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Management of Fisheries in the EU: A Principal-Agent Analysis

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Abstract *In this paper, an EU tax on fishing effort is studied as an alternative to the system of Total Allowable Catches (TACs). The analysis is conducted under imperfect information, and the hypothesis adopted is that the EU lacks information about the costs of individual fishermen. In light of this imperfection, there are at least two reasons for considering an EU tax. First, it can be used to correct part of the market failure associated with fisheries. Second, it can be used to secure correct revelation of fishermen types in light of asymmetric information.*

Key words Double principal-agent problems, EU fishery, imperfect information, taxes.

Introduction

Regulation of the EU fisheries is undertaken on two levels for most important species. The level of the total allowable catch (TAC) is decided every year by the Council of Ministers. The TAC is then allocated as quotas to the Member States, and the Member States determine which fishermen are going to harvest the quota (for example in Denmark a regulated open-access regime is adopted). The main purpose of TACs is to protect the stocks.

From an economics standpoint, there are several problems with this scheme. First, calculation of the TAC is not based on economic principles (Arnason *et al*. 2000). Instead, biological and political principles dominate when the TACs are fixed (Karagiannakos 1995). Second, the allocation scheme of the TACs (relative stability) was established in 1983 and has not been changed since. It is, therefore, inefficient because the relative efficiency has changed since then. Third, there are incentives in a quota management system to exceed the quota (Copes 1986). Indeed, for cod in the North Sea these problems are considerable (Svelle *et al*. 1997). Fourth, the Member States do not have incentives to conduct an efficient control and enforcement system. Within the EU, the competence to control is placed at the Member States' level, which raises free-riding problems. Finally, many information requirements arise when an optimal quota must be calculated. Thus, it is important to search for alternatives to the TAC system. In this paper, a management system based on an EU tax under imperfect information is investigated. The main purpose of the

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paper is to evaluate which variables must be included in the EU tax under various assumptions about the behavior of the Member States.

Another regulatory regime that secures gains in economic efficiency could be based on individual transferable quotas (ITQs). Within the EU, two systems can be imagined. First, a system where the EU determines a TAC and allocates this TAC as ITQs to Member States is possible. It is then up to the Member States to allocate the ITQs to fishermen, but it seems reasonable to let both the Member States and the fisherman trade the ITQs. Second, a system where the ITQs are allocated directly to the fishermen is also possible. In the fisheries economic literature, there is much discussion of the advantages and disadvantages of taxes and ITQs. Arguments against taxes are presented later in the text. With regard to ITQs, the system requires that markets perform perfectly. Furthermore, in quota management systems there are incentives to exceed the quota. Finally, the distributional consequences of ITQs have been criticized, since the resource rent falls in the hands of the current fishermen. However, an EU ITQ system and an EU tax are both promising areas for future research.

On the basis of the previous comments, the management structure of an EU tax can be illustrated by figure 1.

In this paper, an economic incentive system where the EU taxes the Member States is analyzed. Such an incentive system would give the Member States an economic incentive to regulate the fishermen. Alternatively, a system where the EU taxes the fisherman directly would also be possible. However, this system would not recognize the existing structure, where the EU determines a TAC and allocates this as quotas to the Member States. Thereafter, the Member States determine which fishermen harvest the quota. Therefore, a system where the EU taxes the Member States is examined.

A principal-agent approach is adopted, and principal-agent analysis is defined by the restrictions that are included. Under full information, participation restrictions are included, and under imperfect information, participation and incentive compatibility restrictions are included. Other definitions could be analysis of imperfect information and analysis of situations where the principal wants to induce the agent to do something that is costly.

Whether an EU tax is likely to be implemented can be questioned. Wilen (2000) mentions that over 55 fisheries are managed with individual quotas, while none are managed with taxes. However, within the EU, the idea of taxes and subsidies is not remote. This point can be seen from the structural policy. The purpose of the structural policy is to facilitate structural change in the fishing sector by granting finan-

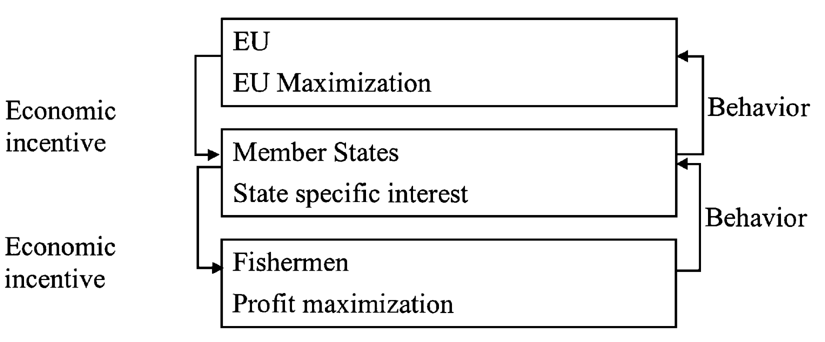

Figure 1. A Double Principal-Agent Model

cial aid. Therefore, the EU is already financially engaged in the fishing sector, and taxes may be seriously considered.

Herein, effort is used as a tax variable. The fisheries economic literature concludes that both effort and harvest can be used as a tax variable under full information (Anderson 1986). However, as previously mentioned, there exists a compliance problem with the TAC within the EU. This problem has the effect that the harvest is unobservable, so recommending an EU tax based on harvest is of little value. A problem with taxing effort is that the variable is multidimensional. However, based on the work of Dupont (1991), it can be argued that days at sea can be used as the tax variable in the short run.[1] The reason for this is that days at sea are a good proxy for total effort because of the sign and magnitude of the input substitution elasticities. Furthermore, days at sea are easy to monitor using satellites and by counting at ports.

Three problems associated with taxing fisheries are often mentioned. First, the information requirements have been criticized. Clark (1990) and Arnason (1990) point to the fact that cost data is difficult to obtain. Within the double principal-agent model, one hypothesis could be that the Member States are better informed about fishermen's costs than the EU, and have an interest in hiding this information. With a principal-agent approach, it is possible to solve this imperfect information problem, since taxes can be designed to secure correct revelation of private information. To keep matters as simple as possible, it is assumed that the Member States are perfectly informed about costs, and that the EU has imperfect information regarding costs. Furthermore, a simple adverse selection hypothesis is adopted (imperfect information about an exogenous cost parameter (Laffont and Tirole 1993). That such an adverse selection problem arises in the EU fisheries can be explained with reference to Denmark. Anon (1998) gives statistics for the Danish fisheries based on, among other things, the accounts of six groups of vessels. Within these groups, the statistics are mean numbers. Assume now that a tax schedule, which is increasing in effort, is designed on the basis of account statistics, and the mean values of costs must be the basis of the tax. Assume further that the fishing fleet is heterogeneous within the groups. Now it is possible that the least-cost fishermen within the groups have an incentive to pretend to be high-cost fishermen, because the tax payment becomes lower by lowering effort. Therefore, all fishermen end as high-cost fishermen, and an adverse selection problem occurs. However, the Danish Directory of Fisheries is better informed about the fishermen's costs than the EU, but because of its own best interests, it has an incentive to hide this information from the EU. Therefore, if the EU wants to tax the Member States, it has to recognize the adverse selection problem and design taxes to secure correct revelation of types. By securing correct revelation of types, the EU uses the tax to collect valuable information about fishermen.

Second, the distributional implications of taxes have also been criticized (Clark 1990), since the fishermen only get infra-marginal rents. This problem can also be solved by applying a principal-agent approach. In such an analysis, it is customary to include a participation restriction with a reservation utility (Varian 1992). By correct choice of the reservation utility, parts of the resource rent can be allocated to the fishermen.

Third, stock fluctuations raise problems, since the tax must be constantly adjusted. However, a solution to this problem could be to transfer the part of the tax

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[1] In the long run, it will be necessary to construct an index for effort because technology can change. However, the problem that arises in this case also arises when effort regulation is used. Furthermore, traditional principal-agent analysis of pollution uses pollution control effort as a tax variable, even though this variable is also multidimensional (Jebjerg and Lando 1997).

revenue generated by stock fluctuations back to the fishermen. With this solution, the fishermen will be compensated for the losses that random fluctuations in stock size generate. Note also that stock fluctuations generate problems for ITQ systems, since quotas must be constantly adjusted.

Only one principal-agent analysis of fisheries exists in the literature (Clarke and Munro 1987). This analysis is conducted under full information, and a combination of a harvest and effort tax is studied. Clearly, the information requirements of this structure can be questioned, and an imperfect information approach seems more appropriate. Clarke and Munro (1987) also call for models that include uncertainty. Furthermore, as noted earlier, the realism of taxing harvest is limited in light of compliance problems associated with quota management.

Further comments on the literature are relevant for this paper. Within the environmental economics literature, there is some discussion of optimal regulation of pollution in light of imperfect information (Roberts and Spence 1976; Kwerel 1977; and Jebjerg and Lando 1997). Roberts and Spence (1976) and Kwerel (1977) combine the use of transferable pollution permits and taxes/subsidies to arrive at a first-best solution. The assumption is, however, that there is no market failure in the market for pollution permits, which is a restrictive assumption. Others, therefore, prefer to use one economic instrument and analyze a second-best solution in light of imperfect information. For example, Jebjerg and Lando (1997) conduct a principal-agent analysis of taxes under moral hazard and adverse selection. The analysis in this paper is in line with the principal-agent analysis of Jebjerg and Lando (1997), but applied to a federal tax for a renewable resource.

Within environmental economics there is also some discussion about central versus decentralized regulation, often in light of imperfect information (Jeppesen 1997; List 1997; Klibanoff and Morduch 1995; Rob 1989; Silva and Caplan 1997; and Farrell 1987). A main conclusion within this literature is that imperfect information at the federal level can be an argument for decentralized regulation. The analysis here differs, since the issue is taxing a natural resource at the federal level.

In the next section, the model used will be introduced and analyzed for the full information case. The analysis of full information can be seen as a reference case for the purpose of comparison with imperfect information. Then, a simple adverse selection model where the Member States do not take any resource considerations is presented, while the next section presents some possible extensions of the model. Finally, the paper is concluded.

Introduction to the Model — Full Information

A model with short-run production functions inspired by Smith (1968, 1969) and Brown (1974) is formulated, where the stock for fishermen i in country j is exogenously given. At the EU level, total production is assumed to be equal to the growth of the stock. The reason for selecting this model is that it is well suited for analyzing problems of imperfect information, since it does not include discussions of adjustments toward equilibrium.[2]

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[2] In most advanced fisheries economics, adjustment processes toward equilibrium are discussed (Conrad and Clark 1987). With the assumed non-linearity of the objective function, a gradual adjustment toward equilibrium is optimal, and a feedback rule can be used to describe the optimal path. Now, the approach taken in Sandal and Steinshamn (1997) seems promising, since this model makes it easy to describe the optimal path. The argument for selecting a steady-state model in this article is that principal-agent studies of fisheries management are a new research topic. However, optimal adjustment processes toward equilibrium with a principal-agent approach is a promising future research area.

The first question encountered is how to model the Member States. A traditional open-access assumption between Member States could be used. However, in reality, the EU is engaged in various entry and exit adjustment programs (Holden 1994; and Frost *et al.* 1995). It is, therefore, assumed that an industry in Member State j with n_j fishermen exists, where the n_j is the number of fishermen in Member State j. However, what do the Member States maximize? Clearly, the resource rent must be incorporated, but unlike most traditional fishery economics, tax costs are subtracted from the resource rent, which appears to be consistent with the theory of regulation of firms under imperfect information (Laffont and Tirole 1993). In this and the following section, it is assumed that the Member States totally disregard resource conservation measures. This assumption can be explained with reference to Hannesson (1997), who considers the possibility of reaching a cooperative equilibrium in a fishery game and shows that as the number of firms exploiting a renewable resource increases, the likelihood of reaching a cooperative equilibrium decreases. This assumption is translated to the Member States' level in our analysis.

The choice variables are the effort levels for the individual fishermen. The reality of allowing the Member States to maximize over individual effort levels can be questioned. In practice, the fishermen can be collected in homogeneous groups. However, in order to keep the theoretical analysis as general as possible, it is useful to let the maximization occur over the effort levels of individual fishermen.

Therefore, Member State j maximizes:

$$\max\left[\sum_{i=1}^{n_j} pG_{ij}(x, E_{ij}) - C_{ij}(E_{ij}) - T_{ij}(E_{ij})\right] \tag{1}$$

where x is the fish stock, E_{ij} is the level of effort for the fisherman i of Member State j, and p is an exogenous price. $G_{ij}(x, E_{ij})$ is a short-run production function relating the catch for fisherman i in Member State j, G_{ij}, to the stock and effort (Andersen 1979). It is assumed that $\partial G_{ij}/\partial E_{ij} > 0$, $\partial^2 G_{ij}/\partial E_{ij}^2 \leq 0$, $\partial^2 G_{ij}/\partial x^2 \leq 0$ and $\partial G_{ij}/\partial x > 0$. This implies that the marginal product of effort is positive and non-increasing and that the marginal product of stock size is positive. $C_{ij}(E_{ij})$ is the cost function for effort for fisherman i in Member State j. It is assumed that $C'_{ij}(E_{ij}) > 0$ and $C''_{ij}(E_{ij}) > 0$. In other words, the marginal costs are positive and increasing. $T_{ij}(E_{ij})$ is the EU tax function. Note that the EU taxes fishing effort, and a system where the EU taxes the Member States on the basis of individual fishermen is analysed. Note also that a non-linear tax system in E_{ij} is considered. The realism of this tax structure may be questioned. When applied in practice, the tax structure can be approximated with a uniform tax schedule within groups of fishing vessels. Furthermore, a two-part linear tax can be a proxy for the non-linear tax. However, the assumption of a non-linear, individual tax is useful to retain in a theoretical analysis.

The Member State has the following first-order condition for fisherman i:

$$p\,\frac{\partial G_{ij}}{\partial E_{ij}} - C'_{ij}(E_{ij}) - T'_{ij}(E_{ij}) = 0 \quad \text{for } i = 1, \ldots, n_j. \tag{2}$$

The condition indicates that the value of the marginal product for effort ($p\partial G_{ij}/\partial E_{ij}$) is set equal to the marginal costs, which include the marginal tax costs [$C'_{ij}(E_{ij}) + T'_{ij}(E_{ij})$]. A marginal tax on $T'_{ij}(E_{ij})$ in the optimal point will generate E_{ij} units of effort.

How can the EU be modelled? Clearly, maximization of the resource rent must be incorporated. Part of the tax revenue from the Member States is also included as a benefit for the EU. From the normative perspective, this might be explained with the double dividend hypothesis, which says that the tax revenue collected by the EU can be used to reduce other distorting taxes. Furthermore, the tax revenue can be used to finance the financial aid that is given throughout the structural policy. With the formulation chosen in this paper, it could be argued that double counting occurs because the tax revenue is a component of the resource rent and included in the objective function. However, it is useful to include the tax revenue in the objective function for two reasons. First, the double dividend hypothesis indicates that double counting shall occur. Apart from correcting a market failure, the tax revenue can also finance other operations without imposing distorting taxes. Second, including tax revenue makes the participation and self-selection restrictions binding. Therefore, the double dividend hypothesis is easy to work with in principal-agent models. Note also that the only principal-agent model within fisheries economics (Clarke and Munro 1987) includes tax revenue in the objective function. However, the double dividend hypothesis does not state that the whole tax revenue is included in the objective function. Indeed, the literature assumes a marginal cost of public funds (Brendemoen and Vennemo 1996). For this reason, only $\mu T_{ij}(E_{ij})$ is included in the objective function as a benefit, where $0 < \mu < 1$ and $1 - \mu$ is the marginal cost of public funds.

It is assumed that there exists k Member States, and that the maximization takes place over stock size, individual effort levels, and individual taxes. As in the maximization problem for the Member States, it may be criticized that individual effort levels are choice variables. Furthermore, whether the EU could impose a non-linear tax on the Member States on the basis of individual fishermen is questionable. However, as mentioned in connection with the Member State maximization problem, it is useful to impose these assumptions in a theoretical analysis.

With long-run economic yield as the objective, it is assumed that the EU will maximize:[3]

$$\max\left[\sum_{j=1}^{k}\sum_{i=1}^{n_j} pG_{ij}(x, E_{ij}) - C_{ij}(E_{ij}) + \mu T_{ij}(E_{ij})\right] \tag{3}$$

s.t.

$$\frac{dx}{dt} = F(x) - \sum_{j=1}^{k}\sum_{i=1}^{n_j} G_{ij}(x, E_{ij}) = 0 \tag{4}$$

$$pG_{ij}(x; E_{ij}) - C_{ij}(E_{ij}) - T_{ij}(E_{ij}) \geq 0 \quad \text{for all } j = 1, \ldots, k \text{ and } i = 1, \ldots, n_j \tag{5}$$

$F(x)$ is the natural growth rate of the fish stock and the implication of equation (4) is that the stock is in steady-state equilibrium, where the natural growth rate is equal to total catch. Note that the maximization procedure implies that the stock in optimum is where $F'(x) < 0$. Furthermore, it is assumed that $F''(x) < 0$.

[3] Maximization of long-run economic yield implies that discounting is excluded. Most advanced fisheries economics includes discounting and gives management of the resource a capital theoretical interpretation (Clark and Munro 1978). Now, optimal control theory can be used as the mathematical method. Discounting is excluded here due to the fact that studies of fisheries management with a principal-agent approach is a new research area, but including discounting in principal-agent studies is a promising future research path.

Equation (5) is a participation restriction, which is standard in a principal-agent analysis (Varian 1992). The participation restriction is formulated such that every fisherman must earn a non-negative resource rent net of taxes. Alternatively, the restriction could have been formulated as a non-negative benefit for the Member States $\{\Sigma[pG_{ij}(x, E_{ij}) - C_{ij}(E_{ij}) - T_{ij}(E_{ij})] \geq 0\}$. The formulation in equation (5) indicates that the EU does not want to give the Member States any incentive to drive their fishermen out of the market. Therefore, a non-negative benefit for every fisherman is assumed. Equation (5) is stronger than a non-negative benefit to the Member States, since the sum of the restrictions for all n_j fishermen in Member State j is $\Sigma[pG_{ij}(x, E_{ij}) - C_{ij}(E_{ij}) - T_{ij}(E_{ij})] \geq 0$. For reasons of simplicity, the reservation utility is set to zero. Alternatively, the zero could be interpreted as a result of normalization. Note that the participation restriction is part of the EU maximization problem and that it captures the assumption that the EU is interested in securing the survival of each individual fisherman in all Member States. It is, therefore, reasonable to apply the restriction even if existing effort is too high because of open-access, or if the fishermen can realize a positive profit by doing something else.

Because taxes enter with a positive sign (Varian 1992), the participation restriction will always be binding:

$$T_{ij}(E_{ij}) = pG_{ij}(x, E_{ij}) - C_{ij}(E_{ij}) \quad \text{for } i = 1, \ldots, n_j \text{ and } j = 1, \ldots k \tag{6}$$

The implication of equation (6) is that the Member States' resource rent is taxed away. From the point of view of the EU, this represents a benefit.

By substituting equation (6) into equation (3), the following maximization problem is obtained (now maximization takes place over the stock size and the individual effort levels):

$$\max\left\{\sum_{j=1}^{k}\sum_{i=1}^{n_j}(1+\mu)\left[pG_{ij}(x, E_{ij}) - C_{ij}(E_{ij})\right]\right\} \tag{7}$$

s.t.

$$F(x) - \sum_{j=1}^{k}\sum_{i=1}^{n_j} G_{ij}(x; E_{ij}) = 0\,. \tag{8}$$

The Lagrange function may be written as:

$$L = \sum_{j=1}^{k}\sum_{i=1}^{n_j}(1+\mu)\left[pG_{ij}(x, E_{ij}) - C_{ij}(E_{ij})\right] + \lambda\left[F(x) - \sum_{j=1}^{k}\sum_{i=1}^{n_j} G_{ij}(x, E_{ij})\right] \tag{9}$$

where $\lambda > 0$ is a Lagrange multiplier and a measure of the value of a marginal increase in the resource stock.

The EU optimality condition for fisherman i in country j is:[4]

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[4] Because $\partial^2 G_{ij}/\partial E_{ij}^2 \leq 0$, $\partial^2 G_{ij}/\partial x^2 \leq 0$, $F''(x) < 0$ and $C_{ij}''(E_{ij}) > 0$, the Lagrange function is concave, and an optimum will exist (Jensen 2001).

$$\frac{\partial L}{\partial E_{ij}} = (1+\mu)\left[p\frac{\partial G_{ij}}{\partial E_{ij}} - C'_{ij}(E_{ij})\right] - \lambda\frac{\partial G_{ij}}{\partial E_{ij}} = 0. \tag{10}$$

The optimal solution for the EU is where the marginal benefits are equal to the marginal costs. The marginal benefits consist of the marginal resource rent $[p\partial G_{ij}/\partial E_{ij} - C'_{ij}(E_{ij})]$ and the value of the marginal tax revenue $\{\mu[p\partial G_{ij}/\partial E_{ij} - C'_{ij}(E_{ij})]\}$. The marginal cost for the EU is the effect on the resource stock of increased effort evaluated by the shadow price $(\lambda\partial G_{ij}/\partial E_{ij})$. Without taxation, the Member States induce the fishermen to catch up to the point where $p\partial G_{ij}/\partial E_{ij} - C'_{ij}(E_{ij}) = 0$. The EU wants the Member States to produce at a point where $p\partial G_{ij}/\partial E_{ij} - C'_{ij}(E_{ij}) > 0$ and the basic welfare economic problem is that effort is too large in the unregulated model (the Member States do not include the effects on the fish stock). Thus, the EU captures part of the production externality associated with the fish stock. Furthermore, it is seen that the EU wants an effort level where the marginal costs are larger than the value of the marginal tax revenue $\{\lambda\delta G/\delta E_{ij} > \mu[p\delta G/\delta E_{ij} - C'_{ij}(E_{ij})]\}$ since $p\delta G_{ij}/\delta E_{ij} - C'_{ij}(E_{ij}) > 0$.

The optimal marginal EU tax on Member State *j* based on fisherman *i* may be found by equations (10) and (2). This yields:

$$T'_{ij}(E_{ij}) = -\mu\left[p\frac{\partial G_{ij}}{\partial E_{ij}} - C'_{ij}(E_{ij})\right] + \lambda\frac{\partial G_{ij}}{\partial E_{ij}}. \tag{11}$$

From the above, we know that $\lambda\partial G/\partial E_{ij} > \{\mu[p\partial G/\partial E_{ij} - C'_{ij}(E_{ij})]\}$. Therefore, the marginal tax is positive. An interpretation of this tax may be found by contrasting it with the tax that would generate a Pareto optimum (where tax revenue is not included in the objective function and there is no participation restriction). This would be $T'_{ij}(E_{ij}) = \lambda\partial G_{ij}/\partial E_{ij}$, which completely captures the externality nature of the fish stock. In this case, call the optimal effort E^*. Since the EU includes tax revenue in the objective function and the value of the marginal tax revenue must be subtracted, it must be expected that $E_{ij} > E^*$. Because $p\partial G/\partial E_{ij} - C'_{ij}(E_{ij}) > 0$, the tax does, however, secure a welfare gain compared to the unregulated optimum. Thus, from a normative perspective, there are some benefits associated with using it.

A Simple Adverse Selection Model

Assume now that the EU knows that fishermen *i* in Member State *j* belongs to one of two types — low cost (type 1) and high cost (type 2), with $C_{ij2}(E) > C_{ij1}(E)$ for all E, where the subscripts 1 and 2 denote types.[5] The EU has incomplete information about the type of fishermen *i*, but sets a probability, π_h for $h = 1, 2$, to type h. A further assumption is that $C'_{ij2}(E) > C'_{ij1}(E)$. This assumption is referred to as the single crossing property and states that the high-cost agent has higher marginal costs than the low-cost agent.

[5] Theoretically, it would be more correct to work with a continuum of types. This is done in some research within the pollution control literature (Jebjerg and Lando 1997). As in the case of discounting, optimal control theory can be used as the mathematical method when working with a continuum of types. The assumption about two types is selected because studies of management of a renewable resource with a principal-agent approach are a new research area. However, studies that work with a continuum of types for renewable resources is a promising area for future research.

The basic incentive problem is that the low-cost agent may pretend to be a high-cost agent, because it can be beneficial. It is assumed that the EU wishes to design the tax system in such a way that there is an economic incentive for the Member States to reveal the correct type of fishermen. Technically, two self-selection restrictions are included in the model.

Now the resource restriction states that the natural growth must equal the sum of expected catches, and with expected long-run economic yield as the objective, the EU maximization problem is:

$$\max\left\{\sum_{j=1}^{k}\sum_{i=1}^{n_j}\pi_1\left[pG_{ij1}(x, E_{ij1}) - C_{ij1}(E_{ij1}) + \mu T_{ij1}(E_{ij1})\right]\right. \tag{12}$$

$$\left. + \sum_{j=1}^{k}\sum_{i=1}^{n_j}\pi_2\left[pG_{ij2}(x, E_{ij2}) - C_{ij2}(E_{ij2}) + \mu T_{ij2}(E_{ij2})\right]\right\}$$

s.t.

$$F(x) - \sum_{j=1}^{k}\sum_{i=1}^{n_j}\left[\pi_1 G_{ij1}(x, E_{ij1}) + \pi_2 G_{ij2}(x; E_{ij2})\right] = 0 \tag{13}$$

$$pG_{ij1}(x, E_{ij1}) - C_{ij1}(E_{ij1}) - T_{ij1}(E_{ij1}) \geq 0 \tag{14}$$

for all low-cost agents in all Member States

$$pG_{ij2}(x, E_{ij2}) - C_{ij2}(E_{ij2}) - T_{ij2}(E_{ij2}) \geq 0 \tag{15}$$

for all high-cost agents in all Member States

$$pG_{ij1}(x, E_{ij1}) - C_{ij1}(E_{ij1}) - T_{ij1}(E_{ij1}) \geq pG_{ij2}(x, E_{ij2}) - C_{ij1}(E_{ij2}) - T_{ij2}(E_{ij2}) \tag{16}$$

for all low-cost agents in all Member States

$$pG_{ij2}(x, E_{ij2}) - C_{ij2}(E_{ij2}) - T_{ij2}(E_{ij2}) \geq pG_{ij1}(x, E_{ij1}) - C_{ij2}(E_{ij1}) - T_{ij1}(E_{ij1}) \tag{17}$$

for all high-cost agents in all Member States

where equations (16) and (17) are the self-selection restrictions. They express that the Member States must have an incentive to reveal the correct types of fishermen. With regard to equations (16) and (17), the following is noted. It is assumed that if the Member States pretend that, for example, a low-cost fisherman is a high-cost fisherman, it must also deliver a high-cost fisherman effort, induce a high-cost fisherman catch, and pay a tax based on the assumption that the fisherman is high cost. This reflects the assumption that the EU uses all the information it can gather about the fishermen when taxing the Member States.

In the appendix, it is shown that type 2's participation restriction and type 1's self-selection restriction are binding. This means that:

$$pG_{ij2}(x, E_{ij2}) - C_{ij2}(E_{ij2}) = T_{ij2}(E_{ij2}) \tag{18}$$

for all high-cost agents in all Member States

$$pG_{ij1}(x, E_{ij1}) - C_{ij1}(E_{ij1}) + C_{ij1}(E_{ij2}) - C_{ij2}(E_{ij2}) = T_{ij1}(E_{ij1}) \tag{19}$$

for all low-cost agents in all Member States

Equation (18) indicates that the tax is designed in such a way that the high-cost agent's surplus is exhausted. Since $C_{ij1}(E_{ij2}) - C_{ij2}(E_{ij2}) < 0$, the low-cost agent receives a surplus — an information rent (equation [19]). The notion of information rents to the most efficient types is a well-known result (Varian 1992), and the rent is the cost difference between the types evaluated at E_{ij2}. The information rent assures that the Member States will reveal type 1 fishermen correctly.

By substituting equations (18) and (19) into equation (12), a rewritten maximization problem is obtained and a Lagrange function can be set up. The EU optimality condition for the effort level for fisherman i in Member State j is:

$$\frac{\partial L}{\partial E_{ij1}} = (1+\mu)\left[p\frac{\partial G_{ij1}}{\partial E_{ij1}} - C'_{ij1}(E_{ij1})\right] - \lambda\frac{\partial G_{ij1}}{\partial E_{ij1}} = 0. \tag{20}$$

for $j = 1, \ldots, k$ and $i = 1, \ldots, n_j$

$$\frac{\partial L}{\partial E_{ij2}} = \pi_1\left[C'_{ij1}(E_{ij2}) - C'_{ij2}(E_{ij2})\right] \tag{21}$$

$$+ \pi_2\left[(1+\mu) * \left(p\frac{\partial G_{ij2}}{\partial E_{ij2}} - C'_{ij2}(E_{ij2})\right)\right] - \lambda\frac{\partial G_{ij2}}{\partial E_{ij2}} = 0.$$

According to equation (20), the EU wishes to set the expected marginal benefit equal to marginal cost for type 1. The expected marginal benefits consist of the expected marginal resource rent and the value of the expected marginal tax revenue. The marginal costs consist of the value of the effect on the resource stock. Note that the value of the marginal tax revenue $\{\mu[p\partial G_{ij1}/\partial E_{ij1} - C'_{ij1}(E_{ij1})]\}$ is less than the marginal cost $(\lambda\partial G_{ij1}/\partial E_{ij1})$, as the marginal resource rent is positive. For type 2, there is an extra cost. Because type 1 is present and must be given an incentive to reveal his type correctly, the first order condition of type 2 must be corrected by $\pi_1[C'_{ij1}(E_{ij2}) - C'_{ij2}(E_{ij2})] < 0$, which is referred to as the marginal incentive cost. Note also that the probability corrected marginal costs are larger than the value of the marginal tax revenue $[\{\pi_1/\pi_2[C'_{ij1}(E_{ij2}) - C'_{ij2}(E_{ij2})] + 1/\pi_2\lambda\partial G_{ij2}/\partial E_{ij2} - \mu[p\partial G_{ij2}/\partial E_{ij2} - C'_{ij2}(E_{ij2})]\} > 0]$, because the marginal resource rent is positive.

Compared with full information, it is seen that a full information optimum is not reached, because x and λ are different between models (Jensen and Vestergaard 1999). This effect is new compared to the standard principal-agent theory (Varian 1992). The reason for this is a restriction on the maximization problem, and in this case, it is a resource restriction. In Jensen (2001), E_{ij} (full information) and E_{ij1} are compared, and it must be expected that $E_{ji1} > E_{ij}$, because the resource restriction must be fulfilled. Comparing the optimal level of effort, E_{ij2}, with the level of effort under full information, E_{ij}, it must be expected that $E_{ij2} < E_{ij}$, because an incentive cost is present for type 2. This is a standard result within analysis of adverse selection (Varian 1992).

The marginal EU tax for Member State j, based on fisherman i, can be found by equalizing equations (20) and (21) with equation (2):

$$T'_{ij1}(E_{ij1}) = -\mu\left[p\,\frac{\partial G_{ij1}}{\partial E_{ij1}} - C'_{ij1}(E_{ij1})\right] + \frac{\partial G_{ij1}}{\partial E_{ij1}}\,\lambda \qquad (22)$$

$$T'_{ij2}(E_{ij2}) = \frac{\pi_1}{\pi_2}\left[C'_{ij2}(E_{ij2}) - C'_{ij1}(E_{ij2})\right] + \frac{1}{\pi_1}\lambda\,\frac{\partial G_{ij2}}{\partial E_{ij2}} - \mu\left[p\,\frac{\partial G_{ij2}}{\partial E_{ij2}} - C'_{ij2}(E_{ij2})\right]. \qquad (23)$$

From the EU first-order conditions, it follows that the marginal tax revenue is less than the marginal costs for type 1 $\{\mu[p\partial G_{ij1}/\partial E_{ij1} - C'_{ij1}(E_{ij1})] < \lambda\partial G_{ij1}/\partial E_{ij1}\}$. Therefore, the marginal tax for type 1 is positive. In the same way, it appears from equation (23) that $T'_{ij2}(E_{ij2})$ is positive because the probability corrected marginal costs are larger than the value of the marginal tax revenue $\{\pi_1/\pi_2[C'_{ij1}(E_{ij2}) - C'_{ij2}(E_{ij2})] + 1/\pi_2\lambda\partial G_{ij2}/\partial E_{ij2} + \mu[p\partial G_{ij2}/\partial E_{ij2} - C'_{ij2}(E_{ij2})] > 0\}$. Compared with full information, the marginal tax for type 1 must be corrected by $1/\pi_1$. For type 2, there is also a correction of the marginal incentive costs. These corrections are made for information revelation reasons.

Extensions of the Basic Model

Some of the assumptions made in the simple model might be questioned. The assumption that the Member States totally disregard the resource restriction may not seem reasonable. Arnason (1990) builds a fisheries economic model where individual fishermen take some resource conservation considerations in a national regulatory framework. Furthermore, the reference made to the model in Hannesson (1997) may not be reasonable because the number of Member States in the EU is restricted. A more reasonable assumption is, therefore, that the Member States take some resource conservation measures.

Moreover, because the Member States are taxed, it must be expected that they tax the fishermen. Therefore, a double principal-agent problem occurs (figure 1). In such a model, the Member States wish to induce the fishermen to deliver an optimal level of effort, but because of the EU tax, the Member States' optimal level of effort cannot be reached. The EU uses its tax to assure that the Member States regulate the fishermen to an optimal level of effort from the EU's point of view.

Jensen and Vestergaard (1999) analyze such a problem. It is assumed that the Member States know the type of the fishermen with certainty but that the EU has the information structure outlined above. The double principal-agent problem is solved backwards — starting with the fishermen, then the Member States, and finally the EU. Jensen and Vestergaard (1999) show that the only difference that arises in the marginal EU tax is that the EU only corrects the part of the production externality that the Member States do not correct. However, the taxes may be a marginal subsidy instead of a marginal tax, if the level of effort the Member States wants is too low compared with the level the EU prefers.

Conclusion

In this paper, an EU tax for fisheries has been analyzed. It seems that allowing the EU to tax the Member States has at least two desirable properties. First, the tax can be used to correct at least part of the production externality associated with a fish stock. Second, in light of adverse selection, the tax can be used to secure correct revelation of the types of fishermen. Note that the second property follows from the first property, in the sense that the EU is only interested in securing correct revelation of types if it corrects a market failure.

A simple principal-agent analysis has been conducted, and it has been concluded that the EU tax will consist of three components — the marginal value of the fish stock, an information revelation component, and a value of the marginal tax revenue component. In a double principal-agent analysis, the EU only corrects the part of the externality that the Member States do not correct.

There are several advantages of an EU tax system compared to TACs. TACs are normally based on the maximum sustainable yield concept. The allocation scheme of TACs to the Member States was determined in 1983 and has not changed since. Furthermore, the total quotas do not take account of differences in efficiency between fishermen and do not lead to economic efficiency (Clark 1990). Finally, TACs and quotas do not incorporate differences in information between the EU, Member States, and fishermen. In principle, an EU tax solves all these problems.

The analysis in this paper is an example of what Russell (1994) calls complex regulation, since some of the restrictive assumptions normally used in the discussions of regulatory regimes have been dropped. Here, the traditional assumptions of perfect information were ignored. Furthermore, tax revenue is included in the objective function. When some simplifying assumptions are ignored, other simplifying assumptions must be accepted. In the models presented here, there is no discussion of adjustment to equilibrium (a steady-state equilibrium is assumed) and no inclusion of a discount rate (long-run economic yield is maximized). Furthermore, it is assumed that the EU taxes fishing effort, not output (effort is a multidimensional component). All these assumptions have been subject to a lot of criticism in the fisheries economics literature. In the present context, they are justified by the fact that a principal-agent analysis is conducted. Indeed, the analysis can be seen as a first attempt to discuss fisheries management with a principal-agent analysis. However, including discounting and adjustment processes toward equilibrium in analysis of imperfect information is a promising future research area.

Despite the fact that the analysis is conducted under imperfect information, the information requirements of the proposed tax structure may be criticized. For example, the tax requires knowledge of individual production functions. Several points are worth mentioning with respect to this criticism. First, in principal-agent analysis it is possible to have imperfect information about several variables. Second, proxies may be used when the necessary data is collected. Third, information requirements can be seen as a challenge, not an obstacle, when work is done within complex regulation. Fourth, the information requirements are by no means higher than in other attempts to regulate in an optimal fashion. Finally, principal-agent taxes reveal information which is valuable for decisionmakers.

It is questionable whether it is reasonable to allow the EU to impose a non-linear tax on the Member States on the basis of individual fishermen. Note, however, that a federal tax is sometimes discussed in the economics literature (Segerson, Miceli, and Wen 1997) and that the individual tax can be approximated with a uniform tax schedule within groups. Furthermore, an EU tax may be reasonable within the fishing industry since it corrects the production externality problem, and a two-part linear tax schedule may be used as a proxy for the non-linear tax. Finally, contrary to a normal resource tax, the tax analyzed here does not induce any exit of fishermen because of the participation restriction and that the tax can be used to cover part of the budget deficit in the EU.

Even though the analysis in this paper departs from the relation between the EU, the Member States, and the fishermen, it can be generalized to several other cases. The analysis could also be extended to other cases where a federal level is responsible for some parts of management, while the Member States of the federal union are responsible for other aspects of the regulation. Furthermore, the analysis can be generalized to the case where a national regulatory authority regulates the resource together with a decentralized regulatory authority.

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Appendix: The Restrictions

For type 1, two restrictions are present and may be written as:

$$T_{ij1}(E_{ij1}) \leq pG_{ij1}(x, E_{ij1}) - C_{ij1}(E_{ij1}) \quad (1)$$

$$T_{ij1}(E_{ij1}) \leq pG_{ij1}(x, E_{ij1}) - C_{ij1}(E_{ij1}) - \left[pG_{ij2}(x, E_{ij2}) - C_{ij1}(E_{ij2}) - T_{ij2}(E_{ij2})\right]. \quad (2)$$

Since taxes enter in the objective function with a positive sign, one of these restrictions must be binding.

According to the participation restriction for type 2:

$$pG_{ij2}(x, E_{ij2}) - C_{ij2}(E_{ij2}) - T_{ij2}(E_{ij2}) \geq 0. \tag{3}$$

The single crossing property implies that:

$$-C_{ij1}(E_{ij1}) > -C_{ij2}(E_{ij2}). \tag{4}$$

Equations (3) and (4) imply that:

$$pG_{ij2}(x, E_{ij2}) - C_{ij1}(E_{ij2}) - T_{ij2}) > pG_{ij2}(x, E_{ij2}) - C_{ij2}(E_{ij2}) - T_{ij2}(E_{ij2}) \geq 0. \tag{5}$$

Therefore, the expressions in the bracket of equation (2) are positive, and since it must be subtracted, it must be the self-selection restriction that is binding for type 1.

Since taxes enter with a positive sign, one of restrictions for type 2 must be binding. Can it be the self-selection restriction? If this restriction is binding and the binding self-selection restriction for type 1 is substituted into the binding self-selection restriction for type 2, the following is obtained:

$$C_{ij1}(E_{ij1}) - C_{ij1}(E_{ij2}) = C_{ij2}(E_{ij1}) - C_{ij2}(E_{ij2}). \tag{6}$$

This violates the single crossing property, and it must, therefore, be the participation restriction for type 2 that is binding.