose is to estimate production functions on the individual vessel level it has been necessary to combine three different databases: (1) the vessel register, (2) the logbook database, and (3) the account database. Firstly, the vessel register contains information related to the characteristics of the registered commercial fishing vessels in Denmark, e.g. vessel type, tonnage, engine, power, building year, length, insurance value and crew size. Secondly, the logbook database contains trip-level information for every commercial vessel with a length of more than 10 meters, such as employed gear, mesh size, fishing area, and days at sea. Finally, the account database contains information on all sales notes from those who first buy, receive or collect fish directly from the fishermen. By combining the three databases the data is available on the individual vessel level.

In this survey the data from the total Danish fleet consist of:

1. Only those trawlers that are working in the North Sea, and only those trawlers for which the monthly aggregated catch value of cod and flatfish in the North Sea constitutes of more than 50 percentage of the total monthly aggregated catch value in the North Sea.
2. Only vessels that are operated under full occupational status are included. Thereby, the partly occupational, other occupational, and unknown occupation are excluded from the survey.
3. Only vessels registered with fewer days at the North Sea in a month than the actual number of days in the months under consideration are included. Consequently, vessels that have been registered to operate more days than the number of days in the considered month has been eliminate from the survey.

As starting year the year 1987 has been chosen as the information obtained from the different databases becomes reliable and accessible from this year. Therefore, the Danish data covers monthly aggregated information for the Danish trawl fleet working in the North Sea during the period 1987 to 1999.

Data has been aggregated at a monthly level resulting in a set containing the total indexed catch value obtained by each vessel in the selected fleet in the month considered, the total crew working in each vessel in the selected fleets in the month considered, and the total amounts of horse power days employed by each vessel in the selected fleets in the month considered.

Information about stocks in the North Sea has been obtained from ACFM (Advisory Committee on Fishery Management) under ICES (The International Council for the Exploration of the Sea) 2000 report. Since stock information is not available for all species caught by the selected fleet only data for cod, haddock, whiting, saithe, plaice, and sole are included. In relation to this survey the value of these species by the selected fleet constitutes of 66 percentage of the total catch value during the 13 years considered. This is considered to be a reasonable amount, and since it has not been possible to obtain information on the remaining stocks of the species caught by the fleet, it has been chosen to employ the stocks of these six species in a measure of the total stock available for the selected fleet. A common stock measure has been obtained by the sum of the six stocks weighted by the mean prices of the species.

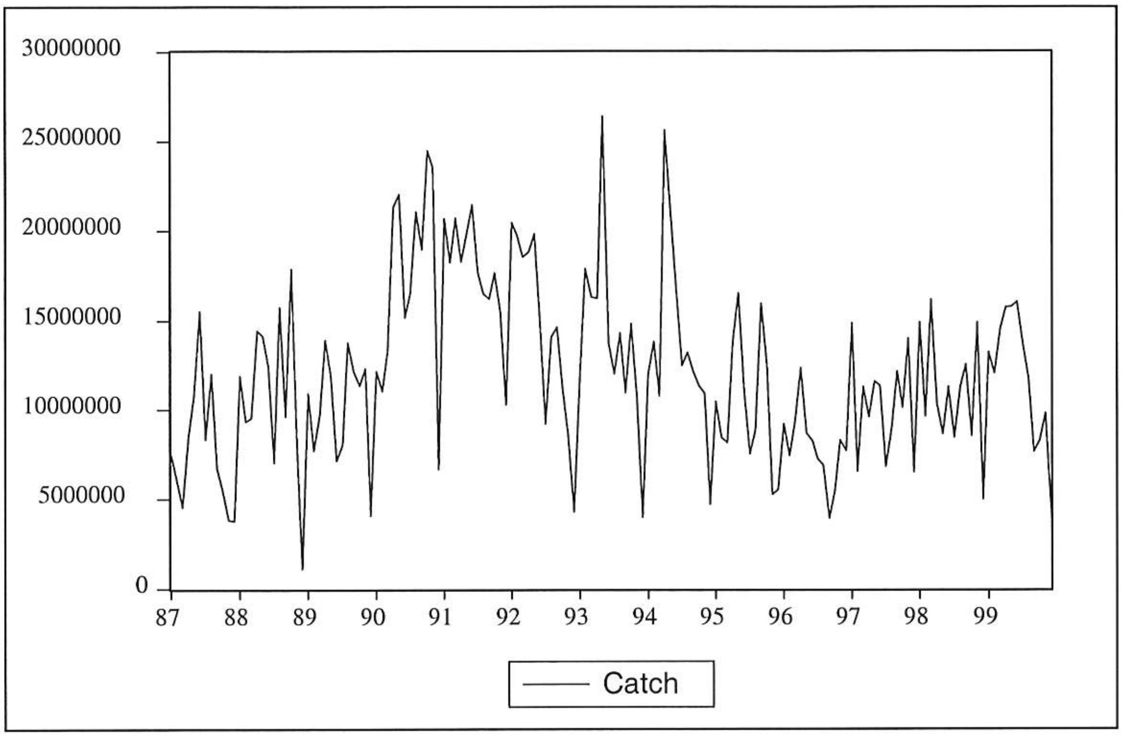
The final data set employed in the Danish analyses contains the following information:

1. Aggregated monthly landed values by the selected fleet, given in mean prices for the 13 years in the question 1987 to 1999.
2. Aggregated monthly crew numbers for the selected fleet.
3. Aggregated monthly horsepower days for the selected fleet.
4. Yearly total available stock measures given in mean prices.

5. Description of the data and estimations

After the description of the data collection the following section will include descriptions of the data and the estimations. The development in the catch (Y) is shown in figure 1.

Figure 1. ***The development in the catch value of consumption demersal fish in the Danish North Sea 1989 - 1999 (monthly aggregated data)***



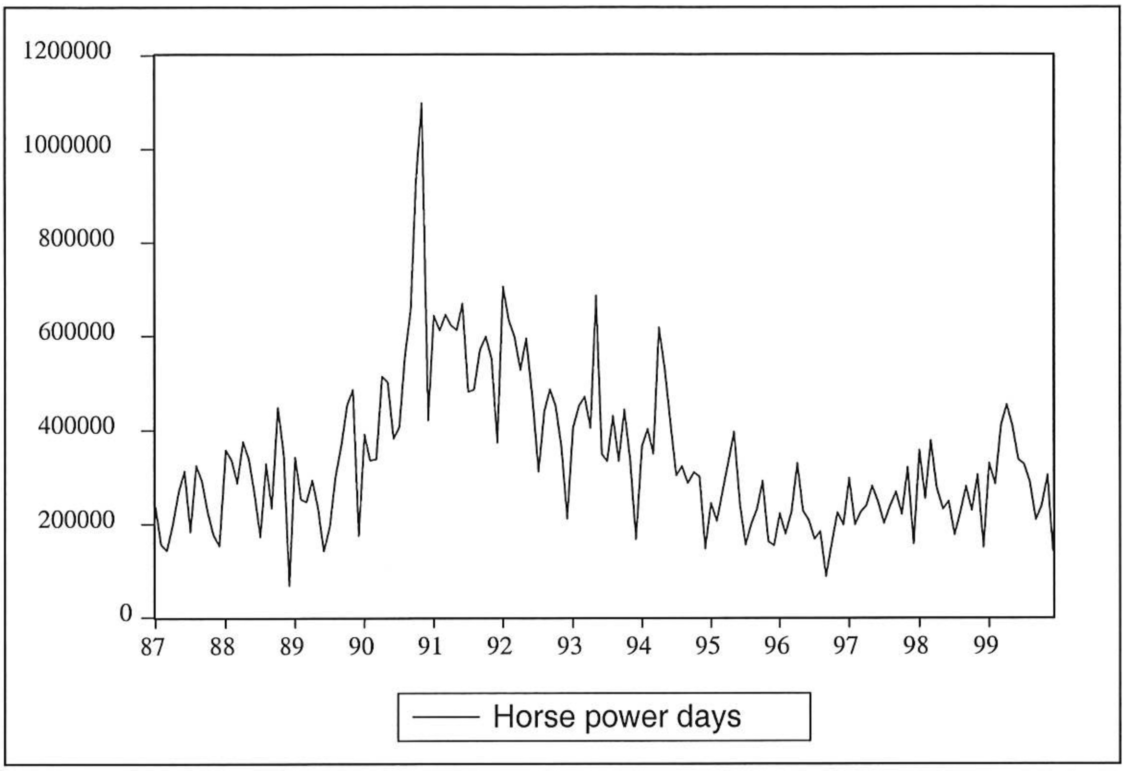
Source: The Danish Directorate of Fisheries

At an overall perspective Figure 1 shows that the catch fluctuates and no trend[4] can be seen for the whole period. Looking a bit closer at the development in the beginning of the period from about 1987 to 1990 there appears not to be any significant trend in the data. This period is followed by a downward trend until 1997 whereafter there is an increasing trend in the catch. In general, the catch in the end of the period corresponds to the catch in the beginning of the period.

Figure 2 shows the how the horse power days have develop in the period.

4 A regression of catch on time shows an insignificant (with a prob-value on 0.22) negatively (-10786.03) trend.

Figure 2. ***The development in the horse power days used in the catch of consumption demersal fish in the Danish North Sea 1989 - 1999 (monthly aggregated data)***

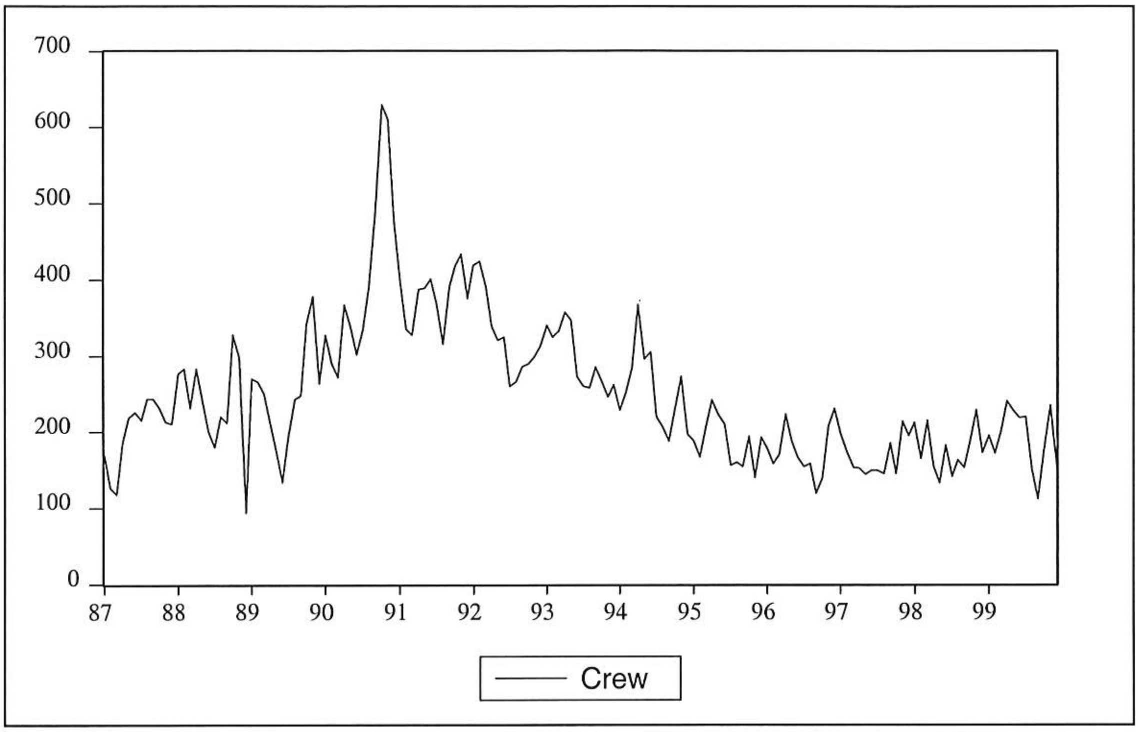


Source: The Danish Directorate of Fisheries

Figure 2 shows that there is no overall uniform trend in the development in horse power days. In the beginning of the period from about 1987 to 1990 no trend exist, from 1990 to 1991 the horse power days increased, this period is followed by a downward trend until 1997. In the end of the period perhaps a slightly increasing tendency exist.

Figure 3 shows the development of the crew.

Figure 3. The development in the crew in the Danish North Sea 1989 - 1999 (monthly data)



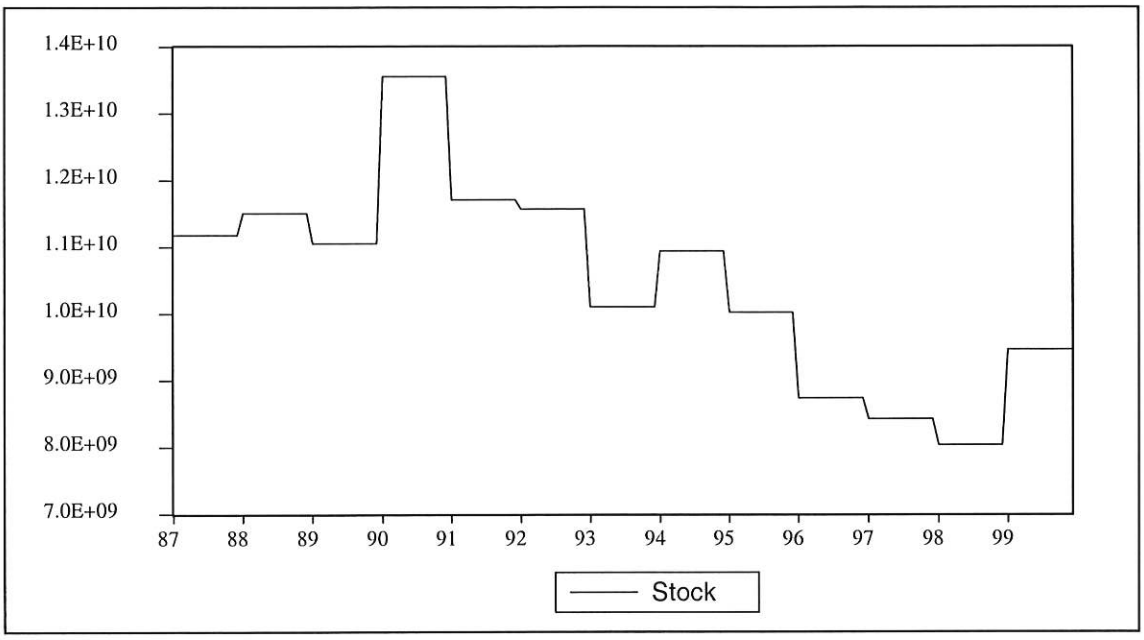
Source: The Danish Directorate of Fisheries

It is seen that the crew seems to follow almost the same pattern as were the case with the catch values and the horse power days. In the beginning of the period from 1987 to 1990 an increasing trend seems to exist and after 1991 the trend[5] is negatively.

The development of the stock index is shown in figure 4.

5 A statistical significant (prob-value less than 0.0001) negatively (- 0.83) trend exist for the hole period.

Figure 4. ***The development of the stock index of the consumption demersal fishes in the Danish North Sea 1989 - 1999 (yearly data)***



Source: ICES

The stock has an overall falling tendency in the period 1990 – 1998. The stock index increases from 1998 to 1999.

General statistics for the four variables are given in table 1.

Table 1. Descriptive statistics for the variables

	Catch (1.000 DKK)	Horse power days (Joule)	Crew	Stock (DKK)
Observations	156	156	156	156
Mean	12126267	340531.1	249.1923	1.05E+10
Median	11679428	310736.6	229.0000	1.09E+10
Maximum	26390318	1097045	629.0000	1.36E+10
Minimum	1129067	68876.63	94.00000	8.03E+09
Std. Dev.	4971085	160903.6	93.12996	1.50E+09
Skewness	0.453576	1.369292	1.158247	0.086878
Kurtosis	2.899433	5.988322	4.943204	2.468798
Jarque-Bera	5.414755	106.7944	59.42424	2.030384
Probability	0.066712	0.000000	0.000000	0.362333

Source: The Danish Directorate of Fisheries and ICES

According to table 1 the maximum catch in the period is 26.390 million, the minimum is 1.130 million and the average is 12.126 million. The horse power days are on the range 1.097 million to 0.069 million with an average of 0.341 million whereas the number of crew is between 629 and 94 with an average 249. The average of the stock is $1.05 * 10^{10}$ with a maximum value of $1.36 *10^{10}$ and a minimum of $0.80*10^{10}$.

The catch and the stock are normally distributed, the horse power days and crew are more left skewed than the stock and the catch that is also left skewed. The stock and the catch are platykurtic (fat) whereas the horse power days and the crew are leptokurtic (slim).

The models are estimated with the general model first followed by the less general model and by the more specific models. Accordingly to this sequence of procedure, the models will be estimated in the following order: Firstly, the Translog model, secondly, the Constant Elasticity of Substitution (CES), thirdly, the Cobb-Douglas (CD), and finally, the Cobb-Douglas model with

Constant Returns to Scale. After these models have been estimated a static Shaefer model will be estimated. Also, a dynamic Shaefer model will be estimated. For these production functions all the variables will be included independent of their significance.

Dummy variables for each month (D2 - D12) are included to take care of the seasonal fluctuations.

Both the Durbin-Watson test for first-order autocorrelation and the Breusch-Godfrey Lagrange multiplier test for higher-order serial correlation have been used. (See Section 3). For all the production function there exists first-order autocorrelation and the Breusch-Godfrey tests show higher-order autocorrelation. As a consequence of this there have been included twelve autocorrelated error terms (AR(1) - AR(12)), which have been dropped one by one according to their significance value. Only, significant dummy variables and autocorrelated error terms are included in the final results.

Also, Lagrangian multiplier tests for the existence of autoregressive conditional heteroscedasticity (ARCH) (see Section 3) have been carried out. All the tests reject the existence of auoregressive conditional heteroscedasticity and therefore the production function will likewise be estimated without autoregressive conditional heteroscedasticity (ARCH) and generalised autoregressive conditional heteroscedasticity (GARCH).

Unit root tests of the catch, the logarithm of the catch, and the season adjusted catch have been done, and they show, that none of the variables were nonstationary. Therefore, no cointegration analysis has been performed.

Multicollinearity exists between horse power days and crew in all cases according to the sign of the coefficient. The VIF value is calculated to be 4.7234, and the Condition number or conditions indeks is calculated to 9923 and shows a high rate of multicollinearity.

6. Result

In Tables 2 - 4 the results for the translog, the constant elasticity of substitution (CES) function, the Cobb-Douglas production function and the Static and Dynamic model in ordinary and logarithm are shown. Three models for each of these models have been estimated. Model 1 includes only horse power days as an explanatory variable, Model 2 includes horse power days and the stock as explanatory variables. Finally, Model 3 shows the catch value as a function of horse power days, the stock, and the crew.

Regardless of the significance level all the variables that describe the mentioned production function are included. For the dummy variables and the higher-order auto-correlation only the statistical significance variables and auto correlation's term are included.

Table 2. ***Comparison of the Regression Results from different specifications production function***[1)]

	Translog Model			CES Model			Cobb - Douglas		
	Model 1	*Model 2*	*Model 3*	*Model 1*	*Model 2*	*Model 3*	*Model 1*	*Model 2*	*Model3*
C	*566.3057*	*-248.6773*	*-8.6781*	*-91.3966*	*8.0469*	3.3585	17.5237	17.4092	3.3585
	(540.0682)	*(422.4038)*	*(6.0790)*	*(59.1560)*	*(6.2174)*	(0.5830)	(5.0497)	(4.8280)	(0.5830)
LOG(HPD)	-25.0003	*-2.7606*	2.9648	*4.6424*	*-0.9381*	1.0233	1.1113	1.0685	1.0233
	(1 2.6191)	*(6.0186)*	(0.9708)	*(4.5418)*	*(0.8649)*	(0.0487)	(0.0706)	(0.0450)	(0.0487)
LOG(STOCK)	*-42.4929*	*24.5852*		*9.9303*	*1.3153*		-0.6538	-0.6363	
	(47.0433)	*(37.4452)*		*(5.4683)*	*(0.8962)*		(0.2238)	(0.2163)	
LOG(CREW)	*35.0103*			*-14.0387*			*-0.0439*		
	(22.7279)			*(8.8079)*			*(0.0970)*		
LOG(HPD)^2	*-0.0090*	-0.0948	-0.0782						
	(0.1781)	(0.0411)	(0.0388)						
LOG(STOCK)^2	*0.7497*	*-0.6208*							
	(1.0318)	*(0.8364)*							
LOG(CREW)^2	*-0.0817*								
	(0.3755)								
LOG(HPD)*LOG(STOCK)	1.1930	*0.2683*							
	(0.5457)	*(0.2749)*							
LOG(STOCK)·LOG(CREW)	*-1.3780*								
	(0.9726)								
LOG(CREW)*LOG(HPD)	*-0.2071*								
	(0.4498)								
(LOG(HPD)-LOG(STOCK))^2				*0.0232*	-0.0944				
				(0.0915)	(0.0408)				
(LOG(HPD)-LOG(CREW))^2				*-0.2134*					
				(0.2198)					
(LOG(STOCK)-LOG(CREW))^2				*-0.3062*					
				(0.1970)					

D10		-0.1064		-0.1099	-0.1048		-0.1068		
		(0.0461)		(0.0533)	(0.0462)		(0.0430)		
D11	-0.0971	-0.1576	-0.1025	-0.1519	-0.1577	-0.1025	-0.1519	-0.1135	-0.1025
	(0.0433)	(0.0461)	(0.0515)	(0.0607)	(0.0467)	(0.0491)	(0.0459)	(0.0437)	(0.0491)
D12	-0.1496	-0.2242	-0.2524	-0.1999	-0.2272	-0.2506	-0.2042	-0.1914	-0.2506
	(0.0744)	(0.0537)	(0.0603)	(0.0822)	(0.0539)	(0.0583)	(0.0582)	(0.0527)	(0.0583)
AR(1)	0.3555	0.4297	0.4726	0.4319	0.4208	0.5204	0.4797	0.4592	0.5204
	(0.0862)	(0.0848)	(0.0702)	(0.0772)	(0.0833)	(0.0679)	(0.0826)	(0.0827)	(0.0679)
AR(2)	0.2720	0.2106			0.2029		0.2019	0.1812	
	(0.0942)	(0.0904)			(0.0833)		(0.0906)	(0.0907)	
AR(4)	-0.2383	-0.2155			-0.2123		-0.1878	-0.1812	
	(0.0781)	(0.0745)			(0.0731)		(0.0717)	(0.0705)	
AR(9)			0.1302			0.1433	0.1341	0.1249	0.1433
			(0.0678)			(0.0587)	(0.0635)	(0.0626)	(0.0587)
AR(12)	0.1708	0.1879	0.2671	0.2361	0.1943	0.2339	0.1516	0.1876	0.2339
	(0.0713)	(0.0688)	(0.0678)	(0.0713)	(0.0681)	(0.0664)	(0.0692)	(0.0679)	(0.0664)
R^2	0.9253	0.9253	0.9120	0.9176	0.9202	0.9085	0.9199	0.9159	0.9085
$\overline{R}^2$	0.9165	0.9165	0.9074	0.9108	0.9074	0.9045	0.9132	0.9103	0.9045
DW	2.0091	1.9819	2.1601	2.1650	1.9905	2.1160	2.0180	2.0026	2.1160
Residual sum of squares	2.2116	2.3549	2.6352	2.4381	2.3620	2.7067	2.3708	2.4887	2.7067

Source: The Danish Directorate of Fisheries and ICES

1) Numbers in italics show that the variable is statistical insignificant on a 5 percentage level

Table 3. ***Comparison of the Regression Results from static and dynamic Shaefer model (Ordinary data)***[1)]

	Static Shaefer Model			Dynamic Shaefer Model		
	Model 1	*Model 2*	*Model 3*	*Model 1*	*Model 2*	*Model 3*
C	*11365397.0* *(7364766.0)*	*7383811.00* *(8317101.0)*	*-1465669* *(1097945)*	*7735785* *(4924396)*	*7432309* *(4853026)*	*7398.865* *(595147.6)*
HPD	51.0069 (4.8082)	45.8544 (3.4568)	47.2043 (0.9708)	56.7043 (4.9674)	46.01143 (2.9420)	46.3545 (2.8134)
STOCK	*-0.0020* *(0.0015)*	*-0.0011* *(0.0016)*		*-0.001713* *(0.00108)*	*-0.0017* *(0.0010)*	
CREW	*-9631.45* *(11630.61)*			-21612.21 (10823.4)		
HPD^2	-0.0000146 (0.00000481)	-0.0000153 (0.0000033)	-0.000016 (0.000003)	-0.0000212 (0.000005)	-0.000014 (0.000003)	-0.0000148 (0.0000029)
STOCK^2	*8.39E-14* *(6.86E-14)*	*2.63E-14* *(7.19E-14)*		*5.96E-14* *(4.69E-14)*	*5.70E-14* *(4.35E-14)*	
CREW^2	*-13.8559* *(18.9212)*			*16.4896* *(17.6035)*		
HPD(-1)				-20.6480 (3.0634)	-16.6058 (2.3084)	-18.2938 (1.9802)
STOCK(-1)				*0.000363* *(0.000324)*	*0.000417* *(0.000329)*	
CREW(-1)				11134.31 (4189.6)		
CATCH(-1)				0.3231 (0.06946)	0.3345 (0.0684)	0.3725 (0.0581)

D4						1233653.0 (484173.4)
D5						1437838.0 (497020.4)
D6				1783996 (733531.9)		1603987 (501131.7)
D10						-1131059 (481079.8)
D11						-1091670 (482237.1)
AR(1)	0.3556 (0.0761)	0.4019 (0.0724)	0.4384 (0.0703)			
AR(6)	-0.2174 (0.0795)	-0.1715 (0.0733)		-0.2691 (0.0836)	-0.2649 (0.0820)	
AR(12)	0.2093 (0.0770)	0.2741 (0.0730)	0.3620 (0.0683)	0.3111 (0.0832)	0.3239 (0.0812)	
R^2	0.8970	0.8847	0.8870	0.9162	0.9060	0.9027
$\bar{R}^2$	0.8901	0.8787	0.8735	0.9078	0.8997	0.8966
DW	2.0871	2.0521	2.0648	1.9909	2.0070	2.0484
Residual sum of squares	3.55E+14	3.97E+14	4.23E+14	2.88E+14	1558967	3.71E+14

Source: The Danish Directorate of Fisheries and ICES

1) Numbers in italics show that the variable is statistical insignificant on a 5 percentage level

Table 4. Comparison of the Regression Results from static and dynamic Shaefer model (The logarithm of the data)[1)]

	Static Shaefer Model			Dynamic Shaefer Model		
	Model 1	*Model 2*	*Model 3*	*Model 1*	*Model 2*	*Model 3*
C	*247.6384* *(406.5995)*	*-89.0104* *(394.2125)*	*-11.4863* *(6.2220)*	*133.3425* *(275.4049)*	*86.6232* *(263.3200)*	*-5.1183* *(6.4261)*
LOG(HPD)	*0.9684* *(1.4998)*	3.2985 (0.9637)	3.4358 (0.9931)	*2.4027* *(1.6223)*	2.2335 (1.0221)	2.4016 (1.0110)
LOG(STOCK)	*-21.5663* *(35.2076)*	*7.3758* *(34.1987)*		*-12.4745* *(23.8468)*	*-8.0148* *(22.9699)*	
LOG(CREW)	3.5078 (1.5141)			*1.0187* *(1.3807)*		
LOG(HPD)^2	*0.006745* *(0.0595)*	-0.0900 (0.03848)	-0.0980 (0.03966)	*-0.0517* *(0.0645)*	*-0.0460* *(0.0408)*	*-0.0532* *(0.0403)*
LOG(STOCK)^2	*0.4582* *(0.7636)*	*-0.1732* *(0.7413)*		*0.3699* *(0.3293)*	*0.1626* *(0.4976)*	
LOG(CREW)^2	-0.3412 (0.1406)			*-0.1052* *(0.1279)*		
LOG(HPD)(-1)				-0.6742 (0.1055)	-0.6319 (0.0784)	-0.6780 (0.0738)
LOG(STOCK)(-1)				*0.3699* *(0.3293)*	*0.3260* *(0.3694)*	
LOG(CREW)(-1)				*0.1769* *(0.0961)*		
LOG(CATCH)(-1)				0.4414 (0.0718)	0.4676 (0.0613)	0.5006 (0.0583)

D6				0.1195 (0.0531)	0.1209 (0.0420)	0.1203 (0.0423)
D10				-0.1111 (0.0534)	-0.1458 (0.0408)	-0.1455 (0.0411)
D11	-0.0991 (0.04489)	-0.1161 (0.0468)		-0.1128 (0.0531)	-0.1465 (0.0414)	-0.1403 (0.0416)
D12	-0.16086 (0.0591)	-0.1981 (0.0554)	-0.2246 (0.0625)	-0.1847 (0.0693)	-0.1754 (0.0524)	-0.1744 (0.0526)
AR(1)	0.3798 (0.0832)	0.4005 (0.0840)	0.4327 (0.0713)			
AR(2)	0.2259 (0.0909)	0.1885 (0.0893)				
AR(4)	-0.2295 (0.0792)	-0.2062 (0.0731)			-0.2649 (0.0820)	
AR(12)	0.1962 (0.0705)	0.2292 (0.0687)	0.3378 (0.0653)	0.2168 (0.0854)	0.3239 (0.0812)	
R^2	0.92205	0.9170	0.9059	0.9280	0.9206	0.9175
$\overline{R}^2$	0.9149	0.9108	0.9025	0.9195	0.9145	0.9129
DW	2.0158	1.9845	2.0257	2.1564	2.0960	2.1032
Residual sum of squares	0.1327	2.4566	0.1420	2.1309	2.7137	2.8212

Source: The Danish Directorate of Fisheries and ICES

1) Numbers in italics show that the variable is statistical insignificant on a 5 percentage level

In model 1 only the horse power days are included as explanatory variable in the estimations. The parameters for horse power days are statistical significant and have the right sign. In the dynamic Shaefer production function the variable logarithm of HPD^2 is statistical insignificant. The determinations of correlation are everywhere very high from 87.70 percentages (the static Shaefer model with the original data) to 91.75 percentages. In other words, the capital variable horse power days is a very important input in the production of fish.

In model 2 the variable stock is included as explanatory variable together with horse power days. At the first sight the parameter estimates have the wrong sign. Only one specification, the static Shaefer model (logarithm model) has the correct signs. Unfortunately, the horse power days variable in this model is now statistical insignificant, which is also a sign of multicollinearity. In fact, these models cannot be used to make conclusions about the elasticity etc.

Model 3 includes the horse power days, the stock, and the crew as explanatory variables. Many of the variables are statistical insignificant. Although, it has been shown that all of the variables included in these models are separetely significant,[6] they appear now to be insignificant, which can only be explained in relation to multicollinearity. The variables are also statistical insignificant.

As mentioned, only the significant dummy variables and the significant autocorrelations are included. Very often, this has been dummies for the tenth (D10), eleventh (D11), and twelfth (D12) month. They are always negative, which means that in October, November, and December the catches are less than in the rest of the year.

As a conclusion the best model according to these data is the dynamic Shaefer model estimated with logarithm data. This model has the highest determination of correlation and the highest adjusted determination of correlation. In fact, all

6 See Appendix 1.

parameters have the right sign. Only the logarithm of horse power days^2 is insignificant. In this situation the Shaefer model is easy to interpret. According to the estimates the usually nice Shaefer form exists here, and the logarithm of the lagged catch is positive. This variable is often used as a proxy of the agents' expectations. If the fisherman had a good catch last period, he expects likewise a good catch in this period. The parameter of the logarithm of the horse power days shows the elasticity of the factor. In this case there exist increasing returns to scale. The elasticity of substitution among the inputs is constant and equal to one but the elasticity of substitution makes no sense here.

7. Conclusion

The existence of multicollinearity between horse power days and crew, and between the stock and the horse power days imply that the recommended method is to use the Dynamic Shaefer model with logarithm data. This model has the highest determination of correlation and the highest adjusted determination of correlation within the group with only horse power days. In fact, all parameters have the rights sign. Only the logarithm of horse power days^2 is insignificant. In this situation the Shaefer model is easy to interpret. According to the estimates the usually nicely Shaefer form exist here, and the logarithm of the lagged catch is positive. This variable is often used as a proxy of the agents' expectations. If the fishermen had a good catch last period, he expects likewise a good catch in this period. The elasticity of the factors is calculated as 2.4 - 2*0.0532*logarithm of horse power days. In this case there exist constant returns to scale.[7] The elasticity of substitution among the inputs is constant and equal to one but the elasticity of substitution makes no sense here.

One way to correct for multicollinearity is to calculate the WTD estimator. Unfortunately, by using the WTD estimator, the problems according multicollinearity still exist since the WTD estimators for the crew are all negatively. In this

7 The elasticity is = 2.4016 – 2*0.0532*12.63611 = 1.0571, since the mean of the logarithm of horsepower days is 12.6361.

situation the WTD estimator did not solve the problem according to multicollinearity. Ridge estimation and other factor analysis models will not be recommended as will not IV methods. In fact, the only solution in this situation is the use of priory information.

The usual method to avoid multicollinearity is to increase the number of observations but if the problem is the structure of the fishery this solution will not overcome the problem. The only possible solution is to use information from other surveys.

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Appendix 1

Table A1. Result of regression analysis including only one production factor [1)]

	Ordinary Data			Logarithm of the Data		
	Model 1	*Model 2*	*Model 3*	*Model 1*	*Model 2*	*Model 3*
C	2884369 (760697.5)	*1298476* *(4104012)*	3837305 (825310.4)	3.358541 (0.583023)	-5.346301 (8.557853)	10.69798 (0.466289)
HPD	28.80232 (1.5754)					
STOCK		0.001139 (0.000390)				
CREW			36207.49 (2980.749)			
LOG(HPD)				1.023310 (0.044872)		
LOG(STOCK)					0.940950 (0.371359)	
LOG(CREW)						1.047770 (0.085544)
D2						-0.124894 (0.056092)
D4		2709298 (1071881)	2381779 (955910.9)		0.191245 (0.095726)	
D5		3529234 (1052991)	3506394 (954097.3)		0.228011 (0.095926)	0.140176 (0.054706)
D7		-2552517 (1009621)			-0.226700 (0.089540)	-0.166753 (0.055370)
D10						-0.150395 (0.059021)

D11	-1635361 (752517.2)		-2685417 (977094.7)	-0.102462 (0.049050)		-0.351494 (0.061308)
D12	-2637933 (813041.4)	-7576215 (989110.8)	-7354274 (950768.2)	-0.250572 (0.058270)	-0.944527 (0.088155)	-0.911339 (0.056779)
AR(1)	0.3842 (0.0763)	0.331962 (0.080355)		0.520386 (0.067878)	0.351676 (0.077545)	0.344332 (0.077784)
AR(3)		0.196364 (0.077153)	0.183251 (0.080774)		0.175008 (0.073823)	0.239576 (0.073452)
AR(9)			0.143349 (0.058709)			
AR(10)						0.204334 (0.070706)
AR(12)	0.2936 (0.0719)	0.165677 (0.070109)	0.228451 (0.078536)	0.233907 (0.066363)	0.157330 (0.067990)	
R^2	0.8635	0.6164	0.7452	0.9085	0.6378	0.8219
$\overline{R}^2$	0.8586	0.5936	0.7321	0.9045	0.6163	0.8087
DW	1.9654	2.0747	1.7553	2.1160	1.9810	2.1117
Residual sum of squares	1845332	3127743	2639762	0.1406	10.7197	0.2054

Source: The Danish Directorate of Fisheries and ICES

1) Numbers in italics show that the variable is statistical insignificant on a 5 percentage level

Appendix 2

Table A2.1. Comparison of the Ordinary Least Squares Regression Results with the Weighted (WTD) Estimator for the Translog Model [1)]

	Model 1		Model 2		Model 3	
	OLS	*WTD*	*OLS*	*WTD*	*OLS*	*WTD*
C	*566.3057* *(540.0682)*	Incl.	*-248.6773* *(422.4038)*	Incl.	*-8.6781* *(6.0790)*	*-8.6781* *(6.0790)*
LOG(HPD)	-25.0003 (1 2.6191)	-19.1771	*-2.7606* *(6.0186)*	2.5595	2.9648 (0.9708)	2.9648 (0.9708)
LOG(STOCK)	*-42.4929* *(47.0433)*	-36.9214	*24.5852* *(37.4452)*	-15.2175		
LOG(CREW)	*35.0103* *(22.7279)*	25.7817				
LOG(HPD)^2	*-0.0090* *(0.1781)*	-0.1067	-0.0948 (0.0411)	-0.0967	-0.0782 (0.0388)	-0.0782 (0.0388)
LOG(STOCK)^2	*0.7497* *(1.0318)*	0.7327	*-0.6208* *(0.8364)*	0.2461		
LOG(CREW)^2	*-0.0817* *(0.3755)*	-0.2599				
LOG(HPD)*LOG(STOCK)	1.1930 (0.5457)		*0.2683* *(0.2749)*			
LOG(STOCK)¨LOG(CREW)	*-1.3780* *(0.9726)*					
LOG(CREW)*LOG(HPD)	*-0.2071* *(0.4498)*					

D10			-0.1064 (0.0461)	Incl.		
D11	-0.0971 (0.0433)	Incl.	-0.1576 (0.0461)	Incl.	-0.1025 (0.0515)	-0.1025 (0.0515)
D12	-0.1496 (0.0744)	Incl.	-0.2242 (0.0537)	Incl.	-0.2524 (0.0603)	-0.2524 (0.0603)
AR(1)	0.3555 (0.0862)	Incl.	0.4297 (0.0848)	Incl.	0.4726 (0.0702)	0.4726 (0.0702)
AR(2)	0.2720 (0.0942)	Incl.	0.2106 (0.0904)	Incl.		
AR(4)	-0.2383 (0.0781)	Incl.	-0.2155 (0.0745)	Incl.		
AR(9)					0.1302 (0.0678)	0.1302 (0.0678)
AR(12)	0.1708 (0.0713)	Incl.	0.1879 (0.0688)	Incl.	0.2671 (0.0678)	0.2671 (0.0678)
R^2	0.9253		0.9253		0.9120	0.9120
$\overline{R}^2$	0.9165		0.9165		0.9074	0.9074
DW	2.0091		1.9819		2.1601	2.1601
Residual sum of squares	2.2116		2.3549		2.6352	2.6352

Source: The Danish Directorate of Fisheries and ICES

1) Numbers in italics show that the variable is statistical insignificant on a 5 percentage level (OLS)

Table A2.2. Comparison of the Ordinary Least Squares Regression Results with the Weighted (WTD) Estimator for the CES Model[1)]

	Model 1		**Model 2**		**Model 3**	
	OLS	*WTD*	*OLS*	*WTD*	*OLS*	*WTD*
C	*-91.3966*	Incl.	*8.0469*	Incl.	3.3585	3.3585
	(59.1560)		*(6.2174)*		(0.5830)	(0.5830)
LOG(HPD)	*4.6424*	1.0251	*-0.9381*	1.0415	1.0233	1.0233
	(4.5418)		*(0.8649)*		(0.0487)	(0.0487)
LOG(STOCK)	*9.9303*	1.0266	*1.3153*	1.0224		
	(5.4683)		*(0.8962)*			
LOG(CREW)	*-14.0387*	0.9553				
	(8.8079)					
(LOG(HPD)-LOG(STOCK))^2	*0.0232*		-0.0944			
	(0.0915)		(0.0408)			
(LOG(HPD)-LOG(CREW))^2	*-0.2134*					
	(0.2198)					
(LOG(STOCK) - LOG(CREW))^2	*-0.3062*					
	(0.1970)					
D10	-0.1099	Incl.	-0.1048	Incl.		
	(0.0533)		(0.0462)			
D11	-0.1519	Incl.	-0.1577	Incl.	-0.1025	-0.1025
	(0.0607)		(0.0467)		(0.0491)	(0.0491)
D12	-0.1999	Incl.	-0.2272	Incl.	-0.2506	-0.2506
	(0.0822)		(0.0539)		(0.0583)	(0.0583)

AR(1)	0.4319 (0.0772)	Incl.	0.4208 (0.0833)	Incl.	0.5204 (0.0679)	0.5204 (0.0679)
AR(2)			0.2029 (0.0833)			
AR(4)			-0.2123 (0.0731)			
AR(9)					0.1433 (0.0587)	0.1433 (0.0587)
AR(12)	0.2361 (0.0713)	Incl.	0.1943 (0.0681)	Incl.	0.2339 (0.0664)	0.2339 (0.0664)
R^2	0.9176		0.9202		0.9085	0.9085
$\overline{R}^2$	0.9108		0.9074		0.9045	0.9045
DW	2.1650		1.9905		2.1160	2.1160
Residual sum of squares	2.4381		2.3620		2.7067	2.7067

Source: The Danish Directorate of Fisheries and ICES

1) Numbers in italics show that the variable is statistical insignificant on a 5 percentage level (OLS)

Table A2.3. ***Comparison of the Ordinary Least Squares Regression Results with the Weighted (WTD) Estimator for the Cobb - Douglas Model*** [1)]

	Model 1		**Model 2**		**Model 3**	
	OLS	*WTD*	*OLS*	*WTD*	*OLS*	*WTD*
C	17.5237	Incl.	17.4092	Incl.	3.3585	3.3585
	(5.0497)		(4.8280)		(0.5830)	(0.5830)
LOG(HPD)	1.1113	1.1111	1.0685	1.0874	1.0233	1.0233
	(0.0706)		(0.0450)		(0.0487)	(0.0487)
LOG(STOCK)	-0.6538	-0.4785	-0.6363	-0.5036		
	(0.2238)		(0.2163)			
LOG(CREW)	*-0.0439*	0.8571				
	(0.0970)					
D10	-0.1068	Incl.				
	(0.0430)					
D11	-0.1519	Incl.	-0.1135	Incl.	-0.1025	-0.1025
	(0.0459)		(0.0437)		(0.0491)	(0.0491)
D12	-0.2042	Incl.	-0.1914	Incl.	-0.2506	-0.2506
	(0.0582)		(0.0527)		(0.0583)	(0.0583)
AR(1)	0.4797	Incl.	0.4592	Incl.	0.5204	0.5204
	(0.0826)		(0.0827)		(0.0679)	(0.0679)
AR(2)	0.2019	Incl.	0.1812	Incl.		
	(0.0906)		(0.0907)			
AR(4)	-0.1878	Incl.	-0.1812	Incl.		
	(0.0717)		(0.0705)			
AR(9)	0.1341	Incl.	0.1249	Incl.	0.1433	0.1433
	(0.0635)		(0.0626)		(0.0587)	(0.0587)
AR(12)	0.1516	Incl.	0.1876	Incl.	0.2339	0.2339
	(0.0692)		(0.0679)		(0.0664)	(0.0664)

R^2	0.9199		0.9159		0.9085	0.9085
$\overline{R}^2$	0.9132		0.9103		0.9045	0.9045
DW	2.0180		2.0026		2.1160	2.1160
Residual sum of squares	2.3708		2.4887		2.7067	2.7067

Source: The Danish Directorate of Fisheries and ICES

1) Numbers in italics show that the variable is statistical insignificant on a 5 percentage level (OLS)

Table A2.4. Comparison of the Ordinary Least Squares Regression Results with the Weighted (WTD) Estimator for the Static Shaefer Model[1)] (Ordinary data)

	Model 1		Model 2		Model 3	
	OLS	*WTD*	*OLS*	*WTD*	*OLS*	*WTD*
C	*11365397.0*	Incl.	*7383811.00*	Incl.	*-1465669*	*-1465669*
	(7364766.0)		*(8317101.0)*		*(1097945)*	*(1097945)*
HPD	51.0069	50.9591	45.8544	45.8528	47.2043	47.2043
	(4.8082)		(3.4568)		(0.9708)	(0.9708)
STOCK	*-0.0020*	-0.0012	*-0.0011*	-0.0002		
	(0.0015)		*(0.0016)*			
CREW	*-9631.45*	229991.4207				
	(11630.61)					
HPD^2	-0.0000146	-1.46E-05	-0.0000153	-1.5E-05	-0.000016	-0.000016
	(0.00000481)		(0.0000033)		(0.000003)	(0.000003)
STOCK^2	*8.39E-14*	7.08E-14	*2.63E-14*	4.8E-14		
	(6.86E-14)		*(7.19E-14)*			
CREW^2	*-13.8559*	-9.9157				
	(18.9212)					
AR(1)	0.3556	Incl.	0.4019	Incl.	0.4384	0.4384
	(0.0761)		(0.0724)		(0.0703)	(0.0703)
AR(6)	-0.2174	Incl.	-0.1715	Incl.		
	(0.0795)		(0.0733)			
AR(12)	0.2093	Incl.	0.2741	Incl.	0.3620	0.3620
	(0.0770)		(0.0730)		(0.0683)	(0.0683)
R^2	0.8970		0.8847		0.8870	0.8870
$\bar{R}^2$	0.8901		0.8787		0.8735	0.8735
DW	2.0871		2.0521		2.0648	2.0648
Residual sum of squares	3.55E+14		3.97E+14		4.23E+14	4.23E+14

Source: The Danish Directorate of Fisheries and ICES

1) Numbers in italics show that the variable is statistical insignificant on a 5 percentage level (OLS)

Table A2.5. Comparison of the Ordinary Least Squares Regression Results with the Weighted (WTD) Estimator for the Dynamic Shaefer Model[1)] (Ordinary Data)

	Model 1		**Model 2**		**Model 3**	
	OLS	*WTD*	*OLS*	*WTD*	*OLS*	*WTD*
C	*7735785* *(4924396)*	Incl.	*7432309* *(4853026)*	Incl.	*7398.865* *(595147.6)*	*7398.865* *(595147.6)*
HPD	56.7043 (4.9674)	56.6248	46.01143 (2.9420)	46.0066	46.3545 (2.8134)	46.3545 (2.8134)
STOCK	*-0.001713* *(0.00108)*	-17278.68	*-0.0017* *(0.0010)*	-0.0016		
CREW	-21612.21 (10823.4)	11325.39				
HPD^2	-0.0000212 (0.000005)	-2.08E-05	-0.000014 (0.000003)	-1.43E-05	-0.0000148 (0.0000029)	-0.0000148 (0.0000029)
STOCK^2	*5.96E-14* *(4.69E-14)*	6.46E-14	*5.70E-14* *(4.35E-14)*	5.86E-14		
CREW^2	*16.4896* *(17.6035)*	7.3627				
HPD(-1)	-20.6480 (3.0634)	-20.5874	-16.6058 (2.3084)	-16.6139	-18.2938 (1.9802)	-18.2938 (1.9802)
STOCK(-1)	*0.000363* *(0.000324)*	0.0006	*0.000417* *(0.000329)*	0.0006		
CREW(-1)	11134.31 (4189.6)	8690.88				
CATCH(-1)	0.3231 (0.06946)	Incl.	0.3345 (0.0684)	Incl.	0.3725 (0.0581)	0.3725 (0.0581)

D4					1233653.0	1233653.0
					(484173.4)	(484173.4)
D5					1437838.0	1437838.0
					(497020.4)	(497020.4)
D6	1783996	Incl.			1603987	1603987
	(733531.9)				(501131.7)	(501131.7)
D10					-1131059	-1131059
					(481079.8)	(481079.8)
D11					-1091670	-1091670
					(482237.1)	(482237.1)
AR(6)	-0.2691	Incl.	-0.2649	Incl.		
	(0.0836)		(0.0820)			
AR(12)	0.3111	Incl.	0.3239	Incl.		
	(0.0832)		(0.0812)			
R^2	0.9162		0.9060		0.9027	0.9027
$\bar{R}^2$	0.9078		0.8997		0.8966	0.8966
DW	1.9909		2.0070		2.0484	2.0484
Residual sum of squares	2.88E+14		1558967		3.71E+14	3.71E+14

Source: The Danish Directorate of Fisheries and ICES

1) Numbers in italics show that the variable is statistical insignificant on a 5 percentage level (OLS)

Table A2.6. *Comparison of the Ordinary Least Squares Regression Results with the Weighted (WTD) Estimator for the Static Shaefer Model[1)] (Logarithm Data)*

	Model 1		Model 2		Model 3	
	OLS	*WTD*	*OLS*	*WTD*	*OLS*	*WTD*
C	*247.6384* *(406.5995)*	Incl.	*-89.0104* *(394.2125)*	Incl.	*-11.4863* *(6.2220)*	*-11.4863* *(6.2220)*
LOG(HPD)	*0.9684* *(1.4998)*	2.8813	3.2985 (0.9637)	3.3284	3.4358 (0.9931)	3.4358 (0.9931)
LOG(STOCK)	*-21.5663* *(35.2076)*	-29.4265	*7.3758* *(34.1987)*	-30.6088		
LOG(CREW)	3.5078 (1.5141)	3.5668				
LOG(HPD)^2	*0.006745* *(0.0595)*	-0.1056	-0.0900 (0.03848)	-0.0926	-0.0980 (0.03966)	-0.0980 (0.03966)
LOG(STOCK)^2	*0.4582* *(0.7636)*	*0.6535*	*-0.1732* *(0.7413)*	0.6774		
LOG(CREW)^2	-0.3412 (0.1406)	-0.3306				
D11	-0.0991 (0.04489)	Incl.	-0.1161 (0.0468)	Incl.		
D12	-0.16086 (0.0591)	Incl.	-0.1981 (0.0554)	Incl.	-0.2246 (0.0625)	-0.2246 (0.0625)

AR(1)	0.3798 (0.0832)	Incl.	0.4005 (0.0840)	Incl.	0.4327 (0.0713)	0.4327 (0.0713)
AR(2)	0.2259 (0.0909)	Incl.	0.1885 (0.0893)	Incl.		
AR(4)	-0.2295 (0.0792)	Incl.	-0.2062 (0.0731)	Incl.		
AR(12)	0.1962 (0.0705)	Incl.	0.2292 (0.0687)	Incl.	0.3378 (0.0653)	0.3378 (0.0653)
R^2	0.92205		0.9170		0.9059	0.9059
$\overline{R}^2$	0.9149		0.9108		0.9025	0.9025
DW	2.0158		1.9845		2.0257	2.0257
Residual sum of squares	0.1327		2.4566		0.1420	0.1420

Source: The Danish Directorate of Fisheries and ICES

1) Numbers in italics show that the variable is statistical insignificant on a 5 percentage level (OLS)

Table A2.7. Comparison of the Ordinary Least Squares Regression Results with the Weighted (WTD) Estimator for the Dynamic Shaefer Model[1] (Logarithm Data)

	Model 1		**Model 2**		**Model 3**	
	OLS	*WTD*	*OLS*	*WTD*	*OLS*	*WTD*
C	*133.3425* *(275.4049)*	Incl.	*86.6232* *(263.3200)*	Incl.	*-5.1183* *(6.4261)*	*-5.1183* *(6.4261)*
LOG(HPD)	*2.4027* *(1.6223)*	2.5816	2.2335 (1.0221)	3.4645	2.4016 (1.0110)	2.4016 (1.0110)
LOG(STOCK)	*-12.4745* *(23.8468)*	-35.8300	*-8.0148* *(22.9699)*	-32.5004		
LOG(CREW)	*1.0187* *(1.3807)*	2.0434				
LOG(HPD)^2	*-0.0517* *(0.0645)*	-0.0670	*-0.0460* *(0.0408)*	-0.0976	*-0.0532* *(0.0403)*	*-0.0532* *(0.0403)*
LOG(STOCK)^2	*0.3699* *(0.3293)*	0.7848	*0.1626* *(0.4976)*	0.7041		
LOG(CREW)^2	*-0.1052* *(0.1279)*	-0.1315				
LOG(HPD)(-1)	-0.6742 (0.1055)	-0.6726	-0.6319 (0.0784)	-0.2685	-0.6780 (0.0738)	-0.6780 (0.0738)
LOG(STOCK)(-1)	*0.3699* *(0.3293)*	0.5068	*0.3260* *(0.3694)*	0.6185		
LOG(CREW)(-1)	*0.1769* *(0.0961)*	0.06704				
LOG(CATCH)(-1)	0.4414 (0.0718)	Incl.	0.4676 (0.0613)	Incl.	0.5006 (0.0583)	0.5006 (0.0583)

D6	0.1195	Incl.	0.1209	Incl.	0.1203	0.1203
	(0.0531)		(0.0420)		(0.0423)	(0.0423)
D10	-0.1111	Incl.	-0.1458	Incl.	-0.1455	-0.1455
	(0.0534)		(0.0408)		(0.0411)	(0.0411)
D11	-0.1128	Incl.	-0.1465	Incl.	-0.1403	-0.1403
	(0.0531)		(0.0414)		(0.0416)	(0.0416)
D12	-0.1847	Incl.	-0.1754	Incl.	-0.1744	-0.1744
	(0.0693)		(0.0524)		(0.0526)	(0.0526)
AR(4)			-0.2649	Incl.		
			(0.0820)			
AR(12)	0.2168	Incl.	0.3239	Incl.		
	(0.0854)		(0.0812)			
R^2	0.9280		0.9206		0.9175	0.9175
$\overline{R}^2$	0.9195		0.9145		0.9129	0.9129
DW	2.1564		2.0960		2.1032	2.1032
Residual sum of squares	2.1309		2.7137		2.8212	2.8212

Source: The Danish Directorate of Fisheries and ICES

1) Numbers in italics show that the variable is statistical insignificant on a 5 percentage level (OLS)

Department of Environmental and Business Economics
Institut for Miljø- og Erhvervsøkonomi (IME)

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