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Stakeholder influence and optimal regulations: A common agency analysis of ecosystem based fisheries regulations

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Abstract

One aspect of ecosystem based management is to include new stakeholders. When an environmental NGO (ENGO) gets a say in the fisheries management, this will affect the authorities' optimal regulation. Combining a principal-agent model and a steady-state bioeconomic model we show that under symmetric information the authorities will moderate their use of regulation as a response to the ENGO's increased influence. However, the aggregate of the authorities' and the ENGO's regulations will be stronger. Introducing asymmetric information, the regulation of the high cost fishers relative to the low cost fishers is weaker than under a single principal. (JEL: Q22, Q28)

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A common agency analysis of ecosystem based fisheries regulations

1 Introduction

During the last decades non-governmental organisations (NGOs), especially those concerned with environmental matters (henceforth ENGOs), have taken an increased interest in fisheries activities. This is the case also in EU fisheries, where overfishing has been a permanent problem the last decades, causing poor economic and environmental performance (COM 2009). The ENGOs interact with the fisheries' management by trying to influence the preferences, and thus decisions of the authorities and fishers, such that environmental concerns obtain a greater weight at the expense of other concerns. In the EU, they primarily do this by approaching the EU Commission or national authorities. When these bodies are insensitive to the ENGOs' efforts, the ENGOs may exert effort more directly upon the fishers. Examples of this are calls for boycotting fish products not harvested sustainably, dumping rocks to mark marine protected areas, and issuing certificates for fisheries with sustainably harvested stocks.

Applying a common agency model in combination with a steady-state bioeconomic model, this paper analyses the consequences of giving an ENGO a say in the regulation of fishers' activity. With symmetric information and identical fishers we show that introducing an additional principal with strong conservation interests implies that the original principal (the authorities) puts forward a weaker regulation than in a single principal situation. The aggregate of the authorities' and the ENGO's regulation, which is the regulation the fishers face, is however stricter compared to the regulation under one principal. The optimal regulation depends on fishers' costs, and letting harvesting costs be private information, when information revelation is an optimal strategy the authorities will regulate a high cost fisher stricter than a low cost fisher. Giving an ENGO a say in the fisheries management will change the authorities' optimal regulation of each type of fisher, and the difference between the high and low cost fisher regulations is reduced. The reason is that introducing a new stakeholder with stronger environmental interests will make the aggregate of the regulations stricter. Thus, effort and harvest is lower, and the need for distorting the high cost fishers' effort downward is lower.

Single principal-agent (PA) models, where one principal regulates one agent, have previously been applied to analyse fisheries regulations. Addressing the problem of overfishing, JENSEN AND VESTERGAARD [2002a] propose that EU authorities can collect a resource tax from the member states based on their fishing activity, and the member states can in turn collect the tax from the fishers. This is suggested as an alternative to the present Total Allowable Catch (TAC) limitations, which have proven ineffective in preventing overfishing because the presence and extent of illegal landings and discards is information private to the fishers, making it difficult for the regulators to assess the stock level and set quotas. They use a PA-model to derive the optimal regulation (tax) in the presence of private information about harvest costs and show that whereas the low cost fishers are regulated as under symmetric information, the high cost fishers are regulated more strictly and their effort and thus harvest is distorted downward. Due to the resource restriction (equilibrium harvest) in equilibrium the low cost fishers may apply more effort and can obtain larger harvests than under symmetric information. This effect is new compared to the standard principal-agent theory, and is explicitly derived in JENSEN AND VESTERGAARD [2002b]. JENSEN AND VESTERGAARD [2007] also develop a tax scheme consisting of a stock tax and a tax on self-reported catches, which can solve several problems connected to overfishing and uncertain stock levels. Other papers concerning the optimal regulation of fishing activities when the fishers have private information about harvest, discards and landings are JENSEN AND VESTERGAARD [2002c] who derive a tax scheme where the tax rate is based on the state of the stock biomass instead of reported landings, and HANSEN, JENSEN, BRANDT AND VESTERGAARD [2006] who derive a tax scheme which is based on the authorities' knowledge about the aggregate of the cost functions, but not the individual costs and the actual landings.

Whereas the above papers' main concern are to derive optimal regulation schemes for fishing activities when the fishers have private information, this paper's focus is on the effects on the optimal regulation of introducing a second regulator and how a second regulator affects the optimal regulation when fishers have private information about harvesting costs. Although we apply the same type of model as in the above mentioned papers, there are some crucial differences. The above papers assume heterogeneous fishers, which imply that the optimal regulation (tax) varies between individual fishers. Further, the optimal tax is non-linear in effort. In practise such schemes are difficult to implement, as is also recognised by JENSEN AND VESTERGAARD [2002a, p.281] stating that "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." We follow these suggestions and apply the so-called Walsh-contract. WALSH [1995] showed that a government's optimal contract regulating the central bank's monetary policy, is linear in money growth, and thus in the inflation rate.

The first to apply Walsh contracts in a common agency setting were DIXIT AND JENSEN [2003], analysing how member countries in a monetary union try to induce the common central bank (CCB) to follow their preferred economic policy. Later, CHORTAREAS AND MILLER [2004] extend the original model of WALSH [1995] taking into consideration the influence of a second principal, e.g. an organisation representing the industries who may be interested in boosting output, and who is in the position of affecting the CCB's behaviour. They develop optimal non co-operative contracts for the two principals when their interests coincide, and when they do not, and show that these are linear in money growth and inflation. CAMPOY AND NEGRETE [2008] is a comment to CHORTAREAS AND MILLER [2004] and shows that there is only one coherent way to solve the type of common agency treated in the latter, namely that the participation constraint of the agent is taken explicitly into consideration. This is not done in CHORTAREAS AND MILLER [2004] and the two approaches give different results. As there seems to be no disagreement that the principal's optimisation problem must be conditioned on the agent's participation constraint, we follow CAMPOY AND NEGRETE [2008], and translated to the fisheries sector this implies that we assume a regulation mechanism which is linear in effort and with a general component (lump sum transfer) which secures participation on behalf of the fishers. One of the most recent contributions to the common agency literature where linear (Walsh) contracts are used, is CICCARONE AND MARCHETTI [2012]. They use the model from CAMPOY AND NEGRETE [2008], but extend it by introducing uncertainty regarding the preference structure of the agent, i.e. the weights attached to the interests represented in the agent's objective function whereas CAMPOY AND NEGRETE [2008] only assume uncertainty regarding the actual value of the interests (output and inflation). The way we treat uncertainty in this paper follows that of CAMPOY AND NEGRETE [2008], introducing uncertainty regarding the fishers' harvesting costs.

To our knowledge the effects on the optimal regulation of including a new stakeholder in the fisheries management has not been treated analytically. We do this in section 2. As long as information is symmetric, optimal regulation by two principals can be treated as an optimisation problem with strategic interaction between the two regulators, and thus solved by the use of a Cournot game. Introducing asymmetric information between the regulators and the fishers, derivation of the optimal regulations becomes a common agency problem. In section 3 we solve this problem analytically and derive the optimal information revealing regulations of the two principals. Section 4 concludes the paper.

2 Optimal fisheries regulations with two regulators and symmetric information

Main objectives of fisheries' management around the world is expressed as a combination of environmental and social, including economic, interests, where the relative weights of these interests have changed over time [COM 2009, NOAA 2007]. The implementation of fisheries management objectives is in the case of EU-fisheries delegated to national authorities and in the US there is also a division of work between federal and state authorities when it comes to fisheries regulations [BURKE 1982]. For the analysis in this paper we assume that the utility of the regulating authorities and the new stakeholder, here represented by an ENGO, is a weighted aggregate of these interests. Hence,

(1) $U = \lambda_1 ENV + \lambda_2 SOC$

denote the utility, *U*, from fishing activities to fisheries' regulators, expressed as a function of the environmental *(ENV)* and the social *(SOC)* interests, and weighted by λ_i, $i=1,2$, where $0 \le \lambda_i \le 1$, and $\sum_{i=1}^{2} \lambda_i = 1$.

It is realistic to assume that the environmental interest (*ENV*) represents a conservationist viewpoint, which establishes that utility increases with fish stock size up to the maximum sustainable yield level, X^{MSY}, i.e. conservationists want to maximise growth of the stock. As a proxy for the environmental interest we use the long run equilibrium harvest function $h(X,E)$, where *X* is the stock level of the species and *E* is effort applied by an individual fisher in the harvest, and harvest equals stock growth. The national authorities maximise the long run production function aggregated over all (national) fishers, and thus we multiply by *K*, the number of (homogenous) fishers in a representative member state. When $X < X^{MSY}, h'_E(X,E) < 0$, whereas when $X > X^{MSY}, h'_E(X,E) > 0$. Hence, if the stock is lower than X^{MSY}, an increase in effort gives an even lower stock, that in turn gives a lower equilibrium harvest. For most EU-fisheries it is a fact that $X < X^{MSY}$, which implies that $h'_E(X,E) < 0$.

The social, including economic interest (*SOC*) is given by the economic rent aggregated over all fishers, $\left(pg(X,E) - aE^2\right)K$, where *p* is the market price for the species harvested, $g(X,E)$ is the short run production (harvest) function. *a* is a cost parameter, and the costs, given by aE^2, imply increasing marginal costs, stating that the higher the effort already is, the more it costs to increase it further [ANDERSEN 1979]. The reason is that for given capacity, the costs will increase as we approach the capacity limit because then the gear is utilised more intensely. For the short run harvest function we assume $g'_E(X,E) > 0, g'_X(X,E) > 0$.

Note that the objective function given in (1), and as explained above, implies a combination of long and short run considerations.[2] Given the composite interests authorities and other stakeholders may have regarding the fisheries, it is not obvious that the maximum sustainable or maximum economic yield is the optimal harvest of a specific stock or fishery. Our point of departure is that the authorities and other stakeholders given a say in the fisheries regulation determine the regulation in order to maximise their objective function. We assume an input regulation, which can be expressed in economic terms, e.g. a tax on effort.[3] Concentrating on an input regulation in the form of a tax makes the model flexible

[2] One may object to this formulation of the objective function arguing that whereas the first term is measured in kg the last term is measured in money. It is a trivial matter to measure the first term in monetary units by multiplying with a unit price.
[3] Specifying a relationship between effort and harvest, e.g. by a Schaefer production function, this input regulation can easily be transformed to an output regulation, i.e. a tax or subsidy on harvest.

in the sense that a negative regulation can be interpreted as a subsidy. The regulation set by the authorities and which each fisher faces is given by $t_0 + t_1 E$, where t_1 is a unit regulation, e.g. a tax rate, aiming at affecting the effort applied in the fishery, while t_0 is a general regulation, e.g. a lump sum transfer from fishers to the regulator. The corresponding regulation for the ENGO is given by $\tau_0 + \tau_1 E$. Each of the parameters may be positive or negative. For tractability of the model we start out by assuming homogenous fishers. Hence, a given set of regulations either enables all fishers a non-negative rent or drives all fishers out of the fishery. As the latter option is of little theoretical interest, we concentrate on situations where the participation constraint is fulfilled, i.e. all fishers are allowed a non-negative rent. We impose this as an explicit condition on the regulators' optimisation, and the lump sum transfer secures that this constraint can be fulfilled. Due to the presence of some (other) regulations the fishers may extract a rent initially, and as long as information is symmetric the use of Walsh-contracts enables the principal(s) to regulate away any potential rent.

We formulate the regulation of the fisheries as a static 2-stage non-cooperative game between the regulators (authorities, ENGO), and the fishers. In the first stage each regulator individually and simultaneously set their regulation and the fishers do nothing. In the second stage the fishers decide whether to participate in the fishery given the regulations, and if yes they fix the effort, *E*. If the fishers do not accept the regulation they leave the fishery, and in this case the pay-off to both fishers and regulators is normalised to zero. We assume the fishers' response to be "immediate", eliminating time costs. The model is static and we do not take into consideration out-of-equilibrium strategies for any of the actors.

For simplicity we assume that each individual fisher maximises economic rent from the fishing activity, and the participation constraint for an individual fisher is given by

$$(2) \qquad (pg(X,E) - aE^2) - (t_0 + t_1 E) - (\tau_0 + \tau_1 E) \geq 0$$

To ensure a biological equilibrium (steady state level for the stock) it must be the case that

$$(3) \qquad \frac{\partial X}{\partial t} \equiv F(X) - g(X,E)KN = 0$$

where *F(X)* is the natural net growth in the stock, and *N* is the number of nations taking part in the fishery. The last right hand term is then total harvest of the specific stock in the relevant sea area, and for simplicity we have assumed that the number of fishers (*K*) is the same in all participating countries/states.

The regulators' optimisation problem now is given by (4):

(4) $max_E\, U^k + M^k$

s.t. (2) and (3)

where the superscript k denotes the regulator, k=*MS* indicates (member) state authorities and k=*NGO* indicates the ENGO. $M^{MS} = \mu(t_0 + t_1 E)K$ is the regulation revenue which accrue to the authorities, and $M^{NGO} = \eta(\tau_0 + \tau_1 E)K$ is the regulation revenue which accrue to the ENGO when regulating domestic fishers. $0 \le \mu, \eta \le 1$ are parameters expressing the share of the total regulation revenue which the authorities and the ENGO respectively receive.

The solution to the optimisation problems, given as optimal effort for the authorities and the ENGO respectively, are,[4]

(5) $$E_{MS}^{**} = \frac{g'_E\,(p(\mu + \lambda_2^{MS}) - \gamma N) + \lambda_1^{MS} h'_E - \mu\tau_1}{2a\left(\mu + \lambda_2^{MS}\right)}$$

(6) $$E_{NGO}^{**} = \frac{pg'_E\,(p(\eta + \lambda_2^{NGO}) - \varphi N) + \lambda_1^{NGO} h'_E - \eta t_1}{2a\left(\eta + \lambda_2^{NGO}\right)}$$

where γ, φ are the Lagrange multipliers, indicating the shadow values of the stock constraint for the authorities and the ENGO respectively.

The left hand side of (2) is the rent of an individual fisher when he/she is regulated by two regulators, and maximising this with respect to E yields the optimal effort for an individual fisher, E_F^{**}.

(7) $$E_F^{**} = \frac{pg'_E - t_1 - \tau_1}{2a}$$

Equalising (7) with (5) and (6) and solving for t_1 and τ_1 yields the optimal regulation for each of the two regulators as a reaction to the regulation of the other regulator (reaction functions):

(8) $$t_1^R = -\frac{\lambda_2^{MS}}{\mu + \lambda_2^{MS}}\tau_1 + \frac{-\lambda_1^{MS} h'_E + \gamma g'_E N}{\mu + \lambda_2^{MS}}$$

(9) $$\tau_1^R = -\frac{\lambda_2^{NGO}}{\eta + \lambda_2^{NGO}} t_1 + \frac{-\lambda_1^{NGO} h'_E + \varphi g'_E N}{\eta + \lambda_2^{NGO}}$$

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[4] For these to be explicit solutions to the optimisation problems we need to assume a harvest function which is linear in effort. In other cases, (5) and (6) implicitly yields the optimal effort.

These reaction functions demonstrate very clearly the point made by BERNHEIM AND WHINSTON [1986] that in constructing optimal regulations in agency problems with more than one principal, each principal first takes out the incentives of the other principal and then creates its own incentives. Or put in their words; "only the net incentive scheme matters, so each principal can take out what others put in before designing his preferred scheme." [*op cit*, p. 929]. As the first part of the first right hand term in (8) and (9) is smaller than one, (8) and (9) show that each principal only takes out a part of what the other principal has put into the regulation. The higher the socio-economic (henceforth economic) interest is, the higher is the part of the regulation set by the other principal which is taken out, whereas the higher μ,η are, for constant economic interests, the lower is the part that is taken out. This is reasonable as high economic interests imply that they prefer a high effort level and thus a low regulation, whereas high μ,η indicates that the regulators to a large degree are financially responsible for the regulation they set.[5]

Solving for (8) and (9) simultaneously yields explicit expressions for the optimal tax rates,[6] and the aggregate regulation, also called the net incentive scheme, and which is what counts for the fishers, is given by

$$(10)\qquad t_1^* + \tau_1^* = \frac{-(\mu\lambda_1^{NGO} + \eta\lambda_1^{MS})h'_E + (\eta\gamma + \mu\varphi)g'_E\, N}{\eta\lambda_2^{MS} + \mu\lambda_2^{NGO} + \eta\mu}$$

The net incentive scheme unambiguously decreases in the economic interest of the regulators, expressed by $\lambda_2^{MS},\lambda_2^{NGO}$ and increases in the environmental interests (when $X < X^{MSY}$), represented by $\lambda_1^{MS},\lambda_1^{NGO}$, in the marginal long run harvest, and in the shadow values of the stock externality.

When the authorities are the sole regulator of the fishery, the optimal regulation is given by[7]

$$(11)\qquad w_1^* = \frac{-\lambda_1^{MS} h'_E + \gamma g'_E\, N}{\mu + \lambda_2^{MS}}\,.$$

PROPOSITION 1 Giving a new stakeholder a say in the fisheries regulation changes the optimal regulation of the original regulator.

PROOF Comparing (8) and (11), shows that the last right hand term of (8) coincides with the right hand side of (11). Hence, when the ENGO forwards a tax

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[5] Since η,μ give the part of the regulation revenue the regulators receive, they also give the part of the net transfer to the fishers the regulators must pay if the regulation revenue is negative.
[6] Explicit expressions for the optimal tax/subsidy rates are given by (A7) and (A8) in appendix AII
[7] In deriving the optimal regulation for one regulator we have used the model of JENSEN AND VESTERGAARD [2002A] and the derivation of (11) is given in the appendix, AI.

($\tau_1>0$) the authorities respond by relaxing their regulation, and when the ENGO forwards a subsidy the authorities strengthen their regulation. Q.E.D.

PROPOSITION 2 Giving a new stakeholder with stronger environmental and weaker economic interests a say in fisheries regulation, increases the regulation pressure and the equilibrium stock.

PROOF The aggregate of the authorities' and the ENGO's regulations is higher compared to the optimal single principal regulation when

$$(12) \qquad g'_E\, N\left(\varphi\lambda_2^{MS} + \mu\varphi - \gamma\lambda_2^{NGO}\right) > h'_E\left(\lambda_1^{NGO}\lambda_2^{MS} - \lambda_1^{MS}\lambda_2^{NGO} + \mu\lambda_1^{NGO}\right)$$

It is realistic to assume that the ENGO has a higher shadow price on the stock than the authorities, i.e. $\varphi > \gamma$, and that the ENGO has higher environmental and the authorities higher economic interests of the two; $\lambda_1^{NGO} > \lambda_1^{MS}, \lambda_2^{NGO} < \lambda_2^{MS}$. Then, if $X < X^{MSY}$, the right hand side of the inequality is negative, whereas the left hand side is positive, and hence (12) is always fulfilled. If $X > X^{MSY}$, both sides of (12) are positive, and then the more equal weights the two regulators have the more likely it is that the inequality is fulfilled. For typical functional forms $h'_E(X,E) < g'_E(X,E)$, and this supports the inequality in (12).

The optimal effort for an individual fisher, given the net incentive scheme in (10), is

$$(13)\, E^{**} = \frac{pg'_E\,(p(\eta\lambda_2^{MS} + \mu\lambda_2^{NGO} + \eta\mu) - N(\eta\gamma + \mu\varphi)) + h'_E\,(\eta\lambda_1^{MS} + \mu\lambda_1^{NGO})}{2a\left(\eta\lambda_2^{MS} + \mu\lambda_2^{NGO} + \eta\mu\right)}$$

When $X < X^{MSY}$, the optimal effort per fisher is always lower compared to when there is only one principal. In standard bio-economic models with logistic growth and Cobb-Douglas production function the equilibrium stock is decreasing in E when $X < X^{MSY}$, and thus the equilibrium stock is higher under two regulators compared to with one regulator. Q.E.D.

As the income from the regulation enters the regulators' objective functions positively, the fishers' participation constraint will always be fulfilled with equality. Hence, in equilibrium $U^F(t_0,t_1,\tau_0,\tau_1)=0$, where U^F is the pay-off to an individual fisher. In equilibrium the fishers have to accept both regulations, because if not, the regulations are not optimal responses to each other. Thus, it must be the case that $U^F(t_0,t_1,0,0)<0, U^F(0,0,\tau_0,\tau_1)<0$. For these conditions to hold, the lump sum transfers, t_0^* and τ_0^*, do not need to satisfy the participation constraint of the fishers individually.[8]

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[8] The derivation of the equilibrium transfers are given in the appendix, AII.

Note that in the case of low effort, caused by a high tax rate, the regulation may imply a transfer from the authorities to the fisher, i.e. a negative t_0 and/or τ_0 .

We have assumed that both regulators behave in a non-cooperative way. However, in making their decision, the authorities take into account the interests of the ENGO, and it is possible to imagine models where the authorities instead cooperate with new stakeholders having an interest in the fisheries. If, for instance, the two regulators have identical interests, the same threat point value, and receive the same share of the regulation revenue, then applying the Nash bargaining solution [NASH 1950], results in the same optimal effort and unit regulation as with a sole regulator. In this case the Nash product equals $NP = \left(U^k - U_0\right)^2, k = MS \equiv NGO$, where U^k is given by (1) and U_0 is an exogenous threat point. Maximising NP with respect to E yields the optimal cooperative effort. It can be shown that this also coincides with the two-regulators, non-cooperative equilibrium solution derived above, but only as long as the assumption about identical regulators holds. As soon as we allow the regulators to differ with respect to the interest weights and regulation revenue share, the two approaches will give different solutions.

3 Optimal fisheries' regulations with two regulators and asymmetric information

Regulating an agent under symmetric information is a straightforward optimisation problem. When we assume that the fishers have private information, e.g. with respect to the harvesting costs, information revelation becomes an issue. Let a_L and a_H denote the cost parameters for a low cost and a high cost fisher respectively. From the symmetric information case it is obvious that a first best solution to the fisheries regulation implies type-specific regulations. The problem of formulating one regulation for each type of fisher, where the participation constraint is binding for both, is that the regulation intended for a high cost fisher will also be chosen by a low cost fisher as this would provide him rent, whereas the regulation intended for a low cost fisher would give him zero rent. It is well known that when formulating regulations under asymmetric information it is necessary to impose an incentive compatibility condition on the regulation of a low cost fisher, ensuring that it is profitable for the low cost fisher to choose the regulation intended for him (information revelation) [FUDENBERG AND TIROLE 1993]. This, however, presupposes that information revelation (disclosing the type of the fisher) is a utility maximising strategy.

LEMMA With one regulator, information revelation is a utility maximising strategy only if the realisation of the regulator's economic interests regarding the fisheries on the margin exceeds the realisation of its environmental interests.

The expressions for the optimal type-dependent effort are given in the appendix (equations (A16) and (A17)), and they show that for effort to be positive for both types of fishers the following must hold:

(15) $pg'_E(\lambda_2^{MS} + \mu) > -\lambda_1^{MS} h'_E + \gamma N g'_E$

The left hand side represents the realisation of the economic interests measured as the short run marginal harvest as valued by the authorities plus the value of the (marginal) regulation. The right hand side represents the realisation of the environmental interests measured as the value of the marginal long term harvest plus the shadow value of the stock externality. For $X < X^{MSY}$ both sides are positive. When (15) is fulfilled, a single regulator will regulate a high cost fisher stricter than he/she will regulate a low cost fisher, and the type dependent regulations are given in the appendix (equations (A19) and (A20)).

The conjunction of high cost fishers' effort being distorted downward and short term equilibrium harvesting implies that we have a new equilibrium compared to that under symmetric information with one principal. In this asymmetric equilibrium the stock size is higher, and thus the first best effort will be different from the symmetric first best equilibrium. This was first time shown by JENSEN AND VESTERGAARD [2002b], who indicate that the asymmetric first best equilibrium effort probably is higher than the symmetric.

The situation when two uninformed principals regulate one and the same agent simultaneously is denoted common agency. The main challenge in common agencies is that each principal's regulation no longer is only a matter between the principal and the agent, but must also be an optimal response to the regulation forwarded by the other principal. We assume that the ENGO, which is allowed a say in the fisheries' regulation, faces the same informational asymmetry as the authorities with respect to whether the fishers have high or low harvest costs. Furthermore, we assume that (15) above is fulfilled, such that it is optimal for the authorities, when the sole regulator, to apply a regulation which implies information revelation.

Let $v_{0i} + v_{1i}E_i, i = L,H$ and $\upsilon_{0i} + \upsilon_{1i}E_i, i = L,H$ be the regulation forwarded by the authorities and the ENGO, respectively. The incentive compatibility restriction, which is binding for a low cost fisher, is given by[9]

(16)
$$\left(pg(X,E_L) - a_L E_L^{\;2} - (a_H - a_L)E_H^{\;2}\right) = (\upsilon_0(a_L) + \upsilon_1(a_L)E_L) + (v_0(a_L) + v_1(a_L)E_L)$$

whereas the participation constraint, which is binding for a high cost fisher, is given by

[9] See the appendix, AIV, for the derivation of this condition.

(17) $$\left(pg(X,E_H)-a_H E_H{}^2\right)=(v_0(a_H)+v_1(a_H)E_H)+(\upsilon_0(a_H)+\upsilon_1(a_H)E_H)$$

Each principal maximises expected utility taking into account the binding constraints for the low and the high cost fishers, and the stock equilibrium constraint, which is now given by (18)[10]

(18) $$\frac{\partial X}{\partial t}\equiv F(X)-\left(\pi_L g(X,E_L)-\pi_H g(X,E_H)\right)KN=0$$

where π_i, i=L,H, is the probability for a low (L) and a high (H) cost fisher respectively.

The optimal regulation for the low and high cost fishers respectively, formulated as reaction functions, are given below:[11]

(19) $$v_{1L}{}^R=-\frac{\lambda_2{}^{MS}}{\mu+\lambda_2{}^{MS}}\upsilon_{1L}+\frac{-\lambda_1{}^{MS}h'_{EL}+g'_{EL}\,\gamma N}{\mu+\lambda_2{}^{MS}}$$

(20) $$\upsilon_{1L}{}^R=-\frac{\lambda_2{}^{NGO}}{\eta+\lambda_2{}^{NGO}}v_{1L}+\frac{-\lambda_1{}^{NGO}h'_{EL}+g'_{EL}\,\varphi N}{\eta+\lambda_2{}^{NGO}}$$

(21) $$v_{1H}{}^R=-\frac{\lambda_2{}^{MS}+\mu Q}{\lambda_2{}^{MS}+\mu(Q+1)}\upsilon_{1H}+\frac{-\lambda_1{}^{MS}h'_{EH}+g'_{EH}\,(p\mu Q+\gamma N)}{\lambda_2{}^{MS}+\mu(Q+1)}$$

(22) $$\upsilon_{1H}{}^R=-\frac{\lambda_2{}^{NGO}+\eta Q}{\lambda_2{}^{NGO}+\eta(Q+1)}v_{1H}+\frac{-\lambda_1{}^{NGO}h'_{EH}+g'_{EH}\,(p\eta Q+\varphi N)}{\lambda_2{}^{NGO}+\eta(Q+1)}$$

where $Q=\frac{\pi_L}{\pi_H a_H}(a_H-a_L)$

PROPOSITION 3 Under asymmetric information, giving a new stakeholder a say in the fisheries regulation changes the original regulation of both types of fisher.

PROOF Comparing the reaction functions given in (19)-(22) with the optimal regulations with one principal (see equations (A19) and (A20) in the appendix)

[10] See (A22) in appendix AIV, for a formal presentation of the optimisation problem.
[11] Explicit expressions for the optimal regulations are given in the appendix, AIV.

shows that the last part of (19) and (20) coincides with (A19) and the last part of (21) and (22) coincides with (A20). Hence, the effect of introducing a new stakeholder in the fisheries regulations is given by the first right hand term of (19)-(22). When it is optimal for the ENGO to tax the fishers' effort, i.e. $\upsilon_{1H}, \upsilon_{1L} > 0$, the authorities reduce their regulation whereas they increase it when it is optimal for the ENGO to support effort, i.e. offer a subsidy. This is the case for both the low and the high cost fisher's regulation. Q.E.D.

PROPOSITION 4 The inclusion of a new stakeholder may contribute to information revelation not being an optimal strategy even if this was the case with one regulator.

PROOF Compared to the results from the case with two principals and symmetric information, it can be seen that (19) and (20) coincide with (8) and (9), as long as $\upsilon_1 = \tau_1, v_1 = t_1$. Hence, the low cost fishers are first best regulated, and the net incentive scheme they face is given by (10). The explicit expressions for the high cost fishers' regulations are given in (A28) and (A29) in appendix AIV, and the net incentive scheme for a high cost fisher is given by

$$(23) \qquad \upsilon_{1H}{}^{*} + v_{1H}{}^{*} = \frac{-h'_{EH}\left(\eta\lambda_1{}^{MS} + \mu\lambda_1{}^{NGO}\right) + g'_{EH}\left(N(\eta\gamma + \mu\varphi) + 2pQ\mu\eta\right)}{\eta\lambda_2{}^{MS} + \mu\lambda_2{}^{NGO} + \mu\eta(1+2Q)}$$

This scheme is stricter than the net incentive scheme for a low cost fisher, i.e. (23) is larger than (10) when

$$(24)\ pg'_{EH}\,(\mu\eta + \eta\lambda_2{}^{MS} + \mu\lambda_2{}^{NGO}) > -h'_{EH}\,(\eta\lambda_1{}^{MS} + \mu\lambda_1{}^{NGO}) + g'_{EH}\,N(\eta\gamma + \mu\varphi)$$

Compared to (15), which secures information revelation with one regulator, it is not obvious that (24) is fulfilled given that (15) is fulfilled. For example, with a high income share of the regulation revenue to the authorities, μ, and a low share to the ENGO, η, combined with a high shadow price on the stock for the ENGO, φ, and a low shadow price on the stock for the authorities, γ, (24) will not be fulfilled even if (15) is fulfilled. Following the argumentation in section 2 for why (12) is always fulfilled for $X < X^{MSY}$, it is less likely that (24) is fulfilled than that (15) is fulfilled. To secure information revelation as an optimal strategy for both regulators it must be the case that the optimal effort for a high cost fisher is positive, or that (24) is fulfilled.[12] Q.E.D.

PROPOSITION 5 Under asymmetric information and given that information revelation is an optimal strategy, the type-dependent regulations become more

[12] The expressions for the optimal effort for a high cost fisher as regarded by the regulators are given by equations (A24) and (A26) in the appendix.

equal when a new stakeholder with stronger environmental interests and weaker economic interests is given a say in the fisheries regulation.

PROOF We now assume that information revelation is an optimal strategy for each of the regulators. Proposition 5 implies that the left hand term in (24) relative to the right hand term is smaller compared to the left and right hand terms in (15). Formally, this is given in (25) [13] [14]

$$(25) \qquad \frac{v_{1H}{}^{*} + \upsilon_{1H}{}^{*}}{v_{1L}{}^{*} + \upsilon_{1L}{}^{*}} < \frac{r_{1H}{}^{*}}{r_{1L}{}^{*}}$$

were $r_{1H}{}^{*}$ and $r_{1L}{}^{*}$ are the optimal type-dependent regulations with one regulator.

This effect can be explained by the fact that giving an ENGO a say in the fisheries' regulation implies a stricter regulation of all fishers, and thus a lower effort and harvest level. Information revelation implies that there is a trade-off between reducing a high cost fisher's effort and acquiring a low cost fisher's rent. The optimal trade-off depends on the first best effort level, and it is lower, i.e. it is optimal with a smaller distortion of the high cost fishers' effort, the lower the first best effort level is. This follows from the fishers' pay off function combined with the incentive compatibility and participation constraints. Q.E.D.

As a low cost fisher is regulated optimally, his effort level is the first best and given by (13), whereas the optimal effort level for a high cost fisher is given by (26):

$$(26)\, E_H{}^{**} = \frac{g'_{EH}\,(p(\eta\lambda_2{}^{MS} + \mu\lambda_2{}^{NGO} + \eta\mu) - N(\mu\varphi + \eta\gamma)) + h'_{EH}\left(\eta\lambda_1{}^{MS} + \mu\lambda_1{}^{NGO}\right)}{2a_H\left(\mu\lambda_2{}^{NGO} + \eta\lambda_2{}^{MS} + \mu\eta(1+2Q)\right)}$$

When the regulation of a high cost fisher is stricter than that of a low cost fisher, expected total effort, and thus harvest, is lower compared to in a first best situation. Then the stock must be at a higher level. However, a higher stock level means that for the same effort level, fishers will harvest more, and thus the equilibrium first best short run effort is higher. This is the same result as that of JENSEN AND VESTERGAARD [2002a)] in their single PA-model. Relative to the single PA model, common agency implies an even higher stock as the introduction of a new stakeholder with higher environmental interests involves a stricter regulation of both types of fishers. On the other hand, under information asymmetries the result is a more equal equilibrium regulation of the two types of fishers, and thus more equal effort levels.

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[13] See the appendix, AIII, for the derivation of $r_{1H}{}^{*}$ and $r_{1L}{}^{*}$.

[14] See the appendix, AIV, equations (A30) and (A31), for the derivation of this result.

Regarding the lump sum transfers, they have to be formulated such that accepting both regulations yields the fishers a higher pay-off than accepting only one regulation. In addition the sum of the lump sum transfers must allow a low cost fisher a rent equal to $(a_H - a_L)E_H^{2} > 0$, whereas a high cost fisher gets no rent. The lump sum transfers from each of the principals do not need to fulfil these conditions separately.[15]

4 Discussion and conclusions

Letting new interest groups, such as ENGOs, have a say in the regulation of the fishing activity has consequences for the authorities' regulation of the fishery. Using a simple optimal regulation model and a Cournot game we show that when an ENGO, with stronger environmental interests than the authorities, is given a say in the fisheries' regulation, the authorities in equilibrium relax their regulation, but the aggregate of the two regulations is higher. Introducing information asymmetries we show that although information revelation was an optimal strategy with one principal, this is not necessarily the case in a common agency. When information revelation is an optimal strategy for both regulators, the result above is valid for the regulation offered to both low and high cost fishers. However, due to the stricter regulation which yields lower effort, in equilibrium harvest is on a lower level under two principals and the steady state stock is higher. As a consequence the difference between the regulation of the high and low cost fishers under information asymmetries will decrease.

The explicit use of so-called Walsh-contracts, i.e. linear contracts with a unit (effort) regulation and a lump sum term, is, admittedly, not very common within fisheries. On the other hand, one may claim that the way fisheries management work in many countries can be compared with a Walsh-contract, as the fishing activity on the one hand is regulated both with respect to input and output, but on the other hand also receive (financial) support in order to secure the survival of the fishers. A more concrete example of this type of contract within the fisheries may be the Norwegian NO_x trust fund, which is a voluntary environmental agreement between the Government and the Norwegian Association of Enterprises (NHO). Instead of paying a general tax on NO_x-emissions, participants in the fund either reduce their emissions or pay a tax into the fund. In return, they are allowed to ask for support from the fund to implement NO_x-reducing efforts.

As of yet there are few empirical examples of how ENGOs have influenced and altered the regulations of fisheries, either at super-national or at national levels. However, currently there are changes taking place which can be interpreted as if ENGOs are gaining influence on the fisheries policy around the world. One such example is the establishment and growth of the Marine Stewardship Council

[15] See the appendix, AII, for the derivation of the optimal lump sum transfers.

(MSC), which in 2009 celebrated its 10th anniversary. The organisation issues certificates to fisheries which operate and are managed in a sustainable manner and with a minimum of environmental impact. During its 10 first years of operation the MSC has certified more than 40 fisheries around the world.

The newly established RACs (Regional Advisory Council) within the European common fisheries policy (CFP) encompass in addition to fishers and the fishing industry also ENGOs. So far, the RACs have only had an advisory function, and their role cannot be interpreted as that of a principal. However, their establishment opens for the inclusion of a wider range of stakeholders, and if regionalisation of EU fisheries management due to ecosystem based management requirements is pursued further, we may end up in a situation where the ENGOs more directly have a say in EU fisheries management and can be regarded as a principal.

The model rests on the assumption that fishers only have economic interests when fishing, and not environmental and social interests. This is obviously a simplification, and expanding the model to a more sophisticated objective function for the fishers so that it encompasses both environmental and economic interests would enable us to treat uncertainty in line with CICCARONE AND MARCHETTI [2012]. This is a task for future research.

Finally, we have assumed away the case when it is optimal for one or both of the principals to close down the fishery. It could be of interest to extend the model and take into account this possibility.

Appendix

AI The optimal regulation with one regulator and symmetric information

With one regulator the optimisation problem of the regulator is as follows:

(A1) $$\max_E U^{MS} = \left(\lambda_1^{MS} h(X,E) + \lambda_2^{MS}\left(pg(X,E) - aE^2\right) + \mu\left(w_0 + w_1 E\right)\right)K$$

(A2) s.t. $$\left(pg(X,E) - aE^2\right) - \left(w_0 + w_1 E\right) \geq 0$$

(A3) and $$\frac{\partial X}{\partial t} \equiv F(X) - g(X,E)KN = 0$$

Using the fact that the participation constraint in equilibrium will be fulfilled with equality, (A2) can be inserted in (A1), and solving (A1) subject to (A3) yields

(A4) $$E_{MS}^{\ *} = \frac{pg'_E\,(p(\lambda_2^{MS} + \mu) - \gamma N) + \lambda_1^{MS} h'_E}{2a\left(\lambda_2^{MS} + \mu\right)}$$

were γ is the Lagrange multiplier, which is also the shadow price of the stock. The fisher's optimisation problem is given in (A5)

(A5) $$max_E U^F = (pg(X,E) - aE^2) - (w_0 + w_1 E)$$

which yields the optimal effort

(A6) $$E_F^{\ *} = \frac{pg'_E - w_1}{2a}$$

Equalising (A4) and (A6) yields (11).

AII The optimal regulations with two regulators and symmetric information

Solving for (8) and (9) simultaneously yields (A7)

(A7) $$t_1^{\ *} = \frac{h'_E\,(\lambda_1^{NGO}\lambda_2^{MS} - \lambda_1^{MS}\lambda_2^{NGO} - \eta\lambda_1^{MS}) + g'_E\,N\left(\gamma\lambda_2^{NGO} - \varphi\lambda_2^{MS} + \eta\gamma\right)}{\eta\lambda_2^{MS} + \mu\lambda_2^{NGO} + \eta\mu}$$

$$\text{(A8)}\ \tau_1^{\ *} = \frac{h'_E\,(\lambda_1^{\ MS}\lambda_2^{\ NGO} - \lambda_2^{\ MS}\lambda_1^{\ NGO} - \mu\lambda_1^{\ NGO}) + g'_E\,N\left(\varphi\lambda_2^{\ MS} - \gamma\lambda_2^{\ NGO} + \mu\varphi\right)}{\eta\lambda_2^{\ MS} + \mu\lambda_2^{\ NGO} + \eta\mu}$$

If the agent chooses to reject the national authorities' regulation it can either accept only the regulation of the ENGO, which will provide them a pay-off equal to $\mathrm{U^F}(0,0,\tau_0,\tau_1)$, or reject both regulations. In the latter case we assume that the pay-off to the fishers corresponds to the outside option. Thus, denoting the pay-off to the agent from rejecting the authorities' regulation $\mathrm{U^F}_{\mathrm{-MS}}$, we get $\mathrm{U^F}_{\mathrm{-MS}} = \max\left\{\mathrm{U^F}(0,0,\tau_0,\tau_1),0\right\}$. Correspondingly, denoting the pay-off to the agent of rejecting the ENGO's regulation $\mathrm{U^F}_{\mathrm{-NGO}}$, we get $\mathrm{U^F}_{\mathrm{-NGO}} = \max\left\{\mathrm{U^F}(t_0,t_1,0,0),0\right\}$. Hence, given the regulation of one principal, the agent's pay-off from accepting the other principal's regulation will equal the pay-off of not accepting it. Formally, this implies $\mathrm{U^F}(t_1,t_0,\tau_1,\tau_0) = \mathrm{U^F}_{\mathrm{-MS}} = \mathrm{U^F}_{\mathrm{-NGO}}$.

If $\mathrm{U^F}(t_0,t_1,\tau_0,\tau_1) > 0$, implying that it is better for the agent to accept at least one incentive scheme than reject both, then $\mathrm{U^F}(t_1,t_0,\tau_1,\tau_0) = \mathrm{U^F}(t_1,t_0,0,0) = \mathrm{U^F}(0,0,\tau_1,\tau_0)$. This means that a vector (t_0,τ_0) must exist which fulfils the following conditions:

$$\text{(A9)}\quad t_0 + \tau_0 = \left(pg(X,E^{**}) - aE^{**2}\right) - t_1^{\ *}E^{**} - \tau_1^{\ *}E^{**}$$

$$\text{(A10)}\quad t_0^{\ *} = \left(pg(X,E^{**}) - aE^{**2}\right) - t_1^{\ *}E^{**}$$

$$\text{(A11)}\quad \tau_0^{\ *} = \left(pg(X,E^{**}) - aE^{**2}\right) - \tau_1^{\ *}E^{**}$$

Unless either $t_1^{\ *}$ or $\tau_1^{\ *}$ equal zero, which we have shown that they do not do in equilibrium, the three conditions can not be fulfilled simultaneously.

If $\mathrm{U^F}(t_0,t_1,\tau_0,\tau_1) = 0$ implying that the agent is indifferent between accepting both or none of the incentive schemes, then $\mathrm{U^F}(t_1,t_0,0,0) < \mathrm{U^{FO}}, \mathrm{U^F}(0,0,\tau_1,\tau_0) < 0$. This means that a vector (t_0,τ_0) must exist which fulfils (A9) and where the conditions (A10) and (A11) need only be fulfilled with inequalities (the left hand side must be less or equal to the right hand side), which is a feasible set of conditions.

AIII The optimal regulation with one regulator and asymmetric information

Let $r_0(a_i) + r_1(a_i)E_i, i = L,H$ denote the type dependent regulation, where E_i is the individual effort of an *i*-type fisher. Incentive compatibility then implies

(A12) $$\left(pg(X,E_L)-a_L E_L{}^2\right)-(r_0(a_L)+r_1(a_L)E_L) \geq \left(pg(X,E_H)-a_L E_H{}^2\right)-(r_0(a_H)+r_1(a_H)E_H)$$

The high cost fishers have no possibility to achieve a positive rent and thus the participation constraint is binding, which implies

(A13) $$\left(pg(X,E_H)-a_H E_H{}^2\right)=(r_0(a_H)+r_1(a_H)E_H)$$

Inserting for the participation constraint for the high cost fisher and taking into account that the incentive compatibility constraint as given by (A12) is binding for the low cost fisher we get[16]:

(A12a) $$\left(pg(X,E_L)-a_L E_L{}^2-(a_H-a_L)E_H{}^2\right)=(r_0(a_L)+r_1(a_L)E_L)$$

Assuming that the probability for a low cost fisher is given by π_L and for a high cost fisher by π_H, the authorities' expected utility is given by

(A14) $$max_E\ EU^{MS}=\pi_L\left[\left(\lambda_1{}^{MS}h(X,E_L)+\lambda_2{}^{MS}\left(pg(X,E_L)-a_L E_L{}^2\right)+\mu(r_0+r_1(a_L)E_L)\right)K\right]+ \pi_H\left[\left(\lambda_1{}^{MS}h(X,E_H)+\lambda_2{}^{MS}(pg(X,E_H)-a_H E_H{}^2)+\mu(r_0+r_1(a_H)E_H)\right)K\right]$$

The authorities maximise the expected utility conditioned on the incentive compatibility constraint for a low cost fisher, (A12'), and the participation constraint for a high cost fisher, (A13), in addition to the equilibrium fishing condition, which is now given by

(A15) $$\frac{\partial X}{\partial t}\equiv F(X)-\left(\pi_L g(X,E_L)-\pi_H g(X,E_H)\right)NK=0$$

Inserting for (A12') and (A13) in (A14) and maximising (A14) with respect to E and subject to (A15) yields the following solutions to the optimal type-dependent individual effort:

(A16) $$E_L{}^{MS}=\frac{pg'_E\,(p(\lambda_2{}^{MS}+\mu)-\gamma N)+\lambda_1{}^{MS}h'_E}{2a_L\left(\lambda_2{}^{MS}+\mu\right)}$$

(A17) $$E_H{}^{MS}=\frac{pg'_E\,(p(\lambda_2{}^{MS}+\mu)-\gamma N)+\lambda_1{}^{MS}h'_E}{2a_H\left[\lambda_2{}^{MS}+\mu(1+Q)\right]}$$

[16] Note that these conditions imply that both types of fishers remain in the fishery

The optimal type-dependent effort for an individual fisher is given by

(A18) $$E_i^{\,F} = \frac{pg'_E - r_{1i}}{2a_i}, i = L, H$$

Equalising (A18) and (A16), and (A18) and (A17) yields the optimal type-dependent regulations:

(A19) $$r_{1L}^{\;*} = \frac{-\lambda_1^{MS} h'_{EL} + g'_{EL}\,\gamma N}{\lambda_2^{MS} + \mu}$$

(A20) $$r_{1H}^{\;*} = \frac{-\lambda_1^{MS} h'_{EH} + g'_{EH}\left(p\mu Q + \gamma N\right)}{\lambda_2^{MS} + \mu\left(Q+1\right)}$$

AIV Optimal regulations with two regulators and asymmetric information (Common agency)

For it to be profitable for the low cost fisher to choose the regulation intended for him, the following must be fulfilled:

(A21) $$\begin{aligned}&\left(pg(X, E_L) - a_L E_L^{\,2}\right) - \left(v_0(a_L) + v_1(a_L)E_L\right) - \left(\upsilon_0(a_L) + \upsilon_1(a_L)E_L\right) \geq \\ &\left(pg(X, E_H) - a_L E_H^{\,2}\right) - \left(v_0(a_H) + v_1(a_H)E_H\right) - \left(\upsilon_0(a_H) + \upsilon_1(a_H)E_H\right)\end{aligned}$$

Inserting for the participation constraint for a high cost fisher, given in (17), in (A21) yields (16).

The optimisation problem for regulator *k, k=MS, NGO,* is now given by

(A22) $$\begin{aligned}&\max_E \; EU^k = \pi_L\left[\left(\lambda_1^{\,k} h + \lambda_2^{\,k}\left(pg - a_L E^2\right) + \mu(x_{k0L} - x_{k1L}E)\right)\right]K + \\ &\pi_H\left[\left(\lambda_1^{\,k} h + \lambda_2^{\,k}(pg - a_H E^2) + (x_{k0H} + x_{k1H}E)\right)\right]K, k = MS, NGO, x_{MS} = v, x_{NGO} = \upsilon \\ &s.t. \quad \frac{\partial X}{\partial t} \equiv F(X) - \left(\pi_L g(X, E_L) - \pi_H g(X, E_H)\right)KN = 0 \\ &and \quad (16), (17)\end{aligned}$$

This optimisation problem has the type dependent solutions given in (A23)-(A26):

(A23) $$E_L^{\,MS} = \frac{\lambda_1^{MS} h'_{EL} + g'_{EL}\left(p(\mu + \lambda_2^{\,MS}) - \gamma N\right) - \mu\upsilon_1}{2a_L\left(\lambda_2^{\,MS} + \mu\right)}$$

(A24) $$E_H^{MS} = \frac{\pi_H \left[\lambda_1^{MS} h'_{EH} + pg'_{EH}\left(p(\mu + \lambda_2^{MS}) - \gamma N\right) - \mu \upsilon_1\right]}{2\pi_H a_H \left[\lambda_2^{MS} + \mu(Q+1)\right]}$$

(A25) $$E_L^{NGO} = \frac{\lambda_1^{NGO} h'_{EL} + g'_{EL}\,(p(\eta + \lambda_2^{NGO}) - \varphi N) - \eta v_1}{2a_L\left(\lambda_2^{NGO} + \eta\right)}$$

(A26) $$E_H^{NGO} = \frac{\pi_H \left[\lambda_1^{NGO} h'_{EH} + g'_{EH}\,(p(\eta + \lambda_2^{NGO}) - \varphi N) - \eta v_1\right]}{2\pi_H a_H \left[\lambda_2^{MS} + \eta(Q+1)\right]}$$

The optimal effort for the fishers is given by (A27)

(A27) $$E_j^{F} = \frac{pg'_{Ej} - v_1 - \upsilon_1}{2a_j},\ j = L, H$$

Equalising the type dependent effort level between the fishers and each of the principals and solving for the principal's regulation, yields the type dependent reaction functions in (19)-(22).

The explicit expressions for the optimal regulations of the high cost fishers are

(A28)

$$v_{1H}^{**} = \frac{-h'_E\left(\lambda_1^{MS}\lambda_2^{NGO} - \lambda_1^{NGO}\lambda_2^{MS} + \eta\lambda_1^{MS} - QD_1\right) + g'_E\left(pQD_2 + N(\gamma\lambda_2^{NGO} - \varphi\lambda_2^{MS}) + R_1)\right)}{\eta\lambda_2^{MS} + \mu\lambda_2^{NGO} + \mu\eta(1+2Q)}$$

(A29)

$$\upsilon_{1H}^{**} = \frac{-h'_{EH}\left(\lambda_1^{NGO}\lambda_2^{MS} - \lambda_1^{MS}\lambda_2^{NGO} + \mu\lambda_1^{NGO} + QD_1\right) + g'_{EH}\left(-pQD_2 + N(\varphi\lambda_2^{MS} - \gamma\lambda_2^{NGO}) + R_2)\right)}{\eta\lambda_2^{MS} + \mu\lambda_2^{NGO} + \mu\eta(1+2Q)}$$

were $D_i = \mu\lambda_i^{NGO} - \eta\lambda_i^{MS}, i = 1,2$, $R_1 = QN(\eta\gamma - \mu\varphi) + \eta(N\gamma + p\mu Q)$, $R_2 = QN(\mu\varphi - \eta\gamma) + \mu(\varphi N + p\eta Q)$

(A30) $$\frac{v_{1H}^{*} + \upsilon_{1H}^{*}}{v_{1L}^{*} + \upsilon_{1L}^{*}} = \frac{\dfrac{-h'_{EH}\,(\eta\lambda_1^{Ms} + \mu\lambda_1^{NGO}) + g'_{EH}\,(N(\eta\gamma + \mu\varphi) + 2p\mu Q)}{\eta\lambda_2^{MS} + \mu\lambda_2^{NGO} + \eta\mu + 2\eta\mu Q}}{\dfrac{-(\mu\lambda_1^{NGO} + \eta\lambda_1^{MS})h'_{EL} + g'_{EL}\,N\left(\eta\gamma + \mu\varphi\right)}{\eta\lambda_2^{MS} + \mu\lambda_2^{NGO} + \eta\mu}}$$

(A31) $$\frac{r_{1H}^{\ *}}{r_{1L}^{\ *}} = \frac{\dfrac{-\lambda_1^{MS} h'_E + g'_{EH}\,(\gamma N + p\mu Q)}{\mu(Q+1) + \lambda_2^{MS}}}{\dfrac{-\lambda_1^{MS} h'_{EL} + g'_{EL}\,(\gamma N)}{\mu + \lambda_2^{MS}}}$$

Let $S = -\left(\mu\lambda_1^{NGO} + \lambda_1^{MS}\right)h'_{EL} + (\eta\gamma + \mu\varphi)Ng'_{EL}$, $K = -\lambda_1^{MS} h'_{EL} + \gamma Ng'_{EL}$, $R = \eta\lambda_2^{MS} + \mu\lambda_2^{NGO} + \eta\mu, L = \lambda_2^{MS} + \mu$

The low-cost fisher regulations are first best regulations, and in section 2 we showed that this regulation was higher when there were two regulators compared to one. From this property and the assumptions made about the parameters when discussing (12) it follows:

$$\frac{S}{R} > \frac{K}{L} \Rightarrow SL > KR, R > L, S > K$$

$$\frac{v_{1H}^{\ *} + \upsilon_{1H}^{\ *}}{v_{1L}^{\ *} + \upsilon_{1L}^{\ *}} < \frac{r_{1H}^{\ *}}{r_{1L}^{\ *}} \text{ implies } \frac{SR + 2\mu Qpg'_E R}{SR + 2\mu QS} < \frac{KL + \mu Qpg'_E L}{KL + QK}$$

which in turn reduces to

$$SKQ(R - 2\mu L) < \mu Qpg'_E\,(RS - 2RKL + 2\mu QSL - 2QKR)$$

For low λ_2^{NGO} the left hand parenthesis is negative and thus the left hand side is negative. For low λ_2^{MS} and high λ_1^{NGO} the right hand side parenthesis is positive and thus the right hand side is positive. Hence (25) is fulfilled.

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