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Climate Change and its Effect on the Norwegian Mackerel Fishery

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Abstract

The background for the paper is the expected climate change and its effect on the Norwegian mackerel fishing industry. Global warming is expected to affect the ecosystem in the Northeast Atlantic. Considerable uncertainty surrounds the prediction of how the NEA mackerel stock will be affected by the climate change. However, qualitative predictions indicate that the NEA mackerel stock will move further north into the northern North Sea, the Norwegian Sea and into the southern Barents Sea. Norway has 31% of the TAC, and shares the NEA mackerel with Faeroe Island and the EU. Climate induced changes in the ecosystem can change the migration pattern and spawning areas, and therefore change the TAC and how it is distributed between countries. Norway exports mackerel products for about 2.5 billion Norwegian kroner per year. The paper shows that changes in gross revenue due to changes in TAC are about three times higher in the infinitely elastic demand case compared with an elastic demand. If the Norwegian TAC increases by 20 %, the gross revenue increases by 25-30 million Norwegian kroner per year in the elastic case and about 120 million Norwegian kroner if the demand is infinitely elastic.

April 2005

1. INTRODUCTION

Today little is known about how the mackerel fishery would be affected by climate change. Oceanographers expect that mackerel will increase in abundance in the northern part of the North Sea and the Norwegian Sea and thus attain a more northerly distribution (Sundby and Stenevik 2003). The oceanographers can, however, only give qualitative estimates as to whether the stock will increase or decrease.

If the herring fishery will expand (see Lorentzen and Hannesson 2005), it is arguable that the mackerel fishery also will expand, because mackerel forages to some extent on the same organisms. In addition the possibility that mackerel will begin to forage in the Barents Sea should not be excluded (Stenevik and Sundby, Addendum 2004).

The Northeast Atlantic (NEA) mackerel stock consists of three spawning components, the Western (ICES area VI, VII, VIIIa,b,d,e), the Southern (VIIIc, IXa), and the North Sea mackerel (IV, IIIa), named after their respective spawning areas. The southern mackerel spawns west of Portugal and in the Bay of Biscay, the western in the waters off Ireland and west of the UK, while the North Sea mackerel spawns in the central North Sea and in Skagerrak. Figure 1 shows the ICES-areas.

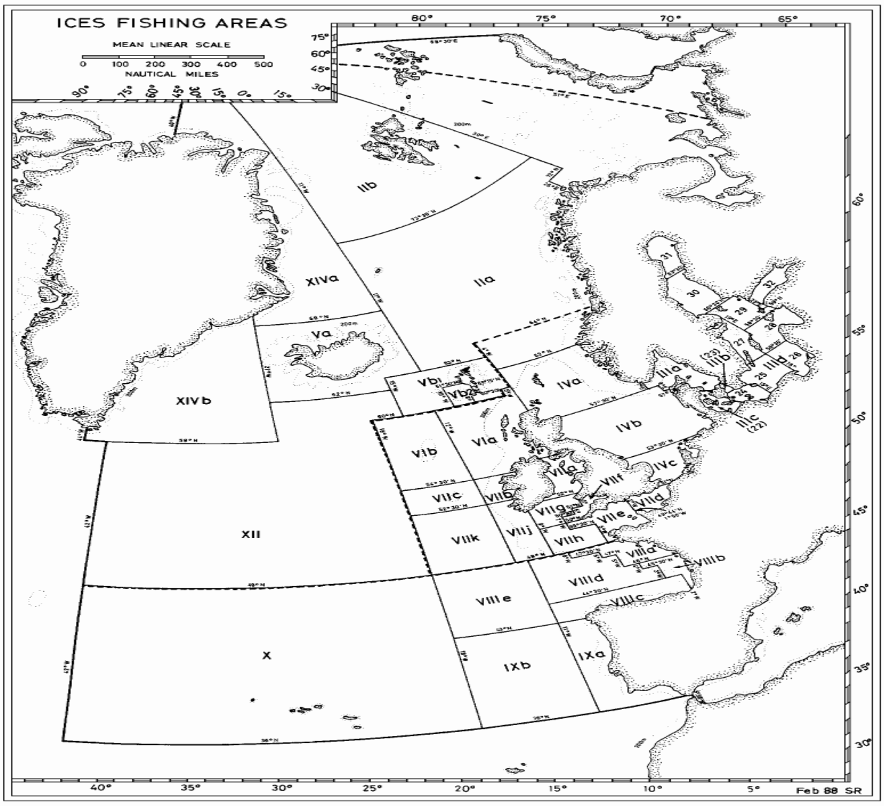

Figure 1: ICES-areas

Source: ICES

There has been a decrease in the spawning stock biomass (SSB) since 1998, which ICES explains by overexploitation. The North Sea component is today considered outside safe biological limits. In the beginning of the 90s the mackerel catches increased from a relatively stable level of 600 thousand tons (Figure 2) to over 800 thousand tons in 1993 and 1994.

ICES recommended in 1999 that Norway, EU and Faeroe Islands should reduce the fishing mortality of mackerel, and in 2004 ICES advised that the total landings of mackerel should be less than 545 thousand tons the next years. Based on ICES' recommendations for the period 1987-2003, the average TAC is 606 thousand tons per year, but the estimated average catch is 100 thousand tons higher per year. The overexploitation is explained by inefficient control in EU and by discards. ICES states:

> "*Medium- and long term projections: Stochastic medium-term projections indicate that there is a low risk of SSB falling below B_{pa} if catches are kept below 600 thousand tons annually"* (ICES Advice p. 378, 2003)[1].

The point is that we can expect that the TAC will be about 600 thousand tons in the future if the parties succeed in managing the mackerel fishery.

The most important catch areas are the North Sea (ICES area IV), the Norwegian Sea (ICES area IIa), and an area west of 4^0 west (ICES areas VI, VII and parts of VIII). The TAC of the Northeast Atlantic mackerel is shared by Norway, EU and the Faeroe Islands, with the Norwegian part of the total quota being 31%. The main catches are taken by purse seiners and mid-water trawlers. Figure 2 shows the catches of Northeast Atlantic mackerel during the period 1980-2001.

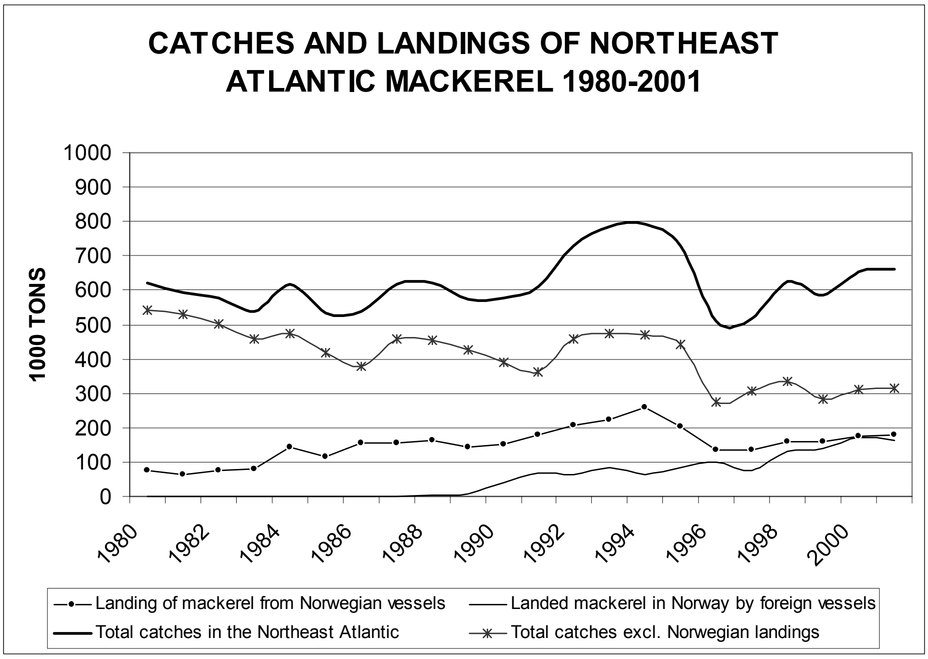

Figure 2: Aggregated catches of mackerel in the Northeast Atlantic

Souce: Statistics Norway and ICES

The landings by the Norwegian vessels increased during the period 1980-1994, followed by two years of decline. Total catches excluding the Norwegian landings followed a weakly negative trend which flattened out during the last part of the period. Total catches of mackerel fluctuated, but were relatively stable during the period, except for the strong increase that

[1] B_{pa} is a precautionary measure. It reflects partly the uncertainty in the assessment of the spawning stock and it reflects the minimum biomass level that keeps the stock from collapsing.

began in 1991/92 and ended in a steep decline in 1995/97. Note that the landings in Norway by foreign vessels have increased steadily from the early 90s to 2001 when the quantity was nearly the same as the quantity landed by the Norwegian vessels.

The landings of mackerel in Norway by foreign vessels follow nearly the same pattern as the foreign landings of herring (Lorentzen and Hannesson 2005). Irish and Scottish vessels have landed a large share of their TAC in Norway. The increase can be explained by the same arguments as for landings of herring, i.e., partly by liberalization of foreign fish landings in Norway, partly by the fact that the EU-fleet can catch a share of its quota in the Norwegian EEZ, and partly by high, competitive prices in the Norwegian raw fish market.

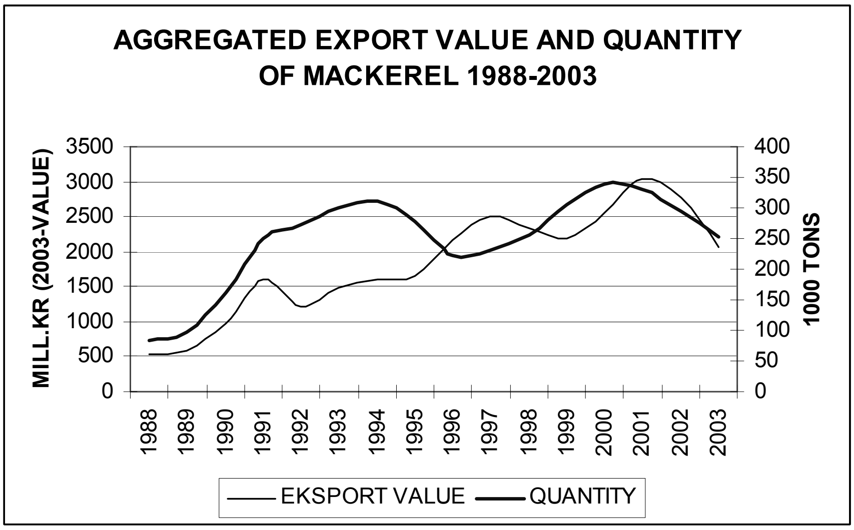

Figure 3: Aggregated export of mackerel from Norway

Source: Statistics Norway

The pelagic industries in Scotland, Ireland and the Faeroe Islands have recently invested in processing capacity and upgraded their factories, and it is expected that the landings of mackerel in Norway will be reduced in the future. The landings pattern will also be influenced by the future migration pattern of mackerel. Figure 3 shows the aggregated real value and quantity of exports of mackerel from Norway during 1988-2003. The export value has had a positive trend during the period, but has declined the last two years. The average export value during the last nine years is about 2.5 billion Norwegian kroner.

3. ESTIMATION OF THE DEMAND FUNCTION

Figure 4 shows quantity and price (2003-value) of Northeast Atlantic mackerel landed in Norway by Norwegian vessels during the period 1980 to 2001. The figure shows an overall positive trend in quantity and price. The quantity landed had a positive trend from 1980 to 1994. In 1995 and 1996 the landings dropped, but increased again after that. The real price fell during 1981 to 1983, but increased after that, except for a drop from 1991 to 1992 and from 1997 to 1999. After the mid-1990s the volatility has also increased. Figure 4 indicates that the variables are not stationary. Table 1 shows how price and catches of mackerel are related.

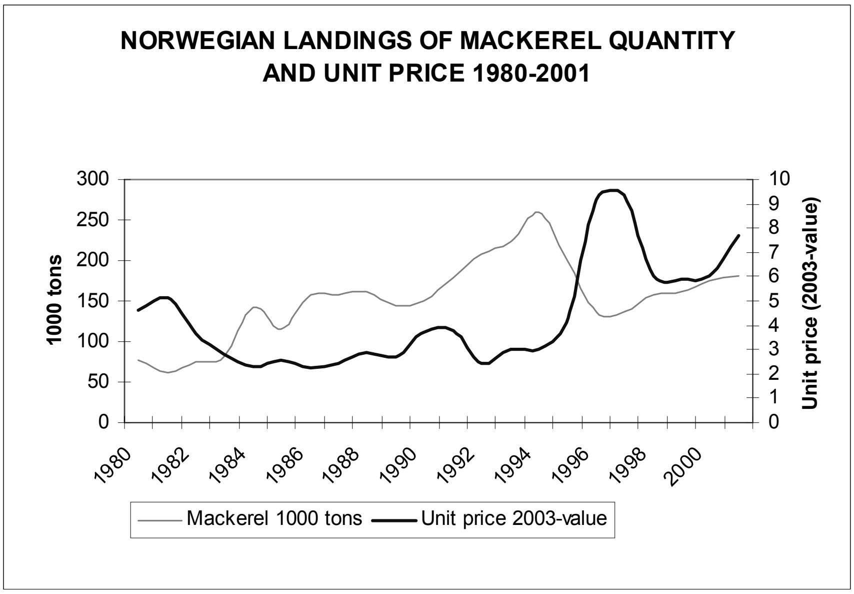

Figure 4: Price of mackerel and landed quantity in Norway by Norwegian vessels

Source: Statistics Norway

Table 1: Pearson's Correlation matrix

		Unit price (p)	Landing of mackerel from Norwegian vessels (x_1)	Landed mackerel in Norway by foreign vessels (x_2)	Total catches of mackerel in NEA excl. landings in Norway (x_3)	Total landings of mackerel in Norway (x_4)
Unit price (p)	Pearson Correlation	1	-.098	.652(**)	-.673(**)	.344
	Sig. (2-tailed)		.665	.006	.001	.117
	N	22	22	16	22	22
Landing of mackerel from Norwegian vessels (x_1)	Pearson Correlation	-.098	1	.133	-.248	.843(**)
	Sig. (2-tailed)	.665		.623	.267	.000
	N	22	22	16	22	22
Landed mackerel in Norway by foreign vessels (x_2)	Pearson Correlation	.652(**)	.133	1	-.626(**)	.875(**)
	Sig. (2-tailed)	.006	.623		.009	.000
	N	16	16	16	16	16
Total catches of mackerel in NEA exclusive landings in Norway (x_3)	Pearson Correlation	-.673(**)	-.248	-.626(**)	1	-.585(**)
	Sig. (2-tailed)	.001	.267	.009		.004
	N	22	22	16	22	22
Total landings of mackerel in Norway (x_4)	Pearson Correlation	.344	.843(**)	.875(**)	-.585(**)	1
	Sig. (2-tailed)	.117	.000	.000	.004	
	N	22	22	16	22	22

** Correlation is significant at the 0.01 level (2-tailed).

The first row in the Pearson's correlation matrix is of special interest. It shows a weakly negative but not significant relation between quantities landed in Norway by Norwegian vessels and the real price of mackerel. The correlation coefficient between price and landings by foreign vessels is positive and significant, which can be explained by positive trend in both variables. The correlation is significantly negative between price and total catches of mackerel in the NEA excluding landings by Norwegian vessels. On the other hand, if we split up the Pearson's correlation coefficient and control for other variables, we get results which are consistent with economic theory. We have also estimated the partial correlation between quantity landed by Norwegian vessels and price measures -0.743 (p=0.001), and the partial element implies in this case a control for respectively price trend and landings of mackerel in Norway by foreign vessels. If in addition it is controlled for aggregated catches in the Northeast Atlantic (excluding landings in Norway), the partial correlation is reduced to -0.164 (p=0.296). The landings in Norway by the foreign vessels have a weak, negative effect on the average price realized by Norwegian vessels [-0.487 (p=0.039)].[2] An important reason why foreign landings do not have any strong influence on the Norwegian prices is the sequential landing structure. The foreign vessels normally land mackerel in the first quarter and some in the last quarter of the year, while the Norwegian vessels normally catch the fish in the period from August to October. Hence the market interaction is limited. Figure 5 shows the relation between price and foreign landings of mackerel in Norway.

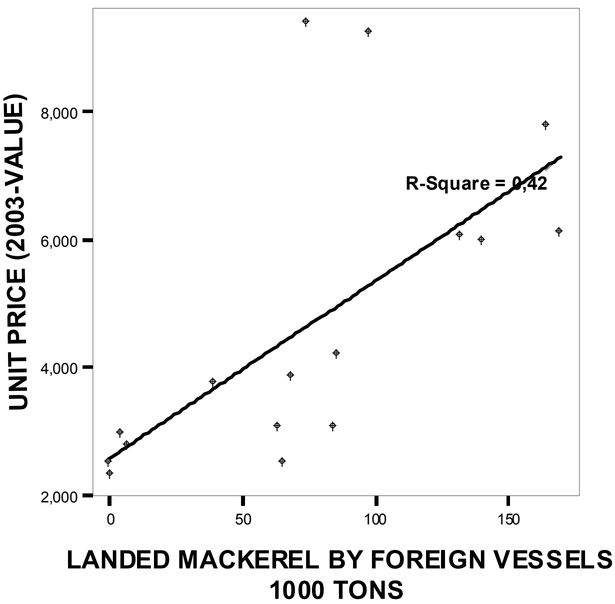

Figure 5: Price of mackerel and foreign landings in Norway 1980-2001

Figure 6 and 7 further explores the relationship between price and quantity. Figure 6 indicates no negative overall relationship between price and quantity, but that there exists an overall negative relation between an increase in quantity and change in price (figure 7). The regression line and R^2 are also shown in the figures. Looking more closely at figure 4, there appears to be an inverse relationship between price and quantity in some periods and a positive one at other times.

[2] The p-value refers to the one sided test for no negative effect.

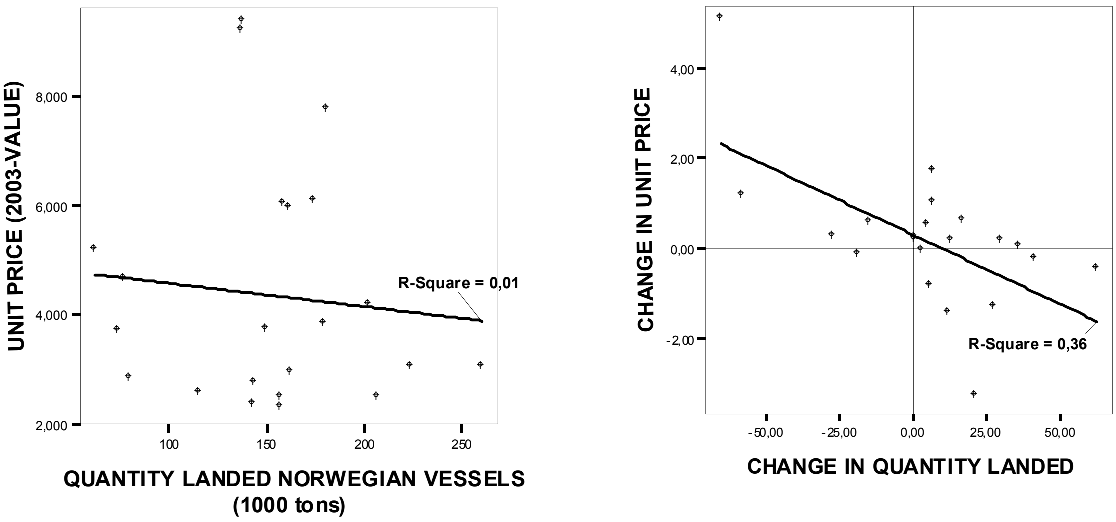

Figure 6 and 7: Price of mackerel and landed fish by Norwegian vessels 1980-2001

Stationary processes and long term relations

The fact that both price and quantity increase during the same time periods, which indicates non stationary processes, implies that it is difficult to identify the demand function. An identification of the demand schedule requires a stable demand and an exogenous given supply. The supply is still supposed to be exogenous, but the demand schedule seems to be exposed to shifts during 1980-2001. An ordinary least squares regression (OLS) between price and quantity shows an insignificant *t*-statistics for the independent variable (quantity) and the constant term. The model explains only 1% of the variation in price, and there is a high positive autocorrelation in the model. Dickey-Fuller unit root tests show that price and quantity are non-stationary. We applied an augmented Dickey-Fuller test to evaluate whether a linear combination of the price and quantity is stationary and cointegrating. If these variables are cointegrated, there is evidence that there exists a long run relationship between the non-stationary variables. The statistical results show that the variables are cointegrated for a constant and a trend (see appendix A).

The variables in the original model are

$$p_t = \alpha + \beta q_t + u_t$$

where

p_t: Natural logarithm of price for year *t*

q_t: Natural logarithm of quantity for year *t*

α_t: Constant term

u_t: Autocorrelated residuals, which have the following estimated structure
$u_t = 0.8672 u_{t-1} + \varepsilon_t$, and $\varepsilon_t \sim N(0, \sigma_\varepsilon^2)$

Price and quantity in the original model are transformed with the use of the coefficient in the autoregressive first order process AR(1), i.e., in general terms $x_t \in (p_t, q_t)$ and

$x_t^* = x_t - 0.8672x_{t-1}$. The processes are stabilized by differencing (DSP). The model to be estimated is:

$$p_t^* = \gamma_0 + \gamma_1 q_t^* + \varepsilon_t$$

Table 2 summarizes the results from the regression

Table 2: Coefficients

Variable name	Estimated coefficient	Standard error	T-ratio 19 DF	P-value	Partial Corr.	Standardized Coefficient	Elasticity at means
Quantity q_t^*	-0.82349	0.2657	-3.099	0.006	-0.579	-0.5795	-2.8542
Constant γ_t^*	0.77652	0.1923	4.039	0.001	0.680	0.0000	3.8542

The model explains about 34% of the variation in the price ($R^2 = 0.34$), and the F-value (F=9.6) indicates that the hypothesis $H_0 : \gamma_0 = \gamma_1 = 0$ can be rejected. Hence, 66 % of the variation in price is not explained by the model, indicating that the model excludes important explanatory variables. Standard error of the estimate is $\sigma_{\hat{p}} = 0.23$, i.e. the average price is $\overline{p} = 4.35$ Norwegian kroner and $e^{\sigma_{\hat{p}}} \approx \pm 1.26$, which indicates about 30% volatility compared to the average price. The estimated coefficients are significantly different from zero, and the sign of the coefficient associated with the quantity variable is consistent with economic theory. The model predicts that, on average, the real (transformed) price will be reduced by 0.8% if the (transformed) landings from Norwegian vessels increase by 1%. The value of the Durbin-Watson statistic DW=1.832 indicates no autocorrelation. Hansen's test for parameter instability indicates an unstable constant term (at the 5% level) and unstable joint parameters (at the 10% level). The Chow test also indicates a structural shift in the parameters in the middle of the time interval, as we also can visualize in figure 4. The variables are linearized by logarithmic transformation, but the processes can still have nonlinear elements in sub-intervals. The regression gives the following estimated model:

$$\hat{p}_t^* = 0.77652 - 0.82349 q_t^*$$

The price of mackerel can be simulated by using the expression for the transformed variables and the estimated coefficients. By substitution we get the following expression for the predicted *short run* price:

$$\hat{p}_t = 0.77652 - 0.82349(q_t - 0.86720 q_{t-1}) + 0.86720 p_{t-1}$$

The simulated and observed short run price is mapped in figure 8.

Suppose that the *long run* equilibrium in the market for mackerel is characterized by stable demand and supply, and the intertemporal real prices and quantities are identical year after year, i.e. $p_{t-1} = p_t = p_{t+1} = p_L$ and $q_{t-1} = q_t = q_{t+1} = q_L$. If we substitute these assumptions in the model, the long run relation between real price and quantity landed of mackerel by Norwegian vessels boils down to the following relation:

$$p_L = 5.8472891 - 0.82349 q_L$$

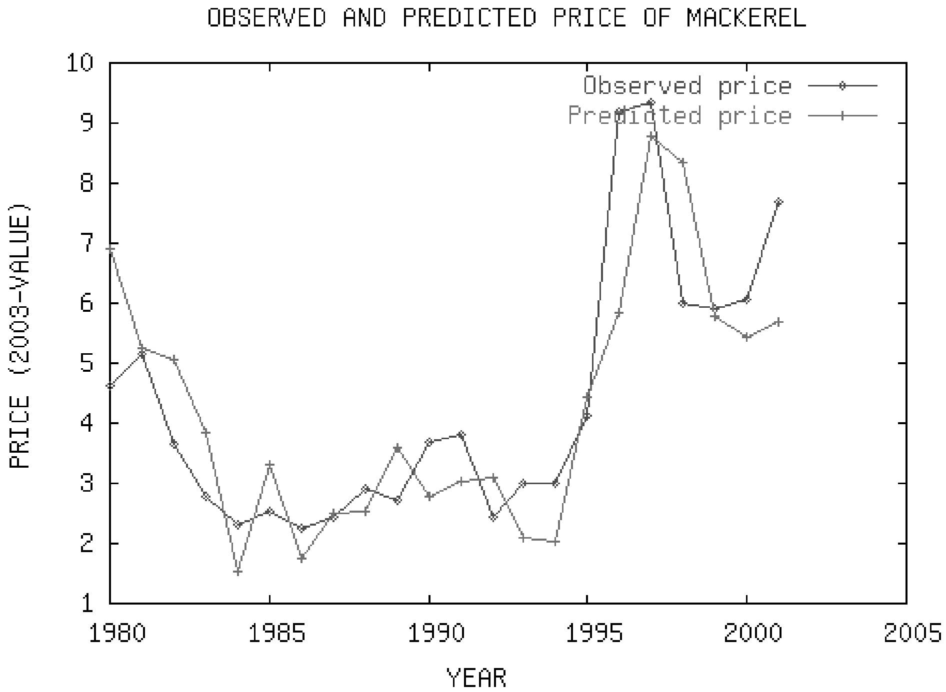

Figure 8: Observed and predicted price of mackerel 1980-2001

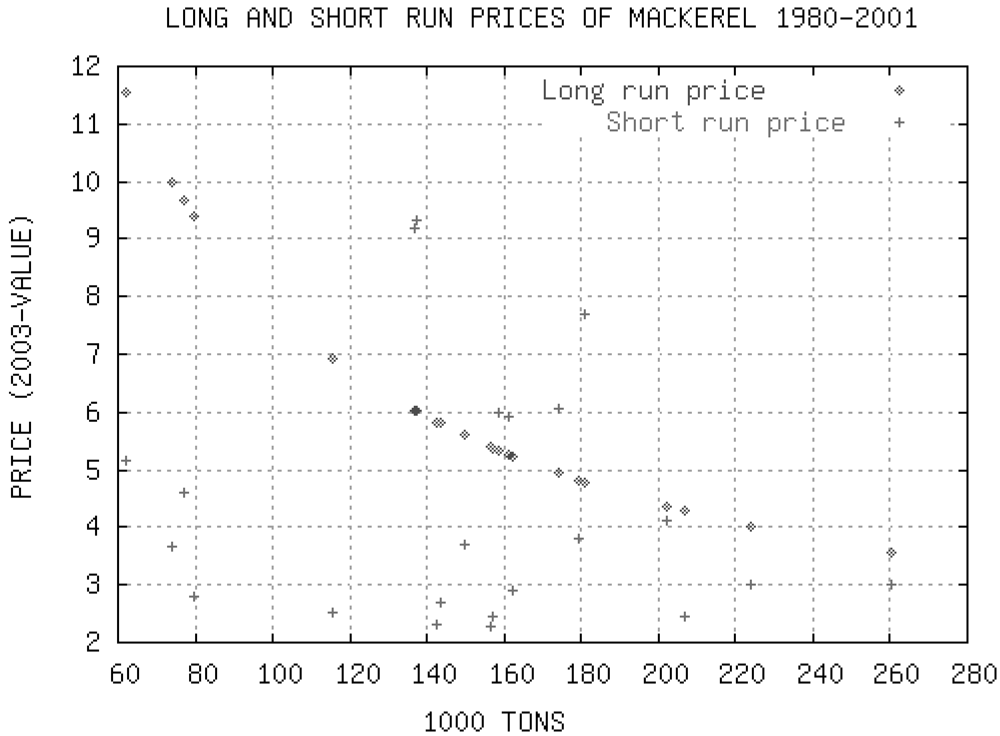

Figure 9: Short and long run price and quantity of mackerel

The long run price model indicates that the price on average is expected to be reduced by 0.8% if the quantity landed increases by 1%. The long run price elasticity is therefore 1.21. The short and long run relation between price and quantity is mapped in figure 9. The price marked 'short run' is the observed prices related to landed quantity. The relatively high variance in the observed prices indicates the complexity to explain the variation in the mackerel prices. The average real price of mackerel is $\overline{p}_M = 4.35$ Norwegian kroner during the period 1980-2001.

4. REVENUE EFFECTS OF CHANGED LANDINGS

In the following we first assume that the aggregated change in mackerel landings does not have any influence on the market price. Secondly we analyse the scenario where the aggregated supply of mackerel has an influence on the market price, as estimated in the above model.

Infinitely elastic demand

The average real unit price on mackerel was $\overline{p}_M = 4.35$ Norwegian kroner during the period 1980-2001. The 95% confidence interval for the average price is: $[3.45, \quad 5.25]$. Given stationarity and that changes in unit price are random, the expected change in gross value of a change in the Norwegian TAC can be expressed as the product of average unit price and expected increase in mackerel landings, i.e.:

$$\Delta R = \overline{p}\Delta q = 4.35\overline{Q}\beta$$

where

$\overline{Q}$ the expected TAC in the status quo situation, i.e. without any change climate

β The percentage change in TAC. The parameter β determined or a function of changes in climate and/or changes in management

The expression shows that the change in gross revenue depends on price, initial quantity, and change in TAC induced by, for example, climate change.

The average landings of mackerel by Norwegian vessels were 152 thousand tons during 1980-2001. The Norwegian TAC was 160 thousand tons in 2003 and about 150 thousand in 2004. The Norwegian TAC is reduced to about 120 thousand tons for 2005, and the reduction in quota reflects that the Northeast Atlantic mackerel is intensively exploited. The 95% confidence interval for the average Norwegian landings $\overline{Q}$ during the period 1980-2001 can be estimated as $\overline{Q} \pm 1.96\frac{s}{\sqrt{n}}$, where *s* is the sample standard deviation and *n* is the number of observations. The confidence interval is: $152 \pm 1.96\frac{49.6}{\sqrt{22}}$, i.e. $[131, \quad 173]$ thousand tons.

Table 3 combines the interval limits for, respectively, average price and quantity, and it shows four possible outcomes (extreme points) for the change in gross revenue, given independence between price and quantity and *no* change in climate and management of the mackerel fishery.

Table 3: Change in revenue, due to deviation from average landings(million Norwegian kroner per year)

		CHANGE IN QUANTITY	
		Low	*High*
Price	*Low*	-72	72
	High	-110	110

The table shows that the changes in gross revenue will be between a maximum negative change of -110 million Norwegian kroner and a maximum increase of 110 million Norwegian kroner per year. Figure 10 is based on the average landed value realized by the Norwegian vessels varies over the period 1980 to 2001. The simulation assumes that the average value is normally distributed (without trend) with estimated variance 362. The average landed value is 650 million Norwegian kroner (2003-value). If price and quantity are independent, stochastic variables, then the average landed value shows trajectories indicated by the simulations mapped in figure 10.

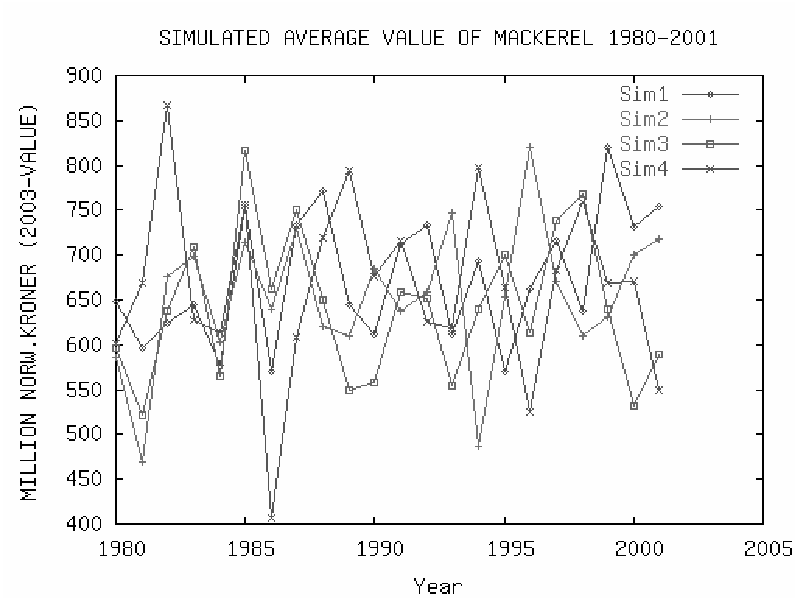

Figure 10: Simulated average landings of mackerel by Norwegian vessels

Elastic demand

In the introduction it was mentioned that oceanographers predict that the climate change will increase the abundance of mackerel in the northern part of the North Sea and in the Norwegian Sea. So far oceanographers and fisheries biologists cannot predict how much the stock will change in the future due to climate change.

Another point is that the NEA mackerel has been and still is heavily exploited. This is commented by ICES:

> *"Catches have exceeded the annual TACs in most years, sometimes by a considerable amount* (ICES Advice 2004, ACFM/ACE Report p. 2-819)…….. *Based on the most recent estimates of SSB and fishing mortality, ICES classifies the stock as being at risk of suffering reduced reproductive capacity and of being harvested unsustainably"* (ibid p. 2-817).

If the countries involved succeed in the management of the mackerel fishery, it will probably increase in the future. It is therefore difficult to isolate changes in stock and TAC due to, respectively, a more efficient management and a climate change.

Because of high uncertainty with respect to future management of the stock and the predicted climate effect, it is difficult to specify a percentage change in TAC due to climate change. To deal with the uncertainty in the future scenario, we have applied the econometric model to assumed changes in TAC and analysed the relationship between changes in TAC and changes in gross revenue. We chose three scenarios for the initial (i.e., prior to climate change) long run TAC: $Q_0 = 120$, $Q_0 = 150$ and $Q_0 = 170$ thousand tons. These values are within the confidence interval for the average landings. The gross revenue change is expressed in the following way:

$$
\begin{aligned}
\Delta R &= p_1 \Delta Q + \Delta p Q_0 \\
&= Q_0 (e^{5.85})((Q_0(1+\beta))^{-0.82} - Q_0^{-0.82}) + (e^{5.85})(Q_0(1+\beta) - Q_0)(Q_0(1+\beta))^{-0.82} \\
&= e^{5.85} Q_0^{0.18} \left[(1+\beta)^{0.18} - 1 \right]
\end{aligned}
$$

where $\beta = \dfrac{r}{100}$, *r*: percentage change in TAC.

Figure 11 shows how the gross revenue changes for the Norwegian fishing fleet due to percentage changes in the Norwegian TAC. The *y*-axis in the figure measures changes in gross revenue (ΔR) in million Norwegian kroner per year and the *x*-axis measures the percentage change in TAC. The figure also maps a possible negative development of TAC. The bold line indicates $Q_0 = 150$ and the thin lines indicate $Q_0 = 120$ and $Q_0 = 170$ above the bold line. The figure shows that an increase in TAC increases the gross revenue. The figure also indicates that there is no big difference between changes given the different long run status quo situations. The relatively small difference can be explained by the constant elasticity model and that the estimated elasticity is close to one. The model shows that the real price is sensitive to changes in the aggregated landings of mackerel. The price-quantity dependence gives the opportunity to set a quota which maximizes the profit and economic rent in the mackerel fishery. This opportunity is discussed in Lorentzen and Hannesson 2005.

Figure 12 takes into account both the infinite elasticity scenario and the previous elastic demand scenario. Three more lines are added and they map the following function

$$
\begin{aligned}
\Delta R &= \overline{p} \Delta Q \\
&= 4.35 \overline{Q} \beta
\end{aligned}
$$

where $\overline{Q} \in \{120, 150 \text{ and } 170\}$. The three topmost lines map the $\Delta R = 4.35\overline{Q}\beta$ -expression.

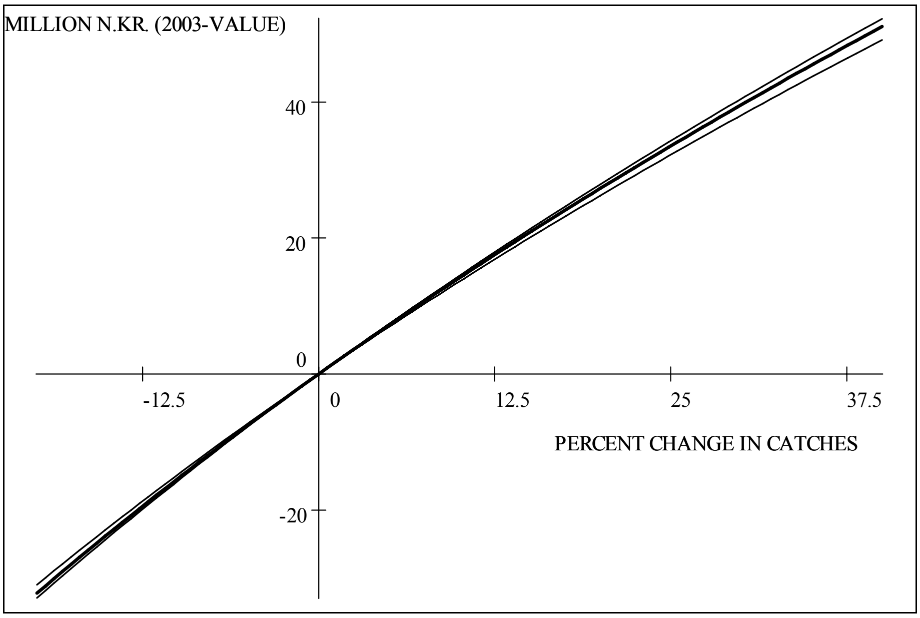

Figure 11: Change in gross revenue per year due to percentage change in TAC

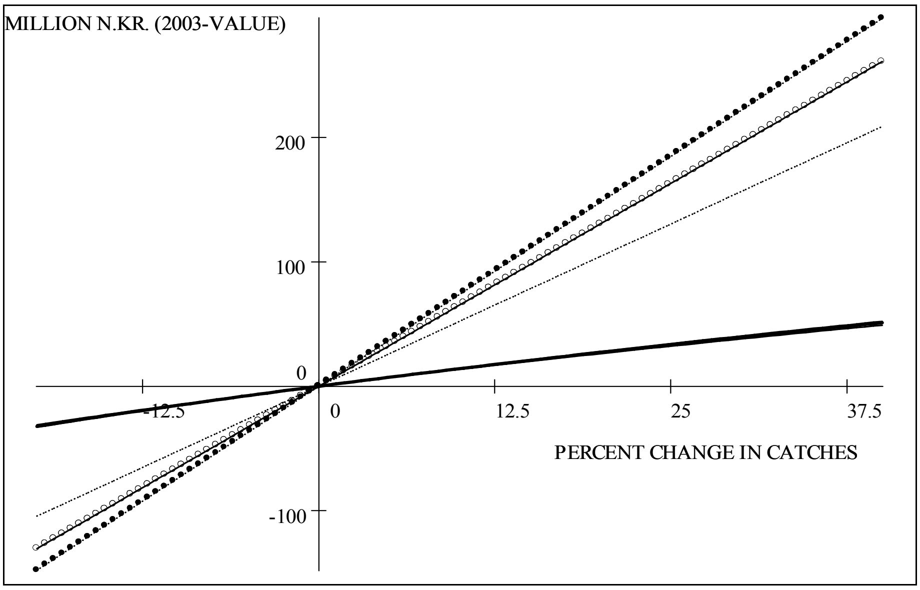

Figure 12: Change in revenue conditioned on infinitely and elastic demand

The figure shows that the magnitude of the effect on the gross revenue due to a change in TAC, for example due to a climate change, is critically dependent on whether the quantity supplied has some influence or not on the market price. The econometric analysis shows that the price is, to some extent, dependent on quantity supplied. The implication of the negative dependence between price and quantity is that the income effect is much smaller if the price depends on quantity caught. An example illustrates the point: If TAC increases by 10 %, the revenue increases by about 15 million Norwegian kroner per year in the latter case. The gross revenue increases by about 50 million Norwegian kroner if the price is constant and independent of quantity, given $\overline{Q} = 120$ thousand tons as initial quantity.

5. SUMMING UP AND COMMENTS

We have only vague, qualitative predictions from oceanographers and fisheries biologists about how climate change is expected to affect the Northeast Atlantic mackerel. The predictions indicate that the mackerel stock will move north, i.e. toward the northern North Sea and into the Norwegian Sea. The said experts also predict that the mackerel may also begin to forage in the Barents Sea. ICES has emphasised that the mackerel stock has been and still is overexploited. Change in future management and climate is expected to change the TAC.

A combination of mismanagement and lack of valid prediction of the connection between climate change and the mackerel stock makes it difficult to be precise about how climate change may affect NEA mackerel. To deal with the uncertainty we have applied a sensitivity analysis. The objective is to analyse how the gross revenue in the Norwegian mackerel fishery changes if the TAC and quantity landed change.

The analysis shows that a change in gross revenue is about three times higher in the infinitely elastic demand case than in the case where the price depends on quantity landed. The models predict that an increase in TAC by about 20 % will increase the gross revenue by about 25-30 million Norwegian kroner per year in the latter case. In the infinitely elastic demand case the gross revenue is expected to increase by about 120 million Norwegian kroner per year.

Norway shares the NEA mackerel stock with the EU and the Faeroe Islands. The Norwegian share is today 31 %. Future climate change can affect the distribution pattern of the mackerel, and of course also the distribution of the TAC between the parties. In one scenario we can anticipate that a relatively large share of the stock moves into international waters, and as a consequence the risk of overexploitation will increase. The involved parties would lose collectively, unless they manage to agree on an appropriate TAC. An alternative scenario would imply that the stock moves from one region to another country's economic zone, and one party will lose and another will win. If the stock moves out of the Norwegian economic zone, the Norwegian fishery sector will probably lose. On the other hand, and symmetric to the preceding scenario, a change in the climate could shift the stock into Norwegian waters. A more northern distribution of the mackerel could increase the possibility that the mackerel will reside in NEZ. It should also be mentioned that about 40% of the total area of the Barents Sea falls within the NEZ. The economic outcome of a change in the migration pattern of the NEA mackerel also depends on how easy it is to terminate a sharing agreement and to renegotiate it.

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Appendix A: Test for stationarity and long run relationship
Dickey-Fuller Cointegration test

Nonstationarity if $|A(1)|$ < |Asy. critical value| 10%

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VARIABLE: Natural logarithm of price

DICKEY-FULLER TESTS - NO.LAGS =   0   NO.OBS =   21
    NULL                 TEST      ASY. CRITICAL
 HYPOTHESIS           STATISTIC     VALUE 10%
---------------------------------------------------------------------------
CONSTANT, NO TREND
A(1)=0  Z-TEST        -3.2044     -11.2
A(1)=0  T-TEST        -1.0516     -2.57
A(0)=A(1)=0           0.63058      3.78
                                                   AIC =    -2.433
                                                    SC =    -2.333
---------------------------------------------------------------------------
CONSTANT, TREND
A(1)=0  Z-TEST        -7.1247     -18.2
A(1)=0  T-TEST        -2.1833     -3.13
A(0)=A(1)=A(2)=0       2.2122      4.03
A(1)=A(2)=0            3.2238      5.34
                                                   AIC =    -2.587
                                                    SC =    -2.438
---------------------------------------------------------------------------
VARIABLE: Natural logarithm of quantity

DICKEY-FULLER TESTS - NO.LAGS =   0   NO.OBS =   21
    NULL                 TEST      ASY. CRITICAL
 HYPOTHESIS           STATISTIC     VALUE 10%
---------------------------------------------------------------------------
CONSTANT, NO TREND
A(1)=0  Z-TEST        -4.4407     -11.2
A(1)=0  T-TEST        -1.8165     -2.57 Critical
A(0)=A(1)=0            2.0975      3.78
                                                   AIC =    -3.159
                                                    SC =    -3.059
---------------------------------------------------------------------------
CONSTANT, TREND
A(1)=0  Z-TEST        -6.1255     -18.2
A(1)=0  T-TEST        -1.7596     -3.13
A(0)=A(1)=A(2)=0       1.5182      4.03
A(1)=A(2)=0            1.8419      5.34
                                                   AIC =    -3.089
                                                    SC =    -2.940
---------------------------------------------------------------------------
```

Test for long term relationship by applying Dickey-Fuller tests on the residuals of cointegrating regressions.

```
COINTEGRATING REGRESSION - CONSTANT, NO TREND   NO.OBS =   22
REGRESSAND: Natural logarithm of price
 R-SQUARE = 0.7652E-02     DURBIN-WATSON = 0.3480
 DICKEY-FULLER TESTS ON RESIDUALS - NO.LAGS =  0   M =  2
                       TEST      ASY. CRITICAL
                     STATISTIC     VALUE 10%
--------------------------------------------------------------------------
 NO CONSTANT, NO TREND
         Z-TEST       -2.7889     -17.1
         T-TEST      -0.96884     -3.04
                                             AIC =    -2.603
                                              SC =    -2.553
--------------------------------------------------------------------------
COINTEGRATING REGRESSION - CONSTANT, TREND      NO.OBS =   22
REGRESSAND : Natural logarithm of price
 R-SQUARE = 0.8313         DURBIN-WATSON =  1.459
 DICKEY-FULLER TESTS ON RESIDUALS - NO.LAGS =  0   M =  2
                       TEST      ASY. CRITICAL
                     STATISTIC     VALUE 10%
--------------------------------------------------------------------------
 NO CONSTANT, NO TREND
         Z-TEST       -17.193     -23.4
         T-TEST       -4.1207     -3.50 Indicates cointegrated variables
                                             AIC =    -3.511
                                              SC =    -3.461
--------------------------------------------------------------------------
```