The Effect of Climate Change on the Probability of Conservation: Fisheries Regulation as a Policy Contest

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Abstract

This paper considers the policy outcome of a contest between two opposing interest groups: the incumbent fishermen and a group of conservationalists. The objective of the fishermen is to maximize profit, and they are (partly) concerned over future profitability as well, while the conservationalists have the aim of reducing current fishing effort in order to protect fish resources. The probability of a result of overfishing is dependent on the relative benefits the two groups receive if their preferred policy wins the contest. This model enables us to predict how climate change induces changes in the underlying bionomic model and affects the probability of conservation. The main result is that the likelihood of conservation increases when climate change implies a larger percentage increase in the conservation value to the conservationalists than the percentage increase in the commercial value for the fishermen.

Keywords: Political contest, probability of conservation, fisheries management, climate change.

JEL classification: Q22, D72, L5.

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1. Introduction

This paper considers the regulation of a renewable resource. The pre-regulation situation is characterized by overfishing. In the regulation stage, regulation is determined as a political economy game between the incumbent fishermen on the one hand and the conservationalists on the other hand. It is assumed that the objective of the fishermen is to maximize profit, and they are (partly) concerned over future profitability as well, while the conservationalists aim to reduce the current fishing effort in order to protect fish resources.

In the political contest model applied in the current paper, only two possible outcomes can result, either a situation with some level of overfishing, or a total temporary closure of the fishery. In this type of model, the probability that a specific outcome is chosen depends on the relative gains the two groups receive from winning the contest. Although only two policy options are considered, there are reasons why this could be acceptable. These probabilities could be interpreted as the expected (*ex ante*) probabilities that a given outcome will result. Another interpretation is that the regulator has a number of regulatory instruments available, which broadly result in the two outcomes of continued overfishing or closure of the fishing effort. It is well established in the literature that the individual fishermen are either in a common pool or an open access situation, both giving the individual fishermen incentives to maximize their short run profit, which implies that they will not consider the future profitability of the industry. It should be noted that many papers find that regulation is not effective in achieving sustainable catch levels. According to Pitcher (2001), the ecosystem is constantly eroded, partly due to the fact that fishing effort acts as a selection mechanism favoring short lived, fast growing fish (Pauly, 1995) and partly due to a series of political and economic imperatives that drives the system in a downward spiral. (Ludwig et al., 1993).[1] The main lesson from

1 There are four elements to Ludwig's ratchet: The promise of profit in the fishery attracts political and economic power that, in the face of uncertainty about resource abundance, drives the decision-making process. Science is unable to measure the abundance of fish accurately enough or to predict future states of fish stocks well enough to demonstrate the negative effects of over-

these observations is that that there is an inherent incentive structure which implies overfishing regardless of regulation, aside from total closure of the fishery.

Political contest models have been applied to analyse contests between competing interest groups (Nitzan, 1994), coordination efforts by interest groups sharing the same objective of influencing the provision of a specific public good (Dijkstra, 1998), and the interaction between an interest group and a two-tier government where the interest group tries to influence the politicians to reject or accept the proposals made by agenda-setting bureaucrats (Epstein and Nitzan, 2002). Political contest models are useful in situations where it is possible to influence a political decision that has two (or more generally a finite and discrete set of) possible outcomes. The specification of the model in the current paper resembles that of Epstein and Nitzan (2002), where two interest groups compete over the provision of a public good which is beneficial to one group and costly to the other group.

The point of departure with respect to the behaviour of the fishermen is an assumption that the fishermen are organized in a (partly) effective lobby group with the objective to maximize the total intertemporal profit for the group as a whole. Why should the fishermen's organizations' preferred policy be a high catch in the first period rather than the level that maximizes intertemporal profit? One obvious reason is that the fishermen's organization does not have sufficient discretion over the individual fishermen. A well established fact in the literature is that the individual fishermen are either in a common pool or open access situation, both of which give the individual fishermen incentives to

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exploitation until it is too late. In the face of scientific uncertainty, investment in the fishery expands to the point that rents are dissipated and the economic viability of individual fishing units becomes marginal. When there is a short-term increase in fish abundance, investment in the fishery expands. When there is a short-term decrease in fish abundance, disinvestment is slow and the industry appeals to the government for assistance. Assistance is typically given by the government, ostensibly as a short-term measure. In reality, the assistance tends to become incorporated into the functional economics of the fishery.

maximize their short run profit, which again implies that they will not consider the future profitability of the industry.[2]

However, even though the fishermen's organization has full discretion over the behaviour of the fishermen in the industry, there are several reasons why it might also be collectively rational for the whole group of fishermen to overfish in the first period. 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.[3]

There might, moreover, also be several reasons for strategic overfishing, such as entry deterrence and subsidy catching.[4] One obvious method of entry deterrence is to propose a regulation that acts as a barrier to entry. This feature has been seen repeatedly in environmental issues (see Brandt and Svendsen, 2004). Johnson and Libecap (1982) report several instances where local fish unions have tried to hinder entry. The incentive for fishermen to deter entry by making the stock smaller through the strategy of overfishing is recognized in several papers. There are, however, countervailing incentives present for the fishermen since they must balance foregone profits in the short run against

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2 Wilen (2000) nicely describes the development of economic theory into fisheries regulation, pointing out that the most promising approach recently has been the introduction of individually transferable quotas (ITQs) [define this acronym. Also, you use ITO first, and then ITQ, make sure you change them to agree]. Although ITQs can solve many of the problems in fisheries with respect to overcapitalization (problems such as insufficient effort per boat and too many fishermen) and therefore tend to increase the profitability of the industry, it will not in itself solve the problem of overfishing resulting from political pressure to set the number of issued quotas too high.

3 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.

4 However, even if the fishermen themselves have the incentive to reduce the fleet size, there might be strategic incentives on the national level to have a large fleet size. Ruseski (1998) reports several situations where fish stocks have been severely depleted due to competition between national fleets. This can be done, either by increasing fleet size directly (licensing policy), or by effort subsidisation. Both policies imply an inflated fleet size and insufficient rent.

discounted future increased profit opportunities given less entry. Brandt (2005) discusses the conditions for entry deterrence to be an optimal strategy. Moreover, the existence of a subsidy structure (or expectations of such a scheme) where the marginal subsidy is negatively related to the size of the stock, will also be an incentive to increase short run catches. The profitability in the fishing industry will suddenly fall dramatically by continuously overfishing such that politicians (regulators) become eager to help the industry by subsidies including de-commissioning schemes.[5]

The second group that has the power to influence the decision of how to manage the fish resource is an environmental group with the aim of conservation of the resource. More specific, their agenda is to increase the stock size of the resource to an "acceptable" level. This could be motivated by safeguarding the stock in case of unforeseen (stochastic) temporary shocks that could force the stock below its minimum level with long lasting adverse consequences.[6] The objective of the conservationalists is to secure the stock of the fish by temporarily closing the fishery.[7] Since the consequence of temporarily closing is a more profitable fishery in the future, the adoption of this policy undermines the incumbent fishermen's ability to deter entry.

When the conservationists win the contest, the adopted policy is one of conserving the resource. The result of the contest depends on the relative gain the two interest groups receive from winning the contest. Since climate change is likely to affect the two interest groups' gain differently, it is possible to

5 A nice introduction to the issue of subsidies in fisheries is provided by Schrank (2003).

6 As an example of the objectives of the conservationalists: The International Council for the Exploration of the Sea (ICES) has been calling for a complete ban on cod fishing in the North Sea, Irish Sea and west of Scotland, in order to prevent cod stocks from going the way of the Canadian cod stocks which collapsed in the early 1990s, See ICES (2005).

7 Brandt and Svendsen (2006) analyze this in a strategic context: if the regulator is uncertain of the true stock, then situations exist where conservationalists prefer overfishing in the short run, since with declining stocks (and eventually declining catches) the biologists might find it easier to convince the regulator to stop the fisheries. This scheme works best in the presence of subsidies.

derive how the probability of conservation changes in different climate change regimes.

The third report of the Intergovernmental Panel on Climate Change (IPCC, 2001) estimates an increase in the global mean temperature of 1.4 - 5.8 degrees from 1990 to 2100, with possible significant regional differences. The temperatures are expected to increase more at high latitudes, affecting the future profitability of fisheries, since climate change is expected to influence the recruitment, size and quality of the fish resource, changes in migration of species, or even changes in transportation of larvae.[8] We will specifically focus on how climate change influences the relative benefit to the two competing interest groups through its effect on biological background variables, and consequently, how the probability of conservation is linked to climate change induced alterations in the model.

The paper is organized as follows: The next section analyses the behaviour of the incumbent fishermen and the conservationalists, while section 3 states the political contest model. Part two of the paper analyses how the probability of conservation is affected by climate change. In section 4 the effect of expected climate changes on the availability of fish in the future is examined and its implication on profits for the fishermen (section 4.1) and utility to the conservationalists (section 4.2) is analysed. 5. The effect of climate change on the probability of conservation is derived in section 5, while section 7 concludes the paper.

2. The behaviour of the fishermen and the conservationalists

In this section a two-period fisheries management model is set up. We assume that second period catch levels are exogenously determined, but where in the

8 See e.g. Buck et al, (2004).

first period the management outcome and catch level are determined by a political contest between the incumbent fishermen and the conservationalists.[9] Let q_1 be the first-period catch level decided upon by the political contest, while $\bar{q}_2$ is the pre-determined second-period catch. $P_t, t=1,2$, are the exogenously determined and constant prices of the fish in periods 1 and 2, respectively. Second-period profits are connected to first period catch levels through the connection between q_1 and S_2, given by

$$S_2 = k^{CC} \cdot g(q_1, S_1)) \tag{1}$$

It is assumed that $g'_{S_1} > 0$ and $g'_{q_1} < 0$, where S_t is the stock at time *t*. $k^{CC} > 0$ is a parameter that measures how climate change affects the growth of the future stock. If climate change is not affecting the stock, then $k^{CC} = 1$, which represents the baseline situation. If $k^{CC} < 1$, then the presence of climate change reduces second period stock for the same size of current stock and current catch levels.[10] This could be due to worse conditions for recruitment of fish if the climate change is severe. Finally, define the cost function as $c_t(q_t, S_t))$, measuring the cost of providing q_t units fish given the present stock is S_t with $c'_{q_t} > 0$ and $c'_{S_t} < 0$.[11] Given that second-period catch is exogenously determined, we can easily determine second-period industry profit as $\pi_2 = P \cdot \bar{q}_2 - c_2(q_2, S_{2,})$ [There is an extra close parenthesis here and a comma after S2 that I cannot delete since they are in the equation, please edit]. Define the highest possible second period profit as $\pi_2^{\max} = \pi_2 |_{q_1=0}$, i.e. second period profits are maximized if no fish are caught in period 1 since second-period catch levels are fixed but costs monotonically decrease with stock size.

9 Other papers also assume a fixed second period stock, e.g.., see Bergland et al. (2001). A comment on this assumption is made in the conclusion.

10 If $k^{CC} > 1$, then the presence of climate change increases second period stock, for the same size of current stock and current catch levels.

11 $c'_{q_t} > 0$ and $c'_{S_t} < 0$ denote the derivatives of the cost function with respect to the catch and the stock, respectively.

A well established fact in the literature is that the individual fishermen have incentive to maximize their short run profit and not to consider the future profitability of the industry. On the other hand, such behaviour is not collectively rational for the group of fishermen as a whole, unless high current catches imply higher profit of rent in the future (see below). Fishermen are, however, often part of an organization that promotes the policies which serve the fishermen's interests, which face the underlying incentives problem between what is best for the group and best for the individual. To capture this incentive problem, we assume that the fishermen's organization has some (but not full) discretion over the individual fishermen, such that the fishermen's organization's objective in the first period is a catch level q_1^F that only partly maximizes intertemporal profit, $q_1^F = \arg\max\{\pi_1 + d \cdot \pi_2\}$ with $0 < d < 1$, where the parameter *d* measures the level of discretion of the fishermen's organization over the member fishermen).[12] We assume for simplicity that *d* is invariant with respect to k^{CC}. Note that in this writing, the problem resembles the maximization of intertemporal profits in the presence of a discount rate. However, if discounting is introduced, this will push catches even closer to the open access catch level.

The parameter *d* measures the level of weight the fishermen's organization assigns to future profitability. If d approaches 0, then we are in a situation where the fishermen act fully myopic. In this case, the resulting outcome in the first period will be independent of how later periods evolve. We denote this level by: $q_1^{MY} = \arg\max\{\pi_1\}$. The other extreme is a situation with a benevolent regulator acting in the long run interest of the incumbent fishermen and with full discretion over the actions of the fishermen, or a sole owner (monopolist) operating in the industry, who would fully take into account how current catches affect future profitability. In this case, the resulting preferred first-period catch level will be given by $q_1^* = \arg\max\{\pi_1 + \pi_2\}$. In total, $q_1^F \in (q_1^*, q_1^{OA})$.

12 Note that the size of *d* is affected by factors such as the probability of entry, the presence of subsidies and the number of incumbent fishermen.

Note that for $d<1$, the catch level is too high compared to a social optimum, denoting the strategy of the fishermen for overfishing.

It is importantly for the analysis in this paper how q_1^F varies with k^{CC}, since this describes how climate change influences the preferred position of the fishermen. In order to derive this relationship, it is necessary to solve the following maximization program given by:

$\max \pi_1 + d \cdot \pi_2 = P \cdot q_1 - c_1(q_1, S_1) + d(P \cdot \overline{q}_2 - c_2(\overline{q}_2, S_2))$ subject to (1).

The first order conditions are $P = c_{q_1}^{'} + d \cdot K^{CC} \cdot c_{S_2}^{'} \cdot g_{q_1}^{'}$. As long as $d>0$, $q_1^{MY} > q_1^*$ such that catches are reduced in the first period compared to the myopic situation. When k^{CC} is reduced, this effect is weakened. This is summarized in lemma 1:

Lemma 1: $\frac{\partial q_1^F}{\partial K^{CC}} < 0$ for $d>0$.

The result is in a sense trivial, since the reason why catches are larger [do you mean smaller?] than under the myopic situation is the expected second period gains from fishing less in the first period. When the expected gains are reduced, the incentive to conserve the resource in the first period is reduced as well.

The conservationalists' utility is derived from the stock size at the end of a period, $u_t(S_t - q_t)$. It is assumed that $(u_t)_{S_t} > 0$ and $(u_t)_{q_t} < 0$.[13] The implication is that lower catches in the first period increase utility for the conservationalists in both periods. The intertemporal utility for the conservationalists reads: $u = u_1(S_1 - q_1) + u_1(S_2 - \overline{q}_2)$. Given (1), it is easy to see that the optimal choice of the conservationalists is $q_1 = 0$.[14]

13 $(u_t)_{S_t}$ denotes the derivative of the utility function with respect to the stock.

14 E.g. ICES (2005) determines lowest safe levels.

In conclusion, the two contestants' preferred strategies are q_1^F for the fishermen and $q_1 = 0$ for the conservationalists. This can be interpreted as an *ex ante* probability to be defined below of a situation with either overfishing or conservation.

3. The political contest model

Consider the following timing of events: currently, the fishery is characterized by overfishing. The fishermen are organized in an interest group that only partially overcomes the "internal" free riding problem (see Olson, 1965). The objective of the organization is to pursue a policy that is in line with the preferences of the fishermen.

However, an environmental group appears with the aim of conserving the resource. More specifically, its agenda is to increase the stock size of the resource to an "acceptable" level.[15] If this policy is applied, it will be very costly for the fishermen in the short run, though they will be better off in the second period. Assume that there are only two policy options, and no possibilities for compromise between them. The two policy options are the incumbent fishermen's preferred action and the conservationalists' optimal conservation policy. The table presents the utilities for each group in the two policy situations:

Table 1. The benefits in the two possible outcomes of the contest

Group	Overfishing policy	Conservation policy
Fishermen	$\pi(q_1^F)$	$\pi(0)$
Conservationalists	$u(q_1^F)$	$u(0)$

15 This could be motivated by safeguarding the stock in case of unforeseen (stochastic) temporary shocks that could force the stock below its minimum level with long lasting adverse consequences. The way this could be accomplished is by a temporary reduction in the total allowable catches (TAC) below the present catch level until the new stock is achieved and then to increase the TAC again, as shown in Munro, 1998.

From the discussion in section 2 it follows that $\pi(q_1^F) > \pi(0)$ and $u(0) > u(q_1^F)$. With a probability p^F the fishermen's preferred policy is selected, while with probability $p^C = 1 - p^F$ the preferred policy of the conservation group is selected. In this type of political contest model, it is generally assumed that the contenders can affect the probabilities by their contribution level. The existence of a contest success function (CSF) is also assumed that specifies the probability of approval of the proposed policy corresponding to the rent-seeking effort of the interest groups (See Epstein and Nitzan, 2002). Let x^F and x^C be the contribution of the fishermen's group and the conservationalists, respectively. A commonly used CSF is the constant returns to scale non-discriminating rule: $p^F = x^F/(x^F + x^C)$ and $p^C = x^C/(x^F + x^C)$. Let $\Delta\pi = \pi(q_1^F) - \pi(0)$ and [in the previous equation, you have $q^F{}_1$ instead of $q_1{}^F$, edit if desired] $\Delta u = u(0) - u(q_1^F)$ be the groups' benefits from winning the contest.[16]

In this model, the Nash equilibrium is given by (see again Epstein and Nitzan, 2002):

$$x_F^* = \frac{(\Delta\pi)^2 \cdot \Delta u}{(\Delta\pi + \Delta u)^2},\quad x_C^* = \frac{(\Delta u)^2 \cdot \Delta\pi}{(\Delta\pi + \Delta u)^2},\quad p_F^* = \frac{\Delta\pi}{\Delta\pi + \Delta u} \text{ and } p_C^* = \frac{\Delta u}{\Delta\pi + \Delta u}.$$

From the equilibrium strategies it is straightforward to determine how changes in the relative gains to the contenders of winning the contest influence the probabilities of winning the contest:

Lemma 2: $\dfrac{\partial p_C^*}{\partial \Delta\pi} = -\dfrac{\Delta u}{(\Delta\pi + \Delta u)^2} < 0$ and $\dfrac{\partial p_C^*}{\partial(\Delta u)} = \dfrac{\Delta\pi}{(\Delta\pi + \Delta u)^2} > 0$.

The probability of conservation is increasing with the relative gain of the conservationalists and decreasing with the relative gain of the fishermen. (When both $\Delta\pi$ and Δu increase with the same percentage, then the probability of conservation remains unchanged).

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16 We do not have a common reference situation, by which winning can be compared.

4. The probability of conservation in the presence of climate change

The focus will now be on the effect of climate change on the success of conservation or the failure to eliminate overfishing. The natural size of the fish stock (net of fishing effort) is dependent on factors such as the average water temperature, either directly or through climate related changes in salinity, average wind and the presence of other species. Changes in these variables can have an effect on the recruitment, size and quality of the fish resource, migration of species or even transportation of larvae. There are several mechanisms through which climate related changes will affect future fish resources. For example, the cod in the North Atlantic is suspected to move to the north, yielding more harvesting possibilities in the North Atlantic and less for the North Sea.[17]

4.1. The implication of lower future stocks on profits

Given the discussion in the previous section, the expected climate changes have the potential to affect the fisheries in several ways. In order to give any predictions about likely future impacts of climate on fisheries, the specific local or regional conditions have to be known. In order to develop some general results, assume a situation where climate change reduces k^{CC} below 1. Given lemma 1, for a reduction in k^{CC}, the preferred catch level in the first period for the fishermen increases. Denote this new catch level $q_1^{CC} = \arg\max\{\pi(k^{CC})\}$, such that $q_1^{CC} > q_1^F$.[18] On the other hand, since the conservationalists' preferred first-period is a temporary closure of the fish-activity, their preferred level is not affected by changes in the growth function of the stock.

What matters here is how much the climate change affects the gain from winning the contest. The following notation is used: $\Delta\pi_t(q_1^F) = \pi_t(q_1^F) - \pi_t(0)$

17 See e.g. Dickson and Brander (1993) and Blindheim et al. (2000).

18 The notation here is chosen to highlight that it is the effect coming from a reduction in k^{CC}.

[again, in the previous equation, you have $q^F{}_1$ instead of $q_1{}^F$, edit if desired] and $\Delta\pi_t(q_1^{CC}) = \pi_t(q_1^{CC}) - \pi_t(0)$ are the net gains from winning in period t for the fishermen in the baseline situation and the climate change situation, respectively. Finally, $\Delta\pi_t^{CC} = \Delta\pi_t(q_1^{CC}) - \Delta\pi_t(q_1^F)$ expresses the change in net gain for the fishermen in period t when moving from a baseline situation to the climate change regime in the first period. Formally, the general expression for the fishermen is:

$$\Delta\pi_1^{CC} = \Delta\pi_1(q_1^{CC}) - \Delta\pi_1(q_1^F) = [\pi_1(q_1^{CC}) - \pi_1(0)] - [\pi_1(q_1^F) - \pi_1(0)] = \pi_1(q_1^{CC}) - \pi_1(q_1^F) \tag{2a}$$

$$\Delta\pi_2^{CC} = \Delta\pi_2(q_1^{CC}) - \Delta\pi_2(q_1^F) = [\pi_2(S_2^{CC}(q_1^{CC})) - \pi_2(S_2^{CC}(0))] - [\pi_2(S_2(q_1^F)) - \pi_2(S_2(0))] \tag{2b}$$

(2a) expresses the change in net gain when moving from a baseline situation to the climate change regime in the first period. In the first period, the gain from winning the contest given climate change implies a larger profit for the fishermen because they fish more, while losing the contest implies the same profit in either situation. For the first period, it is obvious that $\Delta\pi_1^{CC} > 0$.

For the second period, rewrite (2b):
$\Delta\pi_2^{CC} = [\pi_2(S_2^{CC}(q_1^{CC})) - \pi_2(S_2(q_1^F))] - [\pi_2(S_2^{CC}(0)) - \pi_2(S_2(0))]$. The first part measures the change in profit from winning the contest under climate change compared to baseline in the second period. It must be the case that $sign\{\pi_2(S_2^{CC}(q_1^{CC})) - \pi_2(S_2(q_1^F))\}$ = $sign\{S_2^{CC}(q_1^{CC})) - S_2(q_1^F))\}$, which definitely is negative, since the second-period stock is lower for the same first-period catch level in the climate change regime, and catches in the first period are also larger, such that $\pi_2(S_2^{CC}(q_1^{CC})) - \pi_2(S_2(q_1^F)) < 0$. The second part measures the change in profit from losing the contest under climate change compared to baseline, and it follows that $\pi_2(S_2^{CC}(0)) - \pi_2(S_2(0)) < 0$, since the first-period catch is equal, while the stock is smaller under climate change. In total, we have that: $\Delta\pi_2^{CC} \gtrless 0$.

4.2. *The implication of climate change on the conservationalists' utility*

How does climate change affect the utility of the conservationalists? First of all, the conservationalists' preferred catch level in the first period remains unchanged at a zero catch level. The effect of the climate change on the conservationalists' utility appears through the changed action of the fishermen in the first period, the derived effect of this in the second period and the reduced growth of the stock given climate change.

The general expression for the conservationalists reads:

$$\Delta u_1^{CC} = \Delta u_1(q_1^{CC}) - \Delta u_1(q_1^F) = [u_1(0) - u_1(q_1^{CC})] - [u_1(0) - u_1(q_1^F)] = u_1(q_1^F) - u_1(q_1^{CC}) \quad (2c)$$

$$\Delta u_2^{CC} = \Delta u_2(q_1^{CC}) - \Delta \pi_2(q_1^F) = [u_2(S_2^{CC}(0)) - u_2(S_2^{CC}(q_1^{CC}))] - [u_2(S_2(0)) - u_2(S_2(q_1^F))] \quad (2d)$$

(2c) measures the change in the net gain for the conservationalists from winning the contest when comparing the baseline situation with a climate change regime. Since $(u_t)_{q_t} < 0$, and $q_1^{CC} > q_1^F$, it follows that $\Delta u_1^{CC} = u_1(q_1^F) - u_1(q_1^{CC}) > 0$. That is, the net gain for the conservationalists is increased, since the utility from winning remains unchanged, while the utility from losing is reduced.

For period 2, rewrite (2d): $\Delta u_2^{CC} = [u_2(S_2^{CC}(0)) - u_2(S_2(0))] - [u_2(S_2^{CC}(q_1^{CC})) - u_2(S_2(q_1^F))]$. The first bracket measures the change in the utility in the second period from winning the contest. This is clearly negative, since the stock is lower in the climate change regime, that is $u_2(S_2^{CC}(0)) - u_2(S_2(0)) < 0$. The second bracket measures the change in the utility from losing the contest. This is also clearly negative, since the conservationalists' utility in the second period is smaller when losing the contest since catch levels in first period are larger and the reproduction is smaller, that is, $u_2(S_2^{CC}(q_1^{CC})) - u_2(S_2(q_1^F)) < 0$. In total, $\Delta u_2^{CC} \lesseqgtr 0$. Table 2 summarizes the effects.

Table 2. ***Summarizing the effects of climate change***

$\Delta u_1^{CC} > 0$	Catches are higher in period 1 under climate change, while the baseline is identical; therefore the net gain in utility from winning is increased for the conservationalists.
$\Delta u_2^{CC} \lesseqgtr 0$	The utility from losing is reduced, but the utility from winning is also reduced, $\Delta u_2^{CC} > 0$ if $[u_2(S_2^{CC}(q_1^{CC})) - u_2(S_2(q_1^F))] > [u_2(S_2^{CC}(0)) - u_2(S_2(0))]$
$\Delta \pi_1^{CC} > 0$	Fishermen do not care as much about the second period under climate change, and net profit from winning the contest increases in the first period.
$\Delta \pi_2^{CC} \gtreqless 0$	The profit from losing is reduced, while the profit from winning is also reduced, $\Delta \pi_2^{CC} > 0$ if$[\pi_2(S_2^{CC}(q_1^{CC})) - \pi_2(S_2(q_1^F))] > [\pi_2(S_2(0)) - \pi_2(S_2^{CC}(0))]$

Note that the conservationalists often will gain more from winning the contest in the presence of climate change compared to no climate change (that is, when $\Delta u_1^{CC} + \Delta u_2^{CC} > 0$). The reason is that the fishermen act more aggressively in the first period, when climate change reduces the future profitability of the fisheries. This implies that given climate change, the resource will be deteriorated more in the first period and the value of protecting the resource increases. This is also true when all else is equal for the second period, but here there is also the direct effect of climate change, which reduces the stock in the second period. Only if this latter effect dominates the two other effects will the value from winning will be smaller for the conservationalists under climate change. The effect works in the same way for the fishermen, who often gain more from winning the contest in the presence of climate change (when $\Delta \pi_1^{CC} + \Delta \pi_2^{CC} > 0$).

5. The effect of climate change on the probability of conservation

Common sense might suggest that if future stock sizes are likely to be depressed due to climate change, the pressure from the conservationalists to conserve the resource will increase with the effect that the probability of conservation is increased. However, when the policy outcome is determined by a contest between two opposing interested lobby groups, the outcome of an expected climate change regime is more complex. The analysis in the previous section reveals that $\pi^{CC} > 0$ and $\Delta u^{CC} > 0$ are the most likely situations. This means that both interest groups receive a larger net gain from winning the contest, so the probability of conservation is, from the outset, ambiguous. Therefore, it is necessary to deal with this rigorously.

The effect on the probability of conservation as a result of climate change can be derived as:[19]

$$\frac{\partial p_C^*}{\partial (CC)} = \frac{\Delta u^{CC} \cdot \Delta\pi - \Delta\pi^{CC} \cdot \Delta u}{(\Delta\pi + \Delta u)^2}.$$

From this we derive the following main result:

Proposition 1: $\frac{\partial p_C^*}{\partial (CC)} > 0$ if $\frac{\Delta u^{CC}}{\Delta u} > \frac{\Delta\pi^{CC}}{\Delta\pi}$ and $\frac{\partial p_C^*}{\partial (CC)} < 0$ if $\frac{\Delta u^{CC}}{\Delta u} < \frac{\Delta\pi^{CC}}{\Delta\pi}$

That is, the likelihood of conservation increases when climate change increases the value of conservation (measured by changes in utility to the conservationalists) more in percentage than the commercial value of the resource (measured as changes in profit to the fishermen), and vise versa; if the value to the fishermen increases more in percentage than the value to the conservationalists, then the probability of conservation decreases.[20]

Two special cases serve as an explanation of this result: First, in the situation where $\pi^{CC} = 0$ and $u^{CC} > 0$, it follows from proposition 1 that $\frac{\partial p_C^*}{\partial (CC)} > 0$. Here,

19 This follows from totally differentiating the expression for the probability of conservation.

20 This result can also be expressed in reverse; if the likelihood of conserving the resource increases, then the conservation value (utility to the conservationalists) is reduced less than the commercial value of the resource (profit to the fishermen).

only the conservationalists receive more benefit from winning the contest, which implies that they are willing to invest more in the political process to win the contest. Given that the fishermen do not increase their contribution, the likelihood that the conservationalists win the contest increases.

On the other hand, if $\pi^{CC} > 0$, while $u^{CC} = 0$ then $\frac{\partial p_C^*}{\partial (CC)} < 0$. Here, only the fishermen receive more benefit from winning the contest, which implies that they are willing to invest more in the political process to win the contest. Given that the conservationalists do not increase their contribution, the likelihood that the fishermen win the contest increases.

It follows from the proposition that the group that receives the highest percentage increase in benefit from winning the contest also invests the most, and consequently, has a larger likelihood of winning the contest.

6. Conclusion

Mounting evidence suggest that man-made emissions of greenhouse gasses cause climate change and that we are at the beginning of an unstoppable trend of increasing temperatures. This implies several climate change related changes in the background variables relevant for the relative abundance of the fish resource. In light of this, fisheries management schemes need to be adjusted in order to cope with future climate change induced changes in the variables affecting fisheries. The results underpin some of the difficulties future designers of fisheries regulation are likely to face.

By modelling the determination of fisheries management as a contest between interest groups with opposing objectives, it is possible to endogenously determine the probability of conservation as determined by the interest groups' relative gain of winning the contest. Climate change is expected to affect the fisheries in several ways, depending on what type of fishery is the issue, both with respect to type of fish and the geographical location of the fish resource. As a consequence, climate change will have the possibility of influencing the relative gain from winning the contest in different ways. This paper provides a characterization of how the probability of conservation is related to climate change related changes in the biological "background" variables. The results suggest that areas with increasing value from conservation will be more likely to be conserved, while areas with highest increase in commercial value will be likely to experience higher fishing pressure.

There are some assumptions in this paper that deserve further consideration, particularly the fact that second period regulation is treated exogenously. This is critical, since it implies that second period TAC are independent of first period behaviour, or rather that the players have fixed expectations about the second period. A more likely effect could be that in the case of higher fishing pressure in period 1, the regulator would be more inclined to demand higher regulation in the future. This would imply another crowding out effect in the second period from an increase in the catch level in the first period. Not only will the stock be lower, but catches will also be smaller. This effect will, however, not qualitatively change the result. One could also consider each period as a new contest, which seems to be how real life policy works. However, this considerably complicates the analysis, most likely without adding any significant new insights.

Finally, further research is clearly needed into the subject of the political economy of the regulation of renewable resources. Within the framework of the presented analysis, an interesting extension would be to consider what happens if the carrying capacity of the resource is also affected as well. For example, a situation where the climate change reduces the resilience of the resource, implying a larger probability of a possibly irreversible collapse of the resource for the same catch levels in the first period would influence the behaviour of both groups. If overfishing implies a higher probability of collapse of the resource given climate change, and fishermen are to some extent concerned about the future, climate change is likely to reduce the preferred fishing effort of the fishermen in the first period, reducing the likelihood of overfishing. However, in the framework of this paper, we also have to consider the conservationalists. If the likelihood of a collapse of the resource increases, the costs of losing for the conservationalists will be very high.

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