Lobbyism and Climate Change in Fisheries: A Political Support Function Approach

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Abstract

This paper seeks to investigate the following issues: What is the resulting outcome, when regulation is determined by interest groups that compete for influence over the regulatory process? Given this, can we predict how climate change related changes in the underlying biological factors will affect the behaviour of the interest groups and the resulting regulatory outcome.

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1. Introduction

This paper takes a political economy perspective with respect to the exploitation of renewable recourses (with specific focus on the exploitation of fish resources), in order to develop a framework to determine the effects of lobby activities on the level of exploitation of the renewable resource. Buchanan and Tullock (1975) state that in order to present a positive theory of externality control, it is necessary to resort to public-choice theory, since "the interests of those who are subjected to the control instrument must be taken into account as well as the interests of those affected by the external diseconomy".[1] The general framework allows us to investigate how changes in the underlying biological factors affect the outcome of the regulation. This can be important in connection with e.g. the expected changes caused by climate change.

Lobbyism in fisheries has been analysed in several papers. Johnson and Libecap (1982) and Karpoff (1987) consider lobbyism in terms of choice of regulatory instruments.[2] Karpoff (1989) on the effort by incumbent fishermen to reduce the number of active fishermen to increase rent. Berck and Costello (2001) consider a situation where the fishermen use the regulatory process to deter entry.[3] Al these papers concern situations where only the fishermen are active in lobbying. Compared to these papers, we propose a more general framework by including different stakeholders, both representing the industry, the consumers and the environmental interests.[4] Different interest groups have different (and sometimes) opposing objectives (like the industry and the environmental groups on environmental regulation). In such a situation the relative strength of the lobby groups is likely to determine the outcome. Competing interest groups will

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[1] Buchanan and Tullock (1975), page 139.

[2] Karpoff (1989) concludes that traditional regulation such as capital constraints and season closures are preferred because they redistribute the catch towards the politically dominant fishing groups.

[3] The fishermen capture the regulator, which in term cannot legally deter entry. Since the fishermen must weight the current profit against incentives to enter, this unambiguously results in overfishing.

[4] Which has also been done by Horan et al. (1999), although in another setting.

lobby to achieve rent, and an understanding of lobbyism is crucial to an understanding of fishery policy. Therefore, we incorporate lobby group interests into the political arena of fisheries regulating.

We propose a political support function, originally developed by Pelzman (1975) and Hillman (1982). The political support function model has been applied for explaining behaviour of declining industries (Hillman, 1982, Choi, 2000), choice of instrument in trade policies (Casing and Hillman, 1985) and determining choice of instrument in environmental regulation (Brandt and Svendsen, 2003).[5] We let the stakeholders in a fish resource exploitation problem be the regulator, the fishermen, the conservationalists (representing preferences for environmental improvements) and the consumers of the fish. In order to set up a political support function, we need to specify the welfare that the stakeholders derive from different levels of catches. It is assumed that the consumers want as low price as possible (thereby maximizing comsumer surplus), the conservationalists prefer an unchanged ecosystems (compared to as pre-exploitation situation), while the fishermen want as much profit (or intertemporal producer surplus). The behaviour of the policy makers is to pick that policy alternative that maximise the overall support from the interest groups. We analyse this in a standard Gordon-Schaefer type of model focussing exclusively on steady state equilibria.[6]

First we built-up a benchmark model, where the entry of new fishermen is prohibited, capital is perfectly malleable, and without considering climate change related changes in the underlying bio-economic model. Here all three interest groups prefer an increase in the steady state stock size, compared to open ac-

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[5] From a welfare perspective, a political support function will not in general represent a social welfare function, in that the weights attached to the different agents does reflect their ability to influence policy makers, which is argued to depend on a groups size, its homogeneity, and its visibility (see Hillman, 2003, for a discussion).

[6] Both fishermen and consumer behaviour follow standard microeconomic theory of maximizing respectively profit and utility (given that the consumers have quasi linear utility functions). For a discussion of the conservationalists, see e.g. Pearce and Turner (1990).

cess. Even so we might end up in a situation where one group (the consumers) infers a welfare loss.

Since the political support function model is appropriate to consider how lobby incentives (and hence, policy) change when exogenous factors change the origin, and since the origin matter for the relative gains and losses for the relevant stakeholders. The basic model is extended in two dimensions. First the effect of a reduction in the growth rate of the stock due to climate change effects is considered, and secondly, the possibility of entry is considered.

The anthropogenic emissions of green house gasses is estimated to increase global mean temperature by the end of the twenty first century by 1.5-5.8 degrees depending on factors like growth in global use of fossil fuels, which again depends on mitigation efforts, growth in energy demands and technological developments (IPCC, 2001). This also affects the fish stock in a given area. The size of a population of fish in a given area depends on numerous factors, like salinity of the water, the average water temperature, the amount of food, and the number of predators, each of these factors also will affect each others in rather complicated ways. For a given vectors of all, these exogenous factors, a natural equilibrium will emerge. Most of these factors are affected by changes in climatologically conditions, like changes in average water temperature, or changes in prevailing wind pattern or average wind level.[7] In our model, we will introduce climate change as affecting the intrinsic growth rate of the resource that the resulting stock increases. The determination of the effect of reducing the intrinsic growth rate is not straightforward. For a given intrinsic growth rate, a political equilibrium is determined by balancing the marginal support and the marginal resistance at that particular stock size. When the growth rate is re-

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[7] As an example of the effects of a change in water temperature, results demonstrate interannual changes in the abundance of 1-year-old cod in the North Sea appear to be inversely related to sea surface temperature (SST) in the previous spring (Planque and Frédou, 1999; O'Brian et al, 2000). More generally, in specific geographically areas, climate changes might both have negative as well as positive effects on the growth rate or the availability of renewable resources, like fish stocks or forests. Especially in higher altitudes like North Atlantic (fish) or Canada (forests) might experience a positive effect on harvesting from climate change.

duced, it affects all interest groups' marginal evaluation of the change in the stock. For some (not unrealistic) parameter values, we derive the conclusion that reducing the intrinsic growth rate actually increases the equilibrium stock as the resistance from industry group to increase stock is sufficiently reduced.

Given the assumption underlying the basic model, we arrive at the prediction that lobbyism will move the stock considerably above the open access level. This prediction is, however, in contrast to observations in many fisheries. Berck and Costello (2001) note that many populations of marine fisheries in the US are well below the optimal yield, often leading to complete fishery closure. The same picture emerges e.g. for the cod in the North Sea (ICES, 2003). Wilen (2000) surveys and evaluates the contribution of fisheries economics to management and policy since the seminal work of Gordon. He finds that relevant efficiency-generating contributions have been made but that property rights are still not sufficiently strict in many fisheries worldwide to reverse the effects of open access. Some have focussed specifically on the inability of fishery regulators to efficiently offset the rent dissipating consequences of open access.[8]

Hence, as long as entry is not prevented, high rent will imply entry, and hence, overfishing is a way of strategically deterring entry as long as entry is positively, but not perfect correlated with industry profit. This is, obviously, only possible when the stakeholder (the fishermen) have some discretion over the choice of (or amount of) regulation. Mason and Polasky (1994) and Berck and Costello (2001) derive the same basic incentive structure: If fishing efficiency is too high, current profits will spur entry, and profits currently in power will

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[8] The reason for this has been explained either in terms of the "tragedy of the commons" type of arguments, where the individual fisherman does not take into account the "stock externality" his catch level imposes upon the other exploiters of the resource. Moreover, due to e.g. infeasibility (in terms of technology or in terms of costs) of monitoring, or inability to deter entry, the regulator cannot eliminate overfishing. One could imagine that when a country that unilaterally tries to regulate its fishery to achieve a higher equilibrium stock, it might not prevent other countries' fishermen to enter its fishery, or it cannot guarantee that future negotiations (like in the EU) over allocating of catch quotas will yields access to other countries. Moreover, in e.g. high see fisheries, running down the stock to prevent entry could be a profitable strategy, since no physical (or legal) barriers to entry can be established.

fall.[9] On the other hand, if fishing efficiency is too low, current profit will be negative. Berck and Costello (2001) find that the captured regulator allows excessive harvest resulting in equilibrium with completely dissipated rents and inefficiently excessive effort. We find that when low profitability deters entry, a high stock is equally likely to deter entry than a low stock. (Especially when the TAC can be controlled, since free riding incentives are higher at a high stock than at a low stock.) However, since the origin is the open access situation, the focal is a low level, but in the absence of adjustment costs the high level of stock might yield higher overall support.

It is, however, again shown that reduction in the intrinsic growth rate can have both positive and negative effects on the size of the stock in a political equilibrium. Moreover, the possibility exists that a marginal reduction in the growth rate implies a non-marginal change in the political equilibrium stock where the stock jumps from a level below the maximum sustainable yield stock level to a level close to the natural equilibrium.

The paper is organized as follows: In section 2, the basic model is presented, and in the next section the influential function approach is developed and the basic political support model. The influence of climate related changes on the equilibrium stock is the theme of section 4 while the next section is devoted to a discussion of limitations of the basic model, while section 6 introduces entry. The analysis in this section is concluded by an analysis of the effect of climate related changes on the equilibrium stock under entry, while section 7 concludes the paper.

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[9] Berck and Costello (2001) consider management of fisheries those regulators are captured by industry and where directly regulation of entry is a policy tool unavailable to the manager, while Mason and Polasky (1994) analyse a common property resource model with a single incumbent (could be an interest group). As the cost of harvesting is a function of the stock size, by lowering the stock, the incumbent can make entry unprofitable (given the existence of sufficiently high costs of entry), in a subgame perfect equilibrium.

2. The basic model

We apply the traditionel bioeconomic (Gordon-Schäfer type of) model. The growth rate of the stock of the resource, *S*, is called *G*(*S*). Let $S^{MSY} = \arg_S \max G(S)$. Assume that $G_S > 0$ for $S < S^{MSY}$ and $G_S < 0$ for $S > S^{MSY}$, while $G_{SS} < 0$.[10] Finally, let $S^{Max} = \max \arg_S \{G(S) = 0\}$ which is also called the carrying capacity or the natural equilibrium which sets the bounds on the population's growth possibilities.[11] We solely focus on steady state situations. Let the total catch level be *H*, hence in a steady state, $\dot{S} = G(S) - H = 0 \Rightarrow H = G(S)$. In the steady state, the catch level is fully determined by the size of the stock, and this implies for our political support function (PSF) model that the support can be modelled to depending only on the size of the stock. We define steady state harvest function $H = H(S)$.

For now, we assume that the fishermen organisation only cares about total profitability for the fishing industry. (There are no free riding problems internally and no problems of allocating the total profit among its members). Moreover, we assume that capital is perfectly malleable, in which case there are no adjustment cost for the fishermen, when the steady state level of S is changed.[12] Industry profit is given by $\pi = P(H) \cdot H - C(H,S)$. The costs from fishing activity, $C(H,S)$ depends on both *H* and *S*, such that higher catch implies higher costs $C_H > 0$, while higher stock implies smaller costs $C_S < 0$.[13] Inserting $H = H(S)$ yields $\pi = P(H(S)) \cdot H(S) - C(H(S),S)$. Differentiating with respect to S:

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[10] Throughout the paper, subscripts denote derivatives.

[11] By defining $S^{Min} = \min_S \arg\{G(S) = 0\}$ we have that the relevant range for *S* can be stated as $S \in \Sigma = (S^{Min}, S^{Max})$.

[12] (For a discussion of this with respect to fisheries, se Gréboval and Munro (1997).

[13] Note that in steady state, the costs only depend on S: $C = C(G(S), S)$. Differentiating with respect to S yields: $dC / dS = (\partial C / \partial G) \cdot (dG / dS) + \partial C / \partial S$, which is negative for $S > S^{MSY}$, but the size is ambiguous for $S < S^{MSY}$.

$\pi_S = P_H \cdot H_S \cdot H + P \cdot H_S - C_H \cdot H_S - C_S \Leftrightarrow \pi_S = [P_H \cdot H + P - C_H] \cdot H_S - C_S$. At S^{MSY}, $H_S = 0$, and hence, $\pi_S = -C_S > 0$. This implies that $S^M > S^{MSY}$, where $S^M = \arg\max_S \{\pi_S\}$. This is the standard result in fishery economic that the resource rent is maximized at a higher stock than the one representing the maximum sustainable yield.

Second, consumer groups are interested in maximizing consumer surplus, which, given the downward sloping demand curve implies that the consumer organization prefers as low a consumer price as possible. To derive the dependency of *CS* on *S*, take the inverse demand function given by $P = P(H)$. In steady state, $H = G(S)$, in which case $P = P(G(S))$. Let total consumer surplus be $CS = CS(P(G(S))$. Differentiating with respect to *S* yields $CS_S = CS_P \cdot P_H \cdot G_S$. We have that $CS_P < 0, P_H < 0$, while $G_S > 0$ for $S < S^{MSY}$ and $G_S < 0$ for $S > S^{MSY}$, implying that $CS_S > 0$ for $S < S^{MSY}$ and $CS_S < 0$ for $S > S^{MSY}$. Hence, the preferred stock level of the consumers is S^{MSY}.

We call the third group the conservationalists who attach a value on the conservation of the species.[14] It is assumed that the conservationalists dislike human interaction with the ecosystem, so their preferred state is one with a ecosystem without human interference. However, the exact specification of the preferences for this group is rather ad hoc, it is, however, assumed that the conservationalists prefer a larger stock than a smaller. We model the preferences of the conservationalists by a concave increasing utility function $u = u(S)$, reaching its maximum at $S^{\max}$ with $u(0) = 0$.[15]

The revenue from harvesting is $V = P(H) \cdot H$. Let the open access equilibrium stock size be S^{OA}, defined as $S^{OA} = \min_S \arg\{\pi = 0\}$ implying a zero rent situation. The standard argument is that, in such a fishery, each fisherman will have an incentive to act as if the yield on the resource, the "natural" capital is zero (e.g.

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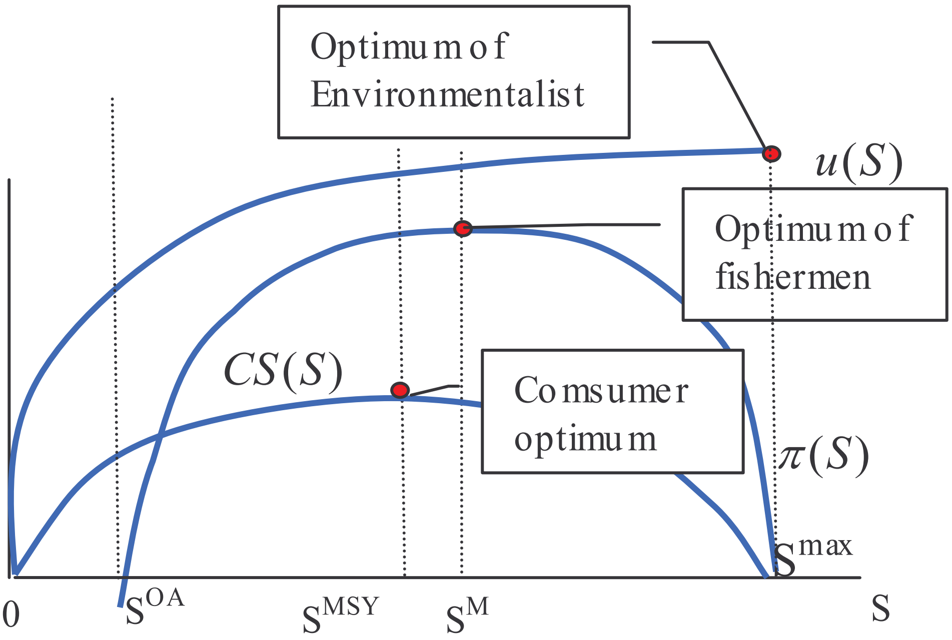
[14] The name is borrowed from Pearce and Turner (1990).

[15] Implying decreasing marginal utility of conservation.

Clark, 1992). Standard economic theory of the fishery, in turn, predicts that the resource will be mined down to the point that the economic rent from the resource is fully dissipated, implying that profits are zero. In figure 1 we present a possible picture of how the three interest group's welfare changes by an by an increase in the stock size compared to S^{OA}.

Figure 1: The Welfare for the interest groups



One important feature of the open access situation is revealed in figure 1. In our specification of interest group's preferences, all three interest groups prefer a higher stock level compared to S^{OA}. Under open access, $S < S^{MSY}$ and a increase in the stock increases catches (up to S^{MSY}). In this case, comsumers are better of, (lowering of prices), incumbent fishermen are better of (higher profits) as long as there is no possibility of entry, and conservationalists better of (higher stock of fish).[16]

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[16] In the next section we discuss reasons why even though fisheries have been regulated for decades, still many fisheries struggling with excess capacity, overexploitation of the resource and low profitability.

3. The Influential function approach

The following model assumes a political economy framework, where the politicians only care about how to achieve maximum support for their policy and our theoretical starting point is within this framework and the political support function model originally developed by Hillman (1982). Here, the political support from a stakeholder group is determined by the gain this group gets from deviating from the origin (the situation before regulation takes place). This model is very appropriate for our analysis, since the origin simply is determined as the non-regulated situation. The origin is a situation with open access, where neither well-defined property rights, nor the exploitation of the resource subject to any controls is present.

3.1. The basic political support model

In a political support function approach, it is asserted that the political support depends upon the welfare levels of winners and losers (in our case determined by the change in the stock from the unregulated level to the level that maximises overall support from the interest group). The political support function is defined as: $\widetilde{M} = M(\pi(\Delta S), CS(\Delta S), u(\Delta S))$. Here $\Delta S = (S - S^{OA})$ is the increase in the steady state stock compared to the open access (S^{OA}) stock level. A political equilibrium is achieved when the support is maximized:

$$\widetilde{M}_S = 0 : M_\pi \cdot \pi_S + M_{CS} \cdot CS_S + M_u \cdot u_S = 0$$

For simplicity, it will be easier to assume a linear support function of the type $\widetilde{M} = \alpha \cdot \pi(\Delta S) + \beta \cdot CS(\Delta S) + \gamma \cdot u(\Delta S)$, where $\alpha + \beta + \gamma = 1$ and $\alpha \geq 0, \beta \geq 0 \text{ and } \gamma \geq 0$. The advantage of this linearization is that the constants α, β and γ can be interpreted as the weight that the policy makers put on the three different groups. The relative strength of the three different interest groups in question has not been specified in the general model but depends on numerous factors, including the policy maker's preferences and also on how effective an interest group can lobby. According to Olson (1965), groups of small size, with homogenous members with comparable goals will be more effective than groups representing a large number of heterogeneous individuals with only partly comparable goals.[17] The first order condition now reads:

$$\alpha \cdot \pi_S + \beta \cdot CS_S + \gamma \cdot u_S = 0$$

For each combination of weights, there exists a unique solution to this problem, called $S^* := \arg_S \{\widetilde{M}_S = 0\}$. We can now present the first result, also shown in figure 1:

Proposition 1: Any $S \in [S^{MSY}, \mathrm{S}^{\mathrm{Max}}]$ could be a political equilibrium outcome for some values of α, β and γ.

The reason is as follows: When almost all weight is attathed to β then the consumer interest are dominating and S^* approaches S^{MSY} ($\beta \to 1 \Rightarrow S^* \to S^{MSY}$). When $\gamma \to 1$, the maximum sustainable yield (the natural equilibrium) will result ($S^* \to S^{Max}$). Finally, when only industry interests matter ($\alpha \to 1$), then the profit maximizing equilibrium stock will emerge ($S^* \to S^M$). The result of evaluating the absolute gain the three groups receives from lobbying activety is:

Proposition 2: Given $\alpha + \beta + \gamma = 1$ and $\alpha \geq 0, \beta \geq 0$ and $\gamma \geq 0$, $\pi(\Delta S^*) \geq 0$, $u(\Delta S^*) > 0$ while $CS(\Delta S^*) \gtreqless 0$.

In proposition 2, $\Delta S^* = S^* - S^{OA}$, is the necessary change in the stock size in order to achieve the maximum political support. For a given politically determined equilibrium stock size, S^*, different interest groups might be winners or losers.

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[17] Olson (1965) states that the commonality of the goals of an interest group's members makes the achievement of these goals a public good for the group, which thus gives rise to the same incentives to free-ride as exist in all public good-prisoners' dilemma situations. Two important conclusions can be drawn from this observation: (1) It is easier to form an interest group when the number of potential members is small than when the number is large; and (2) Thus, the establishment of an organisation that effectively represents large numbers of individuals requires that "separate and 'selective' incentives" be used to curb free-riding behaviour.

They will all be losers compared to their preferred situation, if the weight attached to their welfare change is smaller than one, but the real benefits from lobbyism should be compared to the pre-regulation (pre-lobby) situation.

Figure 2a: A political equilibrium with equal weights

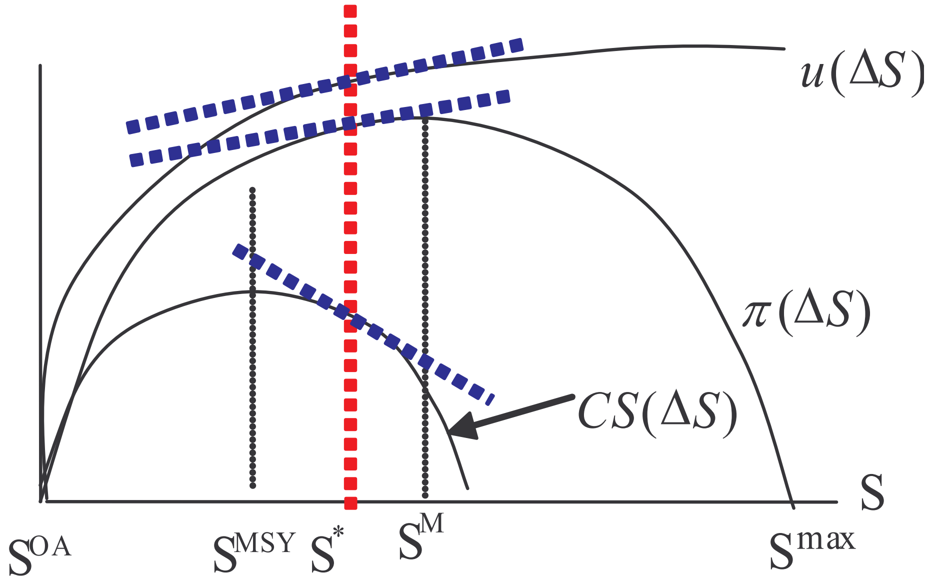
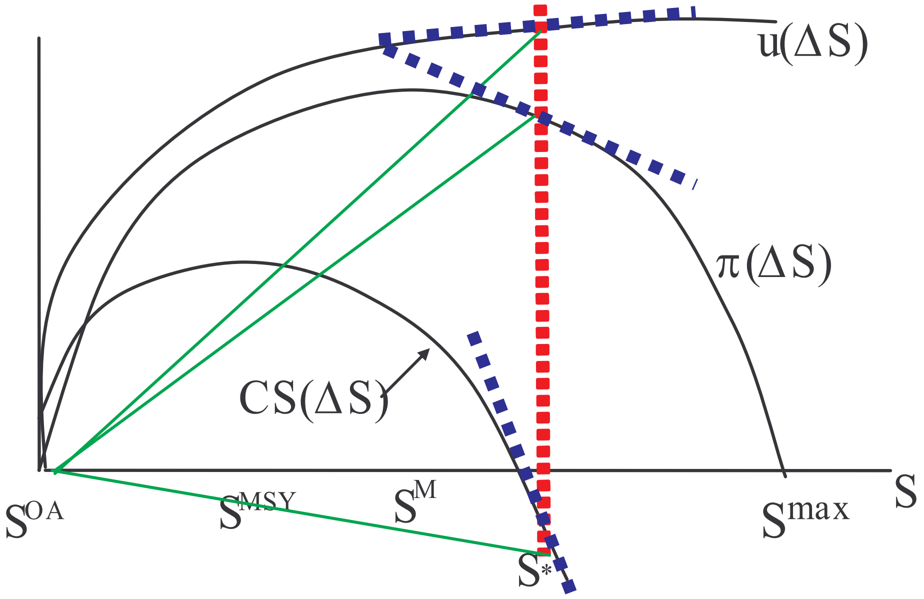


Figure 2b: Benefits from change in stock from S^{OA} to S^* with unequal weights



It follows that benefits for the three groups can be written as $\pi(\Delta S^*) = \pi(S^*) - \pi(S^{OA}) = \pi(S^*)$, $CS(\Delta S^*) = CS(S^*) - CS(S^{OA})$ and $u(\Delta S^*) = u(S^*) - u(S^{OA})$. Note that $\pi(\Delta S^*) \geq 0$, since the origin implies zero profit and the fishermen always can leave the industry. $u(\Delta S^*) > 0$, given proposition 1, while the sign of $CS(\Delta S^*)$ is ambiguous. Figure 2a presents a situation, where all three groups gain from regulation, while Figure 2b shows a situation, where the consumers loss from regulation. The reason is that high weight on the conservationalists' welfare increases the stock so much that we end up in a situation with less catches than under open access.

4. The influence of climate related changes on the equilibrium stock

There might be many reasons to suspect that climate related changes will affect future fish resources. E.g., the cod in the North Atlantic is suspected to move to the north, yielding more harvesting possibilities in the North Atlantic while less for e.g. North Sea. Although climate changes might in this way have both positive and negative effect on the biomass (or the growth rate of the biomass) and the type of fish in a given geographical area, in this paper we focus on situations with a reduction of the biomass or reduction of the reproduction in the biomass.

4.1. Changes in the intrinsic growth rate

The growth rate of the stock, $G(S)$ is dependent on many factors like the present stock, average water temperature, salinity, average wind, presence of and composition of other species. To make the analysis tractable assume the growth rate is given by: $G(S) = r \cdot f(S, S^{\max})$, where $r > 0$ is the intrinsic growth rate such that $r = r$(average water temperature (T), salinity, average wind, presence of other species, ….). In what follows we assume that r is a monotonically decreasing function in *T*, that is $r_T < 0$ for all *T*.[18] We now want to analyse how changes in *r* affects S^* and the welfare to the three interest groups. First of all, a change in *r* might change S^{OA}.

Lemma 1: $S_r^{OA} > 0$.

The reason for this is that at S^{OA}, $MR(H) < MC(H)$. Hence, as long as *S* remains constant, an increase in *r* implies lower profit at S^{OA}. In order to evaluate how a reduction in *r* influences S^*, we have to evaluate how the support changes for the three interest groups at S^* for a change in *r*.

Lemma 2: $\pi_{Sr} \gtreqless 0$, $u_{Sr} > 0$ and $CS_{Sr} < 0$ for $S > S^{MSY}$ while $CS_{Sr} > 0$ for $S < S^{MSY}$.

For the fishermen there are two countervailing effects: Profits increase as $MR(H) > MC(H)$ around S^*. However, as $S^* > S^{MSY}$ then $G_{Sr} < 0$, saying that increased *r* reduces the slope of *G*(*S*). In general, the sign is ambiguous. In lemma 3 and table 1, we state conditions for π_{Sr}, to be positive in a specific functional form for the model. For the conservationalists, the effect of increased *r* unequivocal, as $S_r^{OA} > 0$ and u_s is concave in S. Finally, for the consumers, the effect comes from the sign of G_{Sr} For $S < S^{MSY}$, an increase in *r* increases G_S implying an increase in CS_S. The opposite is true for $S > S^{MSY}$.

We are now able to determine S_r^*. As $u_{Sr} > 0$, when r is reduced, the conservationalists will give less support to S^*. Moreover, as $CS_{Sr} < 0$, and $S^* > S^{MSY}$, the consumers give now more resistance to S^*. On the other hand, for $\pi_{Sr} > 0$ ($\pi_{Sr} < 0$), the fishermen give less (more) resistance to S^*. We can summarize these findings as:

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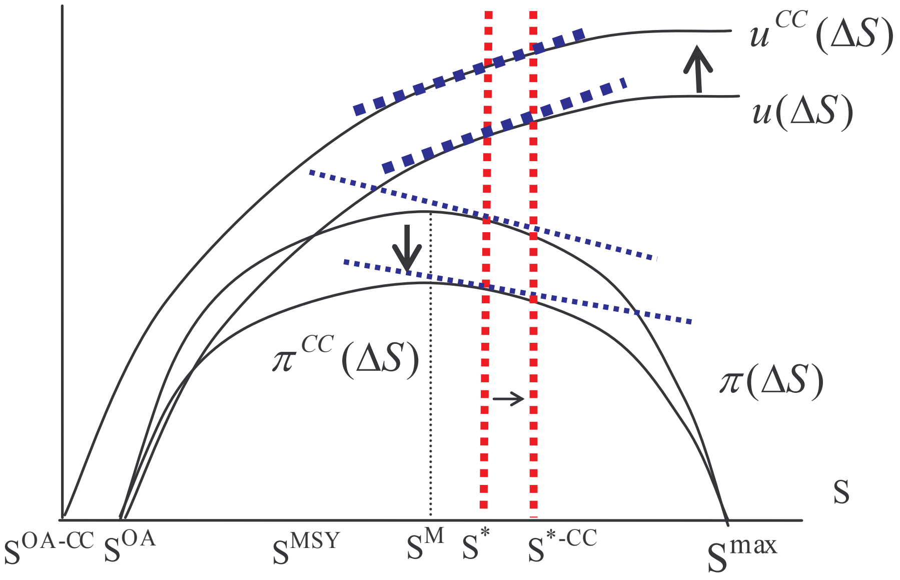
[18] A reduction in *r* could be that the number of fish remains constant, but their size is reduced. Changes in temperature can stress the fish, such that they contain less protein, and reduce their weight (Fish net conference, Esbjerg, 2004).

Proposition 3: When α is large compared to $\beta+\gamma$ and $\pi_{Sr} > 0$, then a reduction in r implies a higher equilibirum stock, $S_r^* < 0$, otherwise $S_r^* > 0$.[19]

The mechanims behind proposition 3 can be seen in figure 3, where we only consider the conservatioalists and the fishermen (hence, $\beta = 0$).

Figure 3: Change in stock when "r" is reduced



At the original S^*, $\alpha \cdot \pi_S + \gamma \cdot u_S = 0$, where π_S and u_S are indicated by the slopes at S^*. Now r is changed, and the new slopes at S^* are that u_S is smaller and π_S numerically smaller, implying less support from the conservationalists, but less resistance from the fishermen. Hence, when the weight attached to the fishermen is sufficiently high, then the stock will increase. On the other hand, if $\pi_{Sr} < 0$ then at the same time the support is reduced, and the resistance is increased, implying that the stock is reduced. The inclusion of the consumers re-

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[19] It must be noted that when other parameters of the bio-economic model are affected, then we get more clear-cut results. If the carrying capacity of the resource is reduced as a result of climate change, then it is easy to show that the equilibrium stock size will be reduced.

inforced the effect that imply a decrease the stock is reduced when r is reduced, and reduces the likelihood that the stock is increased, as $CS_{Sr} < 0$.

Table 1[20]

Calculation of S*:

Profits: $\pi = P \cdot H - C = P \cdot G(S) - C(S)$.

Consumer surplus: $CS = \frac{1}{2}[a - P(G(S))] \cdot G(S)$.

Environmentalists utility: $u = k \cdot \ln(S+1), k > 0$.

Political support function: $\widetilde{M} = \alpha \cdot \pi(\Delta S) + \beta \cdot CS(\Delta S) + \gamma \cdot u(\Delta S)$.

This implies, by inserting the above expressions:

$$\frac{\partial \widetilde{M}}{\partial S} = \alpha \cdot \left[[a - 2b \cdot G(S)] \cdot \frac{\partial G}{\partial S} - \frac{\partial C}{\partial S} \right] + \beta \cdot \left[b \cdot G(S) \cdot \frac{\partial G}{\partial S} \right] + \gamma \left[\frac{k}{S+1} \right]$$

Numerical example: $a = 600$, $b = 0{,}5$, $S^{max} = 100$,
$w = 10000$, $k = 10000$, $\alpha = \beta = \gamma = 1/3$

Values	$R = 10$	r = 5	$r = 2$
S^{OA}	19.13	17.75	17.07
S^*	62.01	62.16	65.20
$\pi(S^*) - \pi(S^{OA})$	75608	44728	19237
$CS(S^*) - CS(S^{OA})$	39438	10629	1572
$u(S^*) - u(S^{OA})$	11410	12148	12985

When we apply specific functional forms for our model, we can be more precise than in proposition 3. Given the growth function $G(S) = r \cdot S \cdot (1 - S / S^{Max})$, the harvest function $h_s = q \cdot E \cdot S$, where q is the catchability coefficient, E is individual effort and hs is individaul catch levels. The demand function $P = a - b \cdot H$ and the cost function $C = w \cdot E$, we have that, $S = S^{Max} \cdot (1 - qE / r)$, $S^{OA} = a / Pq$, $S^M = a / (2Pq)$ and $S^{Msy} = S^{Max} / 2$. Given this model, we can show that

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[20] The utility function that represents the preferences of the conservationalists is only unique up to an affine transformation. However, to the knowledge of the author, different utility functions do not change the qualitative results of this paper.

Lemma 3: $\pi_{Sr} > 0$ for $S \geq S^{Msy}$ when Proof, see appendix

$4b \cdot r \cdot S \cdot (1 - S \cdot (S^{Max})^{-1}) > a$.

In the tabel a simulation result is shown where the requirements of lemma 2 is satisfied.

How does the gain for the groups change at new S^*?[21] When S^* is increased as an result of a reduction in *r*, the utility to the conservationalists increase, as the origin (e.g., S^{OA}) is reduced. This comes arround even though the support from the conservationlists for an increse in the stock is weakened. For the other two groups, both incur a welfare loss when *r* is reduced. This comes around even though there resistance for an increase in the stock is diminished. We summarize these findings in result 1:

Result 1: Given the model presented in table 1, but for any α sufficintly large, and when $\pi_{Sr} > 0$, a reduction in *r* implies: i) lower S^{OA}, ii) higher S^*, iii) higher utilty to the conservationalists compared to origin, and iv) lower profit to fishers and lower consumer suplus to consumers compared to origin.

5. The limitations of the analysis so far

The results in the previous sections indicate that in case of no entry and without adjustment costs, lobby groups exert influence over the political process of determining regulation, and an increase in the stock size can be expected (from S^{OA} to S^*). When the industry group has relatively high weight, implyiong that the optimal level of stock size for the fishermen is close to the one that maximizes long run industry profit, i.e. $S^* \approx S^M$. Moving from S^{OA} to S^* implies that fishing effort must be restricted in a number of periods in order for the stock to

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[21] Hillman (2003) presents an example where more tight environmental policy, although implying more stringent emissions control, the rent to the industry that has to implement the emissions control, never the less increases.

recover. This can be thought of as an investment, where the investment costs are the foregone profit opportunities in the short run, while the pay off of the investment are future increased profit possibilities. It could be expected that the fishermen would be willing to make such an investment, as long as the fishermen are not too impatient, if the temporarily restriction in fishing effort can be implemented effectively and if the incumbent fishermen are granted the main share of the future profitability.[22]

According to Gréboval and Munro (1996), in the Gordon-Schaefer model the model used in this paper), overcapitalization/excess capacity does not exist, in other than a trivial sense. The problem has been assumed away.[23] The reason for this conclusion is that there is no cost of adjusting capital to changes in the steady state stock size. However, moving from S^{OA} to S^* implies that harvests must initially be lowered significantly below $H(S^{OA})$ and only gradually increased to $H(S^*)$. In the Gordon-Schaefer model this is implicitly assumed to happen instantaneously implying that capital is perfectly malleable.[24]

In what follows we assume that it is possible to implement an effect plan for the recovery of fish stock. (Implying that the fishery organisation has full control over its members). However, it has no discretion over potential entrants, being new fishermen, or over future allocation in e.g. EU. If entry cannot be prevented through legislation, either because it is not possible physically, or that fisheries are subject to international agreement (or through EU) then room ex-

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[22] It is obviously that when some or all fishermen are not very patient, then the investment is not worth undertaking. Given that the investment is profitable for all fishermen, the shares of the TAC allocated to each fisherman must be considered. Moreover, since the stock is increasing in the process (of re-cover) the incentives for the individual fishermen to free ride are increasing as well. (At S^*, a fisherman can unilaterally increase his fishing effort and earn extra profits). These are the same incentives that lead to the overfishing problem in the first place. But the fishermen are now assumed to be organized to such an extent that free riding internal among the fishermen can be totally controlled.

[23] Excess harvesting capacity: "harvesting capacity in excess of the minimum amount required to harvest the desired quantity of fish at the least cost" (OECD, 1996).

[24] Perfectly "malleable" capital is capital that one can dispose of without fear of capital loss at a moment's notice. The other extreme, perfectly non-malleable capital, is capital that, once acquired, cannot be disposed of, other than by destroying it. (Gréboval and Munro, 1996).

ists for efforts to strategically deter entry through either choice of regulation or through choice of behaviour.

6. The possibility of entry

Mason and Polasky (1994) and Berck and Costello (2001) derive the same basic incentive structure: If fishing efficiency is too high, current profits will spur entry, and profits currently in power will fall. On the other hand, if fishing efficiency is too low, current profit will be negative. Berck and Costello (2001) find that the captured regulator allows excessive harvest resulting in equilibrium with completely dissipated rents and inefficiently excessive effort.

If the only way to deter entry is by increase fishing effort, and assuming the presence of some fixed entry costs, the strategic considerations can be summarized in the basic fisheries entry deterrence game shown in figure 4, which basically matches the model of Mason and Polasky (1994).

The incumbents prefer no entry to entry, while the deterrence strategy is more costly than acquiescence if no entry occurs. F measures entry costs, and the higher F, the less effort is needed from the incumbents to deter entry. Finally, entry is only worthwhile for the entrant if the incumbent acquiescence. In this stylized game, the numbers are chosen such that for $F<2$, then acquiescence and entry is the unique Nash equilibrium.[25] When $F>2$, (but smaller that 4), there exists two Nash equilibria. One implying that the entrant enters no matter what the incumbent chooses, and the incumbent chooses acquiescence. This strategy, however, contains a non credible thread, since upon deterrence, enter is not optimal for the entry. It follows that deterrence and not enter is the unique subgame perfect Nash equilibrium. Hence, when the costs of entry are sufficiently

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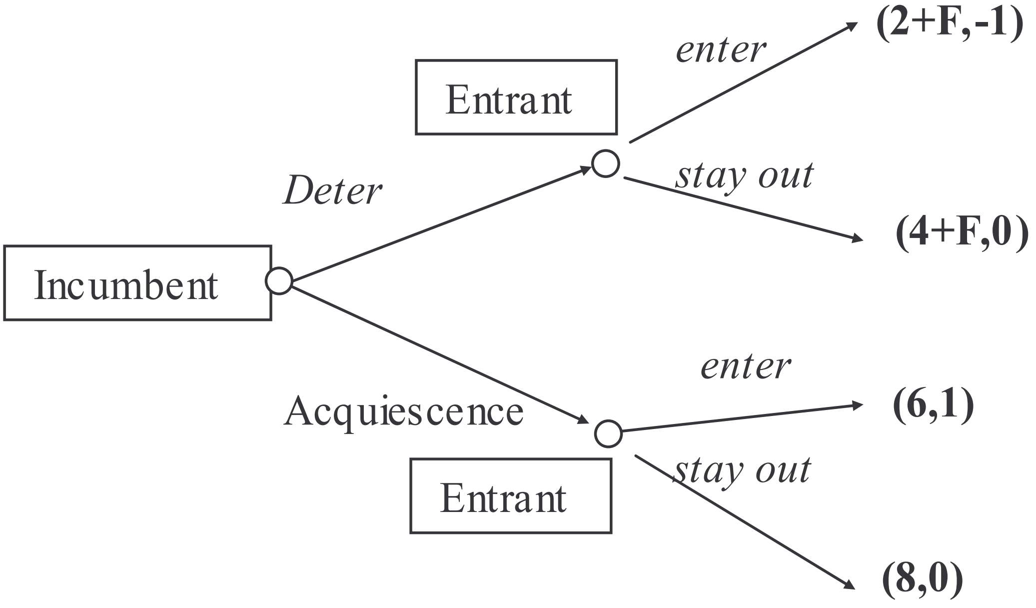
[25] The game has two Nash equilibria, but the one (Acquiescence and enter) is based on an incredible thread, that enter will occur no matter the strategy chosen by the incumbent, however, once deter occurs, entry is no longer optimal. Hence, this strategy is not subgame perfect. The subgame perfect strategy profile is highlighted with bold in the figure.

high, entry deterrence is a profitable strategy, as shown in Mason and Polasky (1994).

Figure 4: The extensive normal form of the fisheries entry deterrence game[26]



In the basic political support function model, we found that the stock level was determined not only by the interests of the fishermen, but also by two groups. While the objective functions of the two other groups remain unchanged, the profit function for the fishermen is now more complicated, taking into account the possibility of entry. In the illustrative example presented above, it was simple assumed that only when profitability exceeded a threshold level, entry would occur, driving profits (but not economic rent) down to zero. In Mason and Polasky (1994), the threshold level and the reason why incumbent have a cost advantage remains unexplained. To sidestep these considerations, we make the following more general set-up. In order to consider the effect of entry, assume that once S^* is determined (by competition among consumer, incumbent fishermen and conservationalists), the catch level is determined according to $TAC(S^*)$. Hereafter, entry is free. Assume that entry is positively related to the

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[26] Payoff (incumbent, Entrant). F should be less than 4, else π^I(Deterrence, Enter) $\geq$ π^I(Acquiescence, Entry).

total industry profit, $\pi^{TOT}(\Delta S)$ (which is fully determined through S), and define an entry-function: $\rho(\pi^{TOT}(\Delta S))$ with $\rho_{\pi^{TOT}} > 0$ and $\rho_{\pi^{TOT}\pi^{TOT}} = 0$.[27] Profit to the incumbent is consequently given as: $\pi^{I}(\Delta S) = [1-\rho(\pi^{TOT}(\Delta S))]\cdot \pi^{TOT}$.

We are interesed in how the presence of entry influences the incumbents profit function. Given the entry function, $\pi_S^I = -\rho_{\Pi^{TOT}} \cdot \pi_S^{TOT} \cdot \pi^{TOT} + (1-\rho)\cdot \pi_S^{TOT} = ((1-\rho) - \rho_{\Pi^{TOT}} \cdot \pi^{TOT})\cdot \pi_S^{TOT}$. The interpretation of this expression is that for $S < S^M$, by increasing *S*, the incumbent looses profits due to entry ($(-\rho_{\Pi^{TOT}} \cdot \pi_S^{TOT})\cdot \pi^{TOT}$), but get increased profit on the part of the increased total profit, it still receives, measured by $(1-\rho)\cdot \pi_S^{TOT}$.

Now look at the sign of $((1-\rho) - \rho_{\Pi^{TOT}} \cdot \pi^{TOT})$. Since $\rho_{\Pi^{TOT}}$ is constant, the second expression $(\rho_{\Pi^{TOT}} \cdot \pi_S^{TOT})$ is concave increasing in *S* up to S^M, but zero at S^{OA}. $(1-\rho)$ is positive, but decreasing in *S* up to S^M, which implies that $((1-\rho) - \rho_{\Pi^{TOT}} \cdot \pi^{TOT})$ is positive at S^{OA}, but decreasing, and possibly turning negative at some *S*. We can now identify three different cases.

Case 1: Entry is not sufficient such that $\pi_{SS}^I < 0$ [$(((1-\rho) - \rho_{\pi^{TOT}} \cdot \pi^{TOT}) > 0$] for all *S*. In this case, the results are qualitatively the same as without entry. However, other possibilities exist due to the result stated in lemma 4.

Lemma 4: For $((1-\rho) - \rho_{\pi^{TOT}} \cdot \pi^{TOT}) < 0$ for some $S \in Z$, then where exists two stock levels where $\pi_S^I = 0$ and $\pi_{SS}^I < 0$.

The lemma follows directly from evaluating π_S^I. Look at the situation where $\rho_{\pi^{TOT}} \cdot \pi^{TOT} > 1-\rho$. When the increase in profits when *S* is increased above S^{OA} attracts sufficiently entrants ($\rho_{\pi^{TOT}}$ sufficiently high), then the profits to the

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[27] ρ can be interpreted as the level of potential competitive (pressure) from the outside. $\rho = 1$ means maximal pressure (fully competitive situation), while $\rho = 0$ implies a monopolic situation.

incumbent falls. Since π^{TOT} is concave in *S*, increasing *S* in the range where $\pi_S^{TOT} > 0$, the negative effect of entry on the incumbents profit dominates the increase in π^{TOT} and π_S^I turns negative. At S^M, $\pi_S^{TOT} = 0$, and $\pi_S^I = 0$. When *S* is increased above S^M, the opposite situation emerges. First, entry is reduced sufficienlty such that profits to the incumbents increase, but since the reduction of entry declines for increased S, while the reduction in total profit increases and π_S^I turns negative again See figure 5 and figure 6. When lemma 3 is satisfied, two additional cases can be identified:

Case 2: Entry is sufficient such that lemma 1 applies. However, still $M_{SS} < 0$ for all *S*.

Case 3: Entry is sufficint such that lemma 1 applies with two stock levels, where $M_S(S) = 0$.

Whether or not case 2 or case 3 applies depends on the weights attached to the welfares of the three interest groups. In what follows we will concentrate on case 3.

Figure 5: $((1-\rho) - \rho_{\pi^{TOT}} \cdot \pi^{TOT})$ ***< 0***

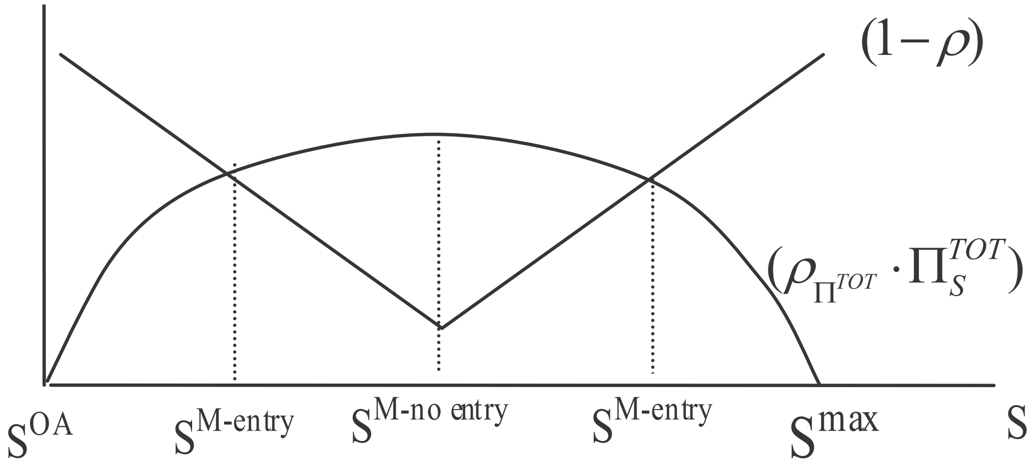
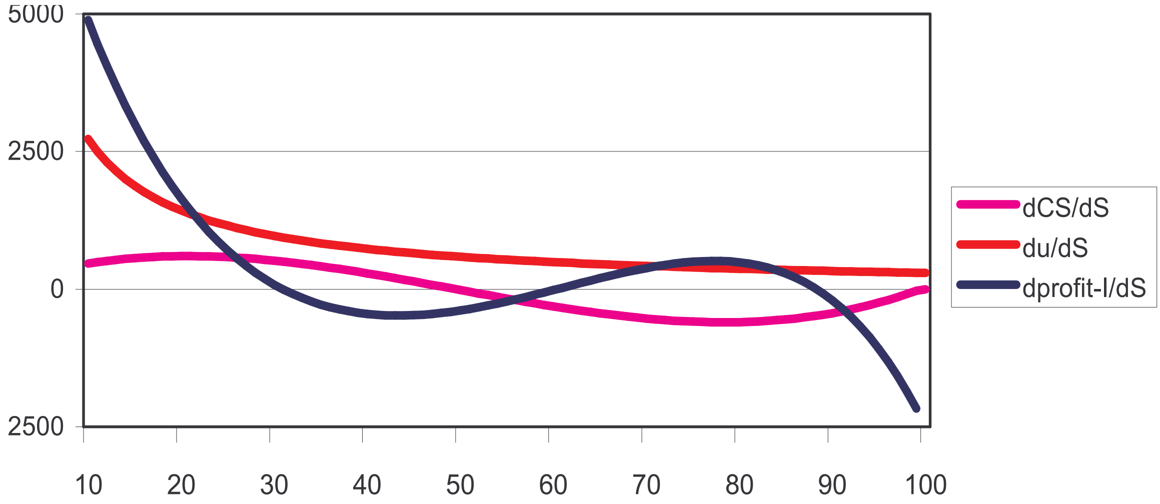


Figure 6[28]



Define S^1 as the smallest S where $\pi_S^{TOT} = 0$, while S^2 is the highest S where $\pi_S^{TOT} = 0$. We can illustrate the possibilities by using the simulation model from section 3. Let the entry function be $\rho(S) = \dfrac{\pi^{TOT}(S)}{\delta \cdot \pi^{MAX}}$, where π^{MAX} is the highest obtainable industry profit and $\delta \geq 1$ measures the severity of entry.

Table 2

				Situation 1: α =0.5, β=0.1, γ=0.4		**Situation 2:** α=0.8, β=0.02, γ=0.18	
	S^{OA}	ΔS^1	ΔS^2	ΔS^{1*}	ΔS^{2*}	ΔS^{1*}	ΔS^{2*}
S	19,13	33,2	89,4	38,1	86,6	34,1	89,4
CS(S)	29925	31523	-18784	35573	-13145	33147	-18778
$\pi^I(S)$	0	20817	20817	19586	20087	20770	20817
$u(S)$	30024	5293	15023	6632	14707	5550	15023
CS_S		1496	-1016	1247,8	-2840	1623	-1022
π_S^I		0	0	-454	479	-105	0,7
u_S		293	111	256	114	285	111
$\rho(\pi^{TOT}(S))$		0.5	0.5	0,62	0,59	0,52	0,50
$\pi^{TOT}(\Delta S)$	0	41634	41634	51757	49430	43620	45047
M(S)	6003	24677	23539	25402	23611	18277	18982

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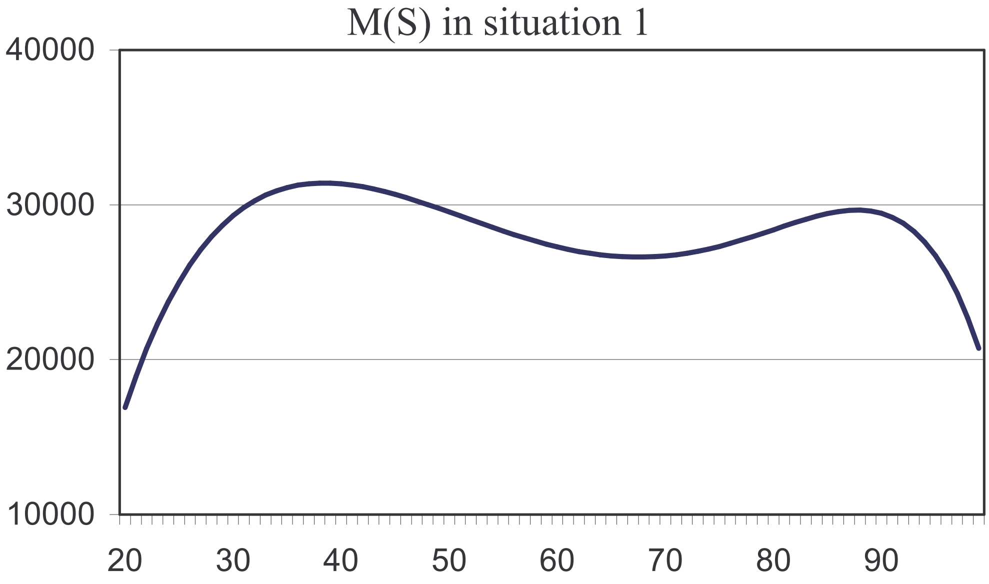
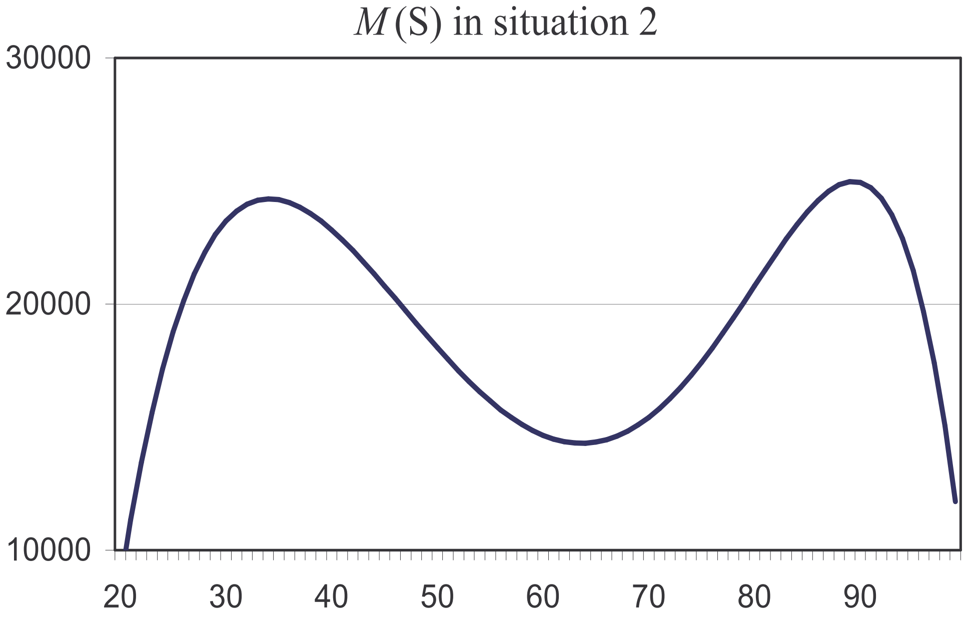
[28] u=300000*ln(S+1), a=600, b=0.5, r = 5, e = 1, w=10000 and S-max = 100 and $\rho(S) = \pi^{TOT}(S)/(\delta \cdot \pi^{MAX})$


M(S) in situation 1


M(S) in situation 2

Note that $\rho_{\pi^{TOT}} = \frac{1}{\delta \cdot \pi^{MAX}} > 0$ such that entry is at its higest level when $\pi = \pi^{MAX}$. When $\delta = 1$, then all profits to the incumbent is gone when industry profit reaches its highest level. The table below shows two cases, one where the equilibirum stock with the level stock level yields the higest support and the other case, where the higest stock level yields the highest support.

Since two stock level locally maximise overall support, and this differ significantly (as seen in the table above) and consider which of the two stocks yields the highest support. From the simulation above we can conclude the following:

Propositon 4: There exists combinations of weights such that $S^* < S^M$ and combination of weights such that $S^* > S^M$.

Propositon 5: When $\alpha \to 1, \beta = 0$ $(\gamma \neq 0)$ then $M(S^{2*}) > M(S^{1*})$.

In several papers it is concluded that when entry is present, then reducing the stock is a credible entry deterrence strategy. Our results only partly confirm these findings. First, a high stock could equally get entry deterrence. (So only if the authorities cannot control TAC their results are valid). So this result is not robust to changes in the way entry is modelled. Moreover, Berck and Costello analyse situations where the fishermen capture the regulator. Again, the main force to get a high stock is the presence of the conservationalists; hence their result is not robust to other types of lobby modelling. Finally, compared to other papers, entry might not be the main reason why stocks cannot recover. It could instead be adjustment costs. Since the costs are only borne by fishermen, and such costs are probably marginally increased when a larger stock is decided upon, low stock reflects this.

7. The effect of climate change and entry on the equilibrium stock

When considering how changes in *r* affect the equilibirum stock size under entry, it is neccesary to derive how π_S^I is affected by changing *r*. Differentiating π_S^I with respect to *r*, holding *S* constant, yields: $\pi_{Sr}^I = \pi_{Sr}^{TOT} \cdot [(1-\rho) - \rho_{\pi^{TOT}} \cdot \pi^{TOT}] - \rho_{\pi^{TOT}} \cdot \pi_S^{TOT} \cdot \pi_r^{TOT} - \rho_r \cdot \pi_S^{TOT}$.

As $\rho_r \cdot \pi_S^{TOT} = \rho_{\pi^{TOT}} \cdot \pi_r^{TOT} \cdot \pi_S^{TOT}$ we got that $\pi_{Sr}^I = \pi_{Sr}^{TOT} \cdot [(1-\rho) - \rho_{\pi^{TOT}} \cdot \pi^{TOT}) - 2 \cdot \rho_{\pi^{TOT}} \cdot \pi_S^{TOT} \cdot \pi_r^{TOT}$.

When *r* is increased, the total profit increases as well for $\pi_S^I > 0$ implying that $(1-\rho) \cdot \pi_{Sr}^{TOT} > 0$ (as seen in section 4) for unchanged entry. However, $-\pi_{Sr}^{TOT} \cdot \rho_{\pi^{TOT}} \cdot \pi^{TOT} < 0$ indicates that when *r* increases, the slope of π_S^{TOT} increases as well leading to higher level of entry, resulting in a reduction of π_S^I. As we assumed in proposition 1 that $((1-\rho) - \rho_{\pi^{TOT}} \cdot \pi^{TOT}) < 0$, the total effect is negative on π_S^I. Look next at $-2 \cdot \rho_\pi \cdot \pi_S^{TOT} \cdot \pi_r^{TOT}$ which is negative, and measures the second effect through which entry reduces π_S^I. When *r* increases, total profit increases and entry increase, leaving less of the total profit to the incumbent. In total, we have that $\pi_{Sr}^I < 0$. To summarize, the total effect of *r* on π_S^I is determined by two opposing effects. When *r* is reduced, then for $\pi_S^I > 0$, increasing *S* has a smaller positive effect on industry profits, on the other hand, the smaller industry profit also attracts less entry, and therefore leaving a higher share of the reduced profit to the incumbents.

Lemma 5: When $((1-\rho) - \rho_{\pi^{TOT}} \cdot \pi^{TOT}) < 0$, and $\pi_S^I > 0$ ($\pi_S^I < 0$), then $\pi_{Sr}^I < 0$ ($\pi_{Sr}^I > 0$).

Finally, $\Delta S_r^M > 0$. To show this, use that $\pi(S^*) = P(H(S^*)) \cdot H(S^*) - C(H(S^*), S^*)$, where at $S^M : V_S = C_S$. Now when $\Delta r > 0$ we have that at $H(S^*) : V_S > C_S$. (When higher catch does not result in reduction of stock, we are not in a profit maximizing situation). An additional increase in the catch will result, such that $\Delta S_r^M > 0$. The implication on S^1 and S^2 is that both increase with *r*, as long as $\rho_{\pi^{TOT}}$ is constant in S.

Lemma 6: $\Delta S_r^M > 0$.

A graph of this is shown below. In total, we now have 4 effects that influence S_r^*. The first effect is that Δr changes π_S^I as described in lemma 5. The second effect is that $S_r^{OA} > 0$ (lemma 1), the third is $CS_{Sr} < 0$ and finally, $S_r^M > 0$ implying that $S_r^1 > 0$ and $S_r^2 > 0$. Remember from section 6 that in case 3, we have two very different stock levels that yield $\widetilde{M}_S = 0$. Let us focus attention on this case and evaluate how a change in *r* might influence the results. Take S^{1*} and $\Delta r < 0$. At S^{1*}, since $\pi_{Sr}^I < 0$, there is less resistance from fishermen (since $S^{*1} > S^1$). Since $S_r^{OA} > 0$, then for $\Delta r < 0$, the support from conservationalists at S^{1*} is reduced. Finally, Since $CS_{Sr} < 0$ and $\Delta r < 0$, the support from consumers is increased. The conclusion is that when S^{1*} still maximizing *M*, then $S_r^{1*} > 0$, unless β is very high.

Figure 7a: The theoretical picture

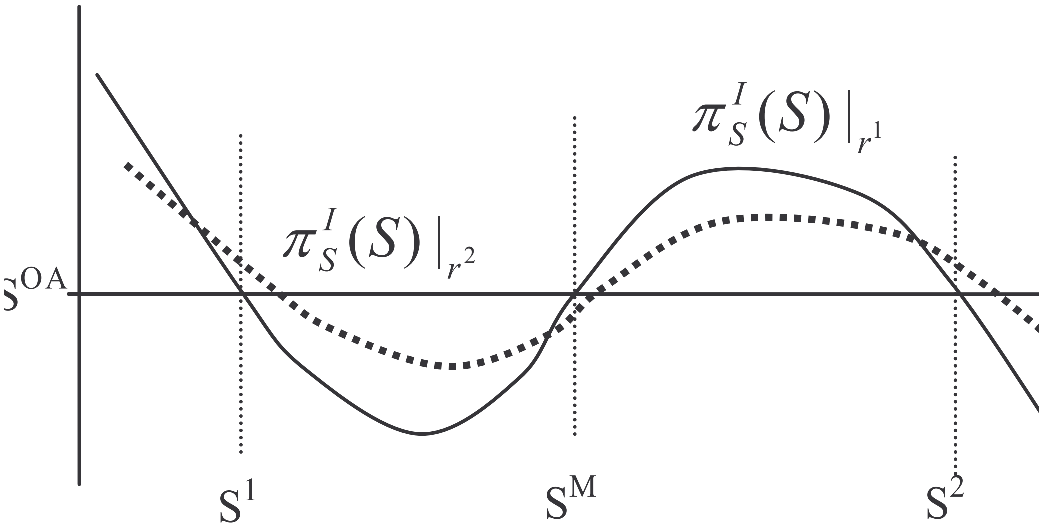
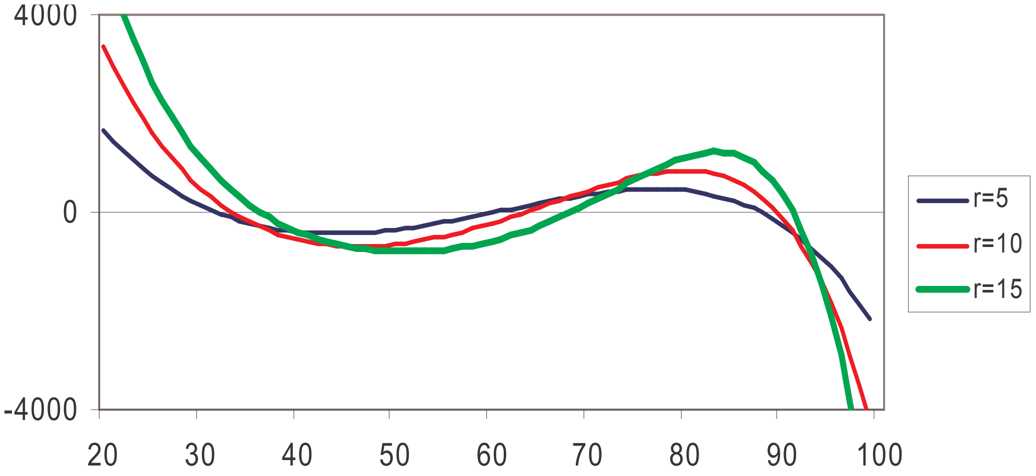


Figure 7b: $M_S(S)$***, model as in table 2***



Evaluate S^{2*} for $\Delta r < 0$. Here we cannot come up with precise predictions. At S^{2*}, we can both have that $S^{2*} > S^2$ or $S^{2*} \leq S^2$. Hence, given proposition 3, the effect from $\Delta r < 0$ on support from fishermen is ambiguous. For the consumers, since $CS_{Sr} < 0$, then since $\Delta r < 0$, the support from consumers is increased and since $S_r^{OA} > 0$, then for $\Delta r < 0$, the support from conservationalists at is reduced.

r	S^{1*}	S^{2*}	$\widetilde{M}(S^{1*})$	$\widetilde{M}(S^{2*})$	$u(S^{1*})$	$u(S^{2*})$	$CS(S^{1*})$	$CS(S^{2*})$	$\pi(S^{1*})$	$\pi(S^{2*})$
10	34.1	89.4	24282	**24987**	35574	45047	63075	11150	20772	20819
15	35.9	91.2	**30282**	29306	36428	45248	153489	17814	25941	26004

Table 3

Finally, as welfare might change differently at S^{1*} and S^{2*}, $\Delta r < 0$ can imply a discontinuous jump. Consumer welfare is generally highest at S^{1*}. Therefore, we can expect that when $\Delta r < 0$, M is reduced more at S^{2*} than at S^{1*}. Profits less affected, and utility neither.

A consistent feature from the simulations is that when r is reduced sufficiently, and initially, $M(S^{2*}) > M(S^{1*})$, then there is a switch to $M(S^{2*}) < M(S^{1*})$. See table

3 for an example. In the model, the reason is that under entry, the profit to the incumbent is not that sensitive to changes in r as are the wealth of the consumers, even in the case where little weight is attached to the consumer welfare. These findings are summerized below:

Propositon 6: $S_r^{1*} > 0$, unless β is very high, while the sign of S_r^{2*} is ambiguous.
$\Delta r < 0$ can imply that $M(S^{2*}) - M(S^{1*})$ changes sign from positive to negative.

8. Conclusion

This paper investigated two main issues. First will climate change induced negative effects on the biological factors necessarily have an negative effect on the equilibrium stock when considering a lobby-support model? And secondly, considering the possibility of entry, how will the effect of strategic entry deterrence influence the stock level when combining this with our political economy model, and how will climate change affect these findings?

Under realistic circumstances (i.e., where the fishermen have high influence over the policy choice), we can very well end up in a situation, where a reduction in the intrinsic growth rate increases the equilibrium stock. This result comes around when the fishermen's profit is reduced and so the reduction in profit when the stock is increased is smaller implying less resistance from fishermen to increase the stock. (Hence, it is the marginal and not the absolute change in welfare for the interest groups that is relevant).

It is, however, fair to say that when other effects are considered, like that climate change reduces the carrying capacity of the resource, then the equilibrium stock will be reduced.

Regarding the second point, the first observation is that when low profitability deters entry, a high stock is equally likely to deter entry than a low stock. (Especially when the TAC can be controlled, since free riding incentives are higher at a high stock than at a low stock.) However, since the origin is the open access situation, the focal is a low level, but in the absence of adjustment costs the high level of stock might yield higher overall support.

Moreover, the strategy of entry deterrence (or the presence of entry) is very costly and more costly when other interest groups are present. Look at S^{*1}. Since $S^{*1} > S^{1}$, the presence of consumers and conservationalists increase the stock above S^{1} implying to much entry from the point of view of the fishermen. We have not discussed the choice of instruments to implement the political equilibrium solution. When assuming that the interest groups have full discretion over the policy goals, it seems natural to consider that the interest groups have discretion over which instrument to choose.

We have not given any arguments to why entry is not fully complete: a sort of “take the money and run” strategy known from the ideas of contestable markets. However, we have implicitly looked at the fishermen as a homogenous group. As shown in several papers (Karpoff, 1987), letting fishermen being heterogeneous can have a significant impact on the results. But at the same time, can justify the assumption of incomplete entry.

The results in this paper show that when interest groups influence the political outcome, then it is necessary to imbed these groups incentives’ in a political economy model to get a more detailed picture and a better understanding of the mechanisms at work, and in the end, to be more able to optimally adapt to climate related changes in the relevant ecosystem.

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10. Appendix

Proof of lemma 1

Evaluate $\pi = P(H) \cdot H - C(H,S)$ at S^{OA}: $\pi_r = P_H \cdot H_r \cdot H + P \cdot H_r - C_H \cdot H_r - C_S \cdot S_r =$ $(P_H \cdot H + P - C_H) \cdot H_r$ as $S_r = 0$. This implies that $Sign\, \pi_r = sign\{MR(H) - MC(H)\}$. To find this, evaluate π_S at S^{OA}. From section 2, we have that at $S^{OA} : \pi_S = [MR(H) - MC(H)] \cdot H_S = C_S$. As $H_S > 0 \text{ for } S < S^{MSY}$ and $C_S < 0 \text{ for all } S$, it follows that $MR(H) - MC(H) < 0$ at S^{OA}. We note that $\pi_r < 0$ around S^{OA}. The reason for this result is that when *r* is increased, the higher catches results in a reduction in profits as long as the stock is unchanged and $MR(H) - MC(H) < 0$. Now fix a S^{OA}. Increasing *r* implies that at S^{OA}, profit is now negative. As the profit function is increasing in *S* for $S < S^{MSY}$, the result follows.

Proof of lemma 2

First look at the profit for the fishermen. We have that $\pi_S = P_H \cdot G_S \cdot G + P \cdot G_S - C_H \cdot G_S - C_S$. It follows that $\pi_{Sr} = P_H \cdot G_{Sr} \cdot G + P_H \cdot G_S \cdot G_r + P \cdot G_{Sr} - C_H \cdot G_{Sr} - C_{Sr}$. rewriting and noting that $C_{Sr} = 0$ yields $\pi_{Sr} = [MR(H) - MC(H)] \cdot G_{Sr} + P_H \cdot G_S \cdot G_r$. It is obvious that $MR(H) - MC(H) > 0$ around S^*, while $G_{Sr} < 0$ for $S > S^{MSY}$. This implies that while the first expression on the LHS is negative, the second part is positive, all in all, the sign of π_{Sr} is ambigious. As $S_r^{OA} > 0$, it follows immediately that $u_{Sr} > 0$ as u is strictly concave in *S*. (This result hinges on the assumption of the curvature of *u*, if linear or even convex in *S*, the opposite conclusion emerges). Hence, for a reduction in *r*, the support from the conservationalists at $S = S^*$ is smaller. Finally, consider the consumers. In section 2 we found that $CS_S = CS_P \cdot P_H \cdot G_S$. Differentiating with respect to r yields: $CS_{Sr} = CS_P \cdot P_H \cdot G_{Sr} + CS_{\mathrm{Pr}} \cdot P_H \cdot G_S$. For $S > S^{MSY}$, all derivates are negative, implying that $CS_{Sr} < 0$. When *r* is increased, then for $CS_{Sr} > 0$, the reduction in CS is larger for $S > S^{MSY}$.

Proof of lemma 3

Let $A = 1 - S \cdot (S^{Max})^{-1}$ and $B = 1 - 2S \cdot (S^{Max})^{-1}$. Moreover, we have that $G_S = r \cdot B$, $G_r = S \cdot A$, $G_{Sr} = B$, $C = w \cdot r \cdot e^{-1} \cdot A$, $C_{Sr} = -w \cdot (e \cdot S^{Max})^{-1}$. It follows that $\pi_{Sr} = (a - 2b \cdot r \cdot S \cdot A) \cdot B - 2b \cdot S \cdot A \cdot r \cdot B + w \cdot (e \cdot S^{Max})^{-1}$ $(a - 4b \cdot r \cdot S \cdot A) \cdot B + w \cdot (e \cdot S^{Max})^{-1}$. Since $A < 0$ for $S < S^{Max}$, and $B < 0$ for $S < S^{Max}/2$ and $B > 0$ for $S > S^{Max}/2$, implies that $\pi_{Sr} > 0$ for $S \geq S^{Msy}$ when $4b \cdot r \cdot S \cdot A > a$.

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