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# A Note on Overfishing, Fishing Rights and Futures Markets[1]

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***Abstract***

Introducing a futures market for fishing rights would increase utility for risk averse fishermen. We use the EV model to analyze possible reductions in (expected) profits for futures trading that would make fishermen indifferent between the situation with and without futures markets. It is found that a futures market for fishing rights enables policy makers to pursue substantial cuts in the size of annual quotas without hurting fishermen. In light of current overfishing and pressure from the sector to avoid dramatic cutbacks in effort, this is an important policy result.

## 1. Introduction

After implementation of exclusive economic zones in the late 1970s, *de jure* open access for many fisheries came to an end. It has been well documented that this did not imply that over-harvesting of fish resources came to an end (FAO 1992). *De facto*, many fisheries still exhibit features of open access management.[2] Conrad (1995) writes that approximation of open access conditions can arise if management regulations are ineffective, for instance because fishermen are adaptive and eliminate or reduce the effect of regulations. Another reason for overharvesting exists. Interest groups pressure governments or supra-national organizations to set quotas at too high levels (see for instance Holden 1994). For example, in 1995 the European Commission proposed drastic reductions of fish quota to protect fish stocks, but after a process of negotiations these propositions were substantially mitigated to achieve a balance between ecological and socio-economic considerations (de Graaf 1995). In this paper we recognise that revision of European fisheries policies without particular attention for the (financial) consequences for the sector may fail.[3] We demonstrate how, under an individual transferable quota (ITQ) scheme, harvest levels can be reduced without reducing utility of (risk averse) fishermen.

The European Union annually determines total allowable catches (TACs) for the European fishery sector. Total allowable catch is divided among the member states, who distribute the national quota among their fishermen. Member states have a certain freedom to formulate national fisheries policies, as long as total catch does not exceed the national quota, and the policy does not conflict with European legislation. There are considerable differences in national fisheries policies between different member states. The Dutch government, for instance, decided to implement an individual transferable quota system (ITQ). Initially this system was implemented just for flatfish, but in recent years also for demersal species. Under an ITQ scheme, fishermen are allocated an individual quota, based on their historic catch. Fishermen are allowed to trade their fishing rights, so that, in theory, fish are caught by the most efficient fishermen in the sector: they are able to “outbid” the other fishermen on the quota market, hence quota gravitate towards the most efficient fishers.[4] The price for fishing rights have fluctuated widely in recent years.

Trading quota implies trading *judicial harvest capacity*. In addition, fishermen invest in vessels and gear, the so called *physical harvest capacity*. In the short and medium run, these investments result in fixed costs for the fishermen. For that reason, fishermen are committed, to a certain extent, to buy, sell or lease quota to achieve some balance between physical harvest capacity and judicial harvest capacity (That is, unless the quota that is handed out to the individual fisherman is just equal to the desired harvest capacity.) Since quota prices are known to be volatile, fishermen face a price risk on the quota market. By introducing futures markets for quota, the fishermen can reduce this risk. In the framework of the certainty equivalent model, we demonstrate that this will increase the utility of harvesting for risk averse fishermen. This implies that, to restore utility neutrality, there is room for the government to combat over-harvesting by *reducing* the size of the quota allocated to the fishermen. This is just the measure of *compensating variation* applied to fisheries management. In the next section we will briefly explain the underlying model. In section 3 the model is empirically applied to the case of Dutch fishing under the ITQ system. The conclusions ensue.

## 2. The model

Consider a fisher who can lock in the price risks regarding fishing rights with the help of fishing rights futures. The fisher is risk averse and wishes to maximize the expected revenue in the next time period adjusted for risk, where risk is measured by the variance of the expected revenue. We assume that the objective function of this fisherman can be reasonably approximated by the expected value-variance (EV) model (Peck 1975, Kahl 1983, Robison and Barry 1987).[5] The objective function can be expressed as:

$$\pi_{ce} = E(\pi) - \lambda\, var(\pi) \tag{1}$$

where $\pi_{ce}$ is the certainty equivalent, $E(\pi)$ is expected revenue and $var(\pi)$ represents the variance of revenues. In (1), $\lambda$ denotes the risk parameter which, for risk-averse decision makers, is positive, thus demanding compensation for risk bearing (Pratt, 1964).

If uncertainty in determining the profit is caused by fluctuations in the price of fishing quota $P$ and the output price $z$, then profit can be expressed as:

$$\pi = \tilde{z}Q - [\tilde{P}(Q - h) + P_f h] - C(Q) - F, \tag{2}$$

where $Q$ is the quantity harvested (assumed equal to the size of the quota, which is a good assumption for sole fishing in the Netherlands); $\tilde{z}$ is the spot price for the output with expected value $z$ and variance $\sigma_z^2$; $\tilde{P}$ is the spot price of the fishery right with expected value $P$ and variance $\sigma_r^2$; and $h$ is the quantity of hedged fishery rights, i.e., the quantity bought or leased on the futures market for known price $P_f$. It is assumed that there is no basis risk; $C(Q)$ are variable costs and $F$ are fixed costs.

Expected profit is:

$$E(\pi) = zQ - [P(Q-h) + P_f h] - C(Q) - F. \tag{3}$$

The variance of profits is

$$var(\pi) = Q^2\sigma_z^2 + (Q-h)^2\sigma_r^2 - 2Q(Q-h)\sigma_{z,r} \tag{4}$$

where $\sigma_{z,r}$ is the covariance between the price of fish and the fishing right. By substituting (3) and (4) into (1), the optimal holdings of futures contracts is obtained by differentiating the objective function with respect to $h$ and setting the first order condition equal to zero:

$$h^* = Q - \frac{P_f - P}{2\lambda\sigma_r^2} - Q\rho\frac{\sigma_z}{\sigma_r}. \tag{5}$$

where $\rho$ is the correlation coefficient between fish prices and fishing rights. For $P_f > P$, there is a tradeoff between (expected) revenues and variance such that $h < Q$. The more risk-averse the fisherman and/or the more price fluctuations in the spot market of the right, the greater the level of hedging for a constant positive difference between $P_f$ and $P$.

The effect of futures markets on fish quota is graphically illustrated in Figure 1.

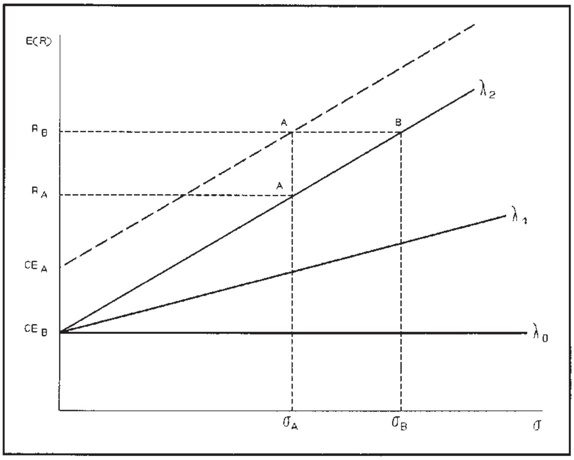


*Figure 1.* Iso-utility curves for various degrees of risk aversion.

In Figure 1, $\sigma$ is the standard deviation of the revenues of harvesting, $E(R)$ are expected revenues of harvesting and $\lambda$ measures the degree of risk aversion: for $\lambda = 0$, the fisherman is risk neutral. Else, the higher $\lambda$, the more the fisher's risk aversion. Finally $CE_B$ is the (initial) certainty equivalent. The lines diverging from $CE_B$ are iso-utility curves, indicating a constant utility level for varying expected revenues and standard deviations. Increasing volatility[6] (i.e. moving from left to right in the graph) indicates how much expected revenues should rise to keep utility constant. Obviously, the more risk averse, the higher the risk premium demanded by the individual to make him not worse off with an increased spread, hence the steeper the iso-utility line. Risk neutral fishermen ($\lambda = 0$) do not require additional expected revenues to compensate for increased fluctuations, hence the iso-utility line is horizontal.

By buying or selling (part of) the judicial capacity on the futures market instead of the future spot market, the price risk of this capacity is reduced and so is over-all volatility of revenues. Suppose trading quota at a futures market reduces over-all volatility from $\sigma_B$ to $\sigma_A$. This implies that a fishermen with degree of risk aversion $\lambda_2$, moves from $B$ to $A'$.[7] This makes him undoubtedly better off (given a degree of risk aversion $\lambda_2$, the new certainty equivalent is $CE_A > CE_B$). To restore utility neutrality, the policy maker next decreases expected revenues with the interval $(R_B - R_A)$ so that the fisherman moves back to the initial iso-utility curve, hence from $A'$ to $A$. Given a certain price per unit of fish, this reduction in expected revenues can be translated in a reduction of quota allocated to this fishermen. This model is applied for the Dutch situation in the next section.

## 3. Empirical results

Equation (4) in the previous section is used to find expressions for the variance of profits with and without hedging. For example, without hedging we find:

$$var_w(\pi) = Q^2\sigma_z^2 + Q^2\sigma_r^2 - 2Q^2\sigma_{z,r}. \tag{6}$$

Similarly, with hedging we find:

$$var_H(\pi) = Q^2\sigma_z^2 + (Q - h^*)^2\sigma_r^2 - 2Q(Q - h^*)\sigma_{z,r}. \tag{7}$$

In this section we will calculate the reduction in $var(\pi)$ that results from optimal hedging for the Dutch sole fishery. We have assumed that, if fishers buy a quota, they expect to use it until the Common Fisheries Policy is open for revision, which is in 2003. This implies that they depreciate their quota in this period (we have assumed a discount rate of 10%), and we have used the capital recovery factor to determine annual quota costs. Prices of sole and fishing rights are from Produktschap voor Vis (1994) and Banning (1993), respectively. Estimated parameters of interest are as follows: $z = 15.4$; $P =$

12.35, $\sigma_z = 2.6$, $\sigma_r = 3.0$ and $\rho = 0.56$ (implying that $\sigma_{z,r} = 4.37$).[8] We have defined $\gamma$ as $P_z/P$, which is a measure for the divergence between the expected spot price and the futures price of the fishing right.

The reduction in supply of fish may increase the price per unit of fish, although we assume constant prices. Similarly, we have assumed that harvesting costs are unaffected by quota cuts. The assumptions of constant prices and constant harvesting costs are for computational convenience and are both conservative: If in reality prices would rise and/or costs would fall when fishing rights are curtailed, the fisher is (partly) compensated for the reduction in quota by high prices and/or cost savings, and even larger quota cuts are possible while keeping utility of fishermen constant. For that reason the results provided in Table 1 can be considered as underestimates of the true potential to cut quota.[9]

As a sensitivity analysis we have varied the values for $P_f$ and $\lambda$, in accordance with reasonable values as indicated in the literature (Peck 1975, Robison and Barry 1987).

We have assumed that a fisher initially has the right to catch 100 units of fish. If, for example, this fisher has a degree of risk aversion equal to 0.01, it is optimal for this fisher to hedge 51% of his fishing rights on the futures market. This would reduce the variance of revenues with 23817. This makes the fisher better off, which enables the policy maker to cut his quota by more than 11%. Given his hedged quantity of 51 units, this cut will take the fisher back to his original utility level. We conclude that the possible reductions in quota are substantial. For modest measures of risk aversion, significant utility-neutral reductions of fishing rights are possible, when those reductions are accompanied by the implementation of a futures market for fishing rights.

Three caveats should be mentioned. First, the analysis is based on an economic analysis, where quota handed out by the government or rights purchased in previous periods represent an opportunity cost for the owner. However, if new policy is aimed at being truly "utility-neutral", the correct basis for the analysis might not be economic accounting but the perception of fishermen. It may be so that fishermen do not consider the fishing rights in their possession as costs. If fishers exclusively consider the costs associated with obtaining new quota, then possible quota cuts would be much more modest. For instance, under the assumption that the share of total quota that changes hands annually (either on the sellers or leasing market) is 15%, and these are the only rights considered as costs by the fishers, the possible reduction in quota size for the parameter values as specified in Table 1 ranges from 0% to 5%.

*Table 1.* Possible "utility neutral" reduction in fish quota under various conditions. $P_f = \gamma P$.

| | $\lambda = 0.01$ | | $\lambda = 0.025$ | | $\lambda = 0.05$ | |
|---|---|---|---|---|---|---|
| $\gamma$ | 1 | 1.1 | 1 | 1.1 | 1 | 1.1 |
| $Q$ | 100 | 100 | 100 | 100 | 100 | 100 |
| $h^*$ | 51 | 44.1 | 51 | 48.3 | 51 | 49.6 |
| $\Delta var(\pi)$ | 23817 | 23333 | 23817 | 23730 | 23817 | 23788 |
| $\Delta Q$ | 11.3 | 11.5 | 34.5 | 34.5 | 73.0 | 73.0 |

Second, even with modest measures of risk aversion as applied in Table 1, we may obtain negative values for $\pi_{ce}$.[10] One possible explanation, consistent with findings in agricultural economics, is that in addition to revenues, fishermen derive utility from the fishing process itself. In other words, fishing may be considered a way of life, yielding benefits outside the scope of simple economic accounting. However, when this additional utility is approximately constant, i.e. not affected by the size of the quota, the results displayed in Table 1 are still valid. For relatively large reductions this assumption is probably violated. If utility associated with the fishing process is increasing in the size of the quota allocated, Table 1 overestimates the true utility-neutral reductions.

Finally, the analysis is based on the assumption that fishermen are myopic in the sense that they do not recognize that hedging influences the quota cut that is inflicted upon them later: they first determine $h^*$, taking $Q$ as given, and are next surprised by the government's decision to cut their quotas. There may be reasons for myopic behavior. For instance, quota cuts will typically be based on hedging performance of the sector as a whole. This implies that optimal hedging for a rational fisherman requires developing expectations of (optimal) hedging for the other fishermen in the sector, which may be costly and cumbersome. In addition, it should be recognized that there is always uncertainty associated with the quota size, even in the absence of considerations brought forward in this paper. Depending on scientific advice on stock size *in situ*, the size of annual quota fluctuates. It may be difficult to estimate the "extra" uncertainty associated with the new policy. It is possible, however, to imagine what the effect is of allowing a sequence of rounds of hedging and quota cutbacks, until an equilibrium is reached. Suppose that it is optimal for a fisherman to hedge 51 units of his initial quota of 100 (see Table 1), and that the government calculates that utility neutrality is restored when the quotum is reduced to 89. In the next period, the fisherman is able to increase his utility by hedging less than 51 units. For example, assume that, given $Q$ equals 89, it is optimal to hedge 45 units. In order to restore utility neutrality, the managing agency should cut the quota further. This implies that $Q$ should be reduced below 89, although the second cut will be more modest that the first one. Again, the fisherman will respond by hedging less to increase his utility, which will provoke further quota cuts by the government, until eventually an equilibrum is reached. (It is important to recognise that strategic actions of the fishermans are completely disregarded in this reasoning.) For that reason, rational expectations will cause larger quota cuts than the ones predicted in Table 1. Formally incorporating rational expectations and strategic actions in the current model will be one of the possible extensions for future research.

## 4. Conclusions

Despite the implementation of exclusive fishing zones that formally ended the era of open access fisheries management, there is still evidence that current fishing effort is excessive. However, combatting overfishing is likely to result in resistance from the sector. Public choice theories predict that a small, well-organized group as the fishery sector may develop sufficient political pressure that it is able to resist painful reorganizing. This implies that an important question for policy makers is how to reduce fishing effort without "hurting" the sector.

In this paper we have analyzed the possibility of cutting quotas combined with implementation of a futures market for fishing rights. A futures market for fishing rights reduces price risk for fishermen, and thereby makes risk averse fishermen better off. Using the EV model we find that considerable quota cuts are possible to bring the fisher back to his original utility level, even with modest measures of risk aversion. The reason is that the price of fishing rights have fluctuated widely in the past, hence there is ample possibility for improvement. The results have been obtained under the conservative assumptions that (i) fish prices do not increase after the reduction in quota size, and (ii) total costs of fishing effort do not fall after the reduction in quota size. If one of these assumptions, or both, is violated, quota size could be reduced even more. Some caveats of the model are recognized and discussed.

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## Notes

1. Bulte et al. (1995) found that establishing property rights to end conditions of open access in Europe has contributed to increased efficiency of exploitation for German fisheries. However, the current situation is still far from optimal, according to many authors (e.g. Schmidt 1993).
2. The reader is referred to the vast literature on interest groups and public choice (e.g. Olson 1965, Mueller 1989) for more information.
3. For an overview of different policy instruments applied for fisheries, see Hartwick and Olewiler (1986).
4. For the conditions that justify the use of the EV model and the discussion on the use of the EV model and the general expected utility model the reader is referred to Bigelow (1993), Pulley (1981), Coyle (1992), Meyer and Rasche (1992), Pope and Chavas (1994), Robison (1996), and Tew et al. (1991).
5. That is, increased the spread of the price distribution while keeping the mean constant.
6. Note that in this graph we assume that the futures price is equal to the expected future spot price. If trading on a futures market implies bearing some cost (for instance because $P_f > P$), then $A'$ will be located below $B$. As long as the new position of the individual is in the interval $(R_B - R_A)$, however, his utility has increased and the (qualitative) result is unaffected. Note that the individual would not decide to trade on the futures market if the futures price is so much lower than the expected future spot price that revenues fall below $R_A$.
7. It is of interest to note that we have used yearly observations from 1987 onwards. Prior to 1987 enforcement of catches and landings was poor, hence the value of official fishing right was relatively modest. This was reflected in very low prices for quota. After the announcement and implementation of additional enforcement, the price of the right to harvest a kilo of sole rose from fl. 17 to approximately fl. 100. Observations prior to this announcement have therefore been ignored. The development of quota prices over time clearly indicate that there may be considerable differences between de facto and the jure fisheries management.
8. We argue that the assumptions of constant prices and costs are not very restrictive. First, since we focus on modeling the effects for the Netherlands, the assumption of constant prices is relatively harmless, as trade

in fish products among member states will reduce price effects. Second, with respect to constant harvest costs, we refer to Davidse and Beijert (1995), where it is reported that fixed costs, on average, account for more than 75% of total costs.

9. Without futures trading and with a very low degree of risk aversion ($\lambda = 0.01$), we find a positive value: $\pi_{ce} = E(\pi) - 0.01\ var(\pi) = 682$. But for higher levels of risk aversion, such as $\lambda = 0.025$, we find $\pi_{ce} = E(\pi) - 0.025\ var(\pi) = -333$. Note that negative values for $\pi_{ce}$ do not imply that fishermen earn a negative income.

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