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Who Should Set the Total Allowable Catch?

Social Preferences and Legitimacy in Fisheries Management Institutions

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Abstract

We develop a decision making model based on constraints that are typically encountered in fisheries management when setting the total allowable quota. The model allows us to assess the differences in outcomes when the decision is made by different management institutions under uncertain conditions. We consider social preferences under uncertain stock conditions and measure the social expected costs raised by different institutions. We take into account stakeholder participation and we include the notion of “legitimacy cost” as the actions stakeholders may take when they do not recognize decisions made by the authority as the right decisions. Within this context, economic policy choices are discussed in terms of what type of institutions will generate a higher expected welfare depending on social preferences and legitimacy costs in specific contexts. We also discuss what aspects should be considered when designing stakeholder and scientific boards in the total allowable catch (TAC) setting process.

Key Words: TAC setting, decision processes, legitimacy costs, preferences misalignment

JEL Codes: Q22, Q28, D71, D72

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Who Should Set the Total Allowable Catch? Social Preferences and Legitimacy in Fisheries Management Institutions

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1. Introduction

One important management tool in commercial fisheries is the setting of a total allowable catch (TAC). This tool is central for different types of management systems ranging from Global Quotas to Individual Transferable Quotas. In fact, the decision about the TAC level must reconcile individual demands of different fishermen with the conservation of a fishing stock. This paper analyses collective decision making done by different institutions that are delegated the task of setting the TAC under conditions of uncertainty about the state of the fishery. It focuses particularly on two issues: stakeholders' perceptions of the decision maker's legitimacy, and the degree of alignment between socially optimal preferences and the preferences of the delegated institution.

Although the TAC decision making process is only one specific issue in fisheries governance, it has been shown to be a very difficult problem to solve. Jentoft and Chuenpagdee [6] define fisheries and coastal governance as a "wicked" problem because there is no right or wrong approach to solve it. This suggests that applying collective decision making theory to study how decisions are made in fisheries management can be fruitful [7]. One reason for this is that there exist several sources of uncertainty in this decision, including biological and socioeconomic sources. On the biological side, decision makers are uncertain about the size of the stock, as well as its age structure, growth rate, natural mortality, and geographic distribution, and consequently the impact that a higher or lower TAC will have on stock conservation. On the socioeconomic side, the decision maker is uncertain about the social and economic effects of reducing or increasing quotas, including not only economic benefits but also social effects such

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as local unemployment and poverty. All these sources of uncertainty create important challenges to decision makers when setting TACs.

Additionally, different actors, including not only fishermen but also workers and local communities, might have different objectives and preferences that affect the optimal size, from their viewpoint, of the TAC. These objectives, such as short run income and employment, are not necessarily consistent with each other and with the long run conservation of the fishing stock. Moreover, some actors might mistrust the decisions taken by other actors, generating legitimacy costs that make more difficult to set the TAC.

Thus, uncertainty about the stock and conflicting objectives/preferences imply that the socially optimal TAC cannot be easily determined, even when it is crucial for the long run conservation of the fish stock and for fulfilling socioeconomic expectations for the fisheries. The Magnuson-Stevens Fishery Conservation and Management Act in the US, the Common Fisheries Policy in Europe, and other institutions around the world have failed to keep the stock at sustainable levels for a significant number of fisheries [1,2]. From a political point of view, some of the reasons for this failure have been that, on the one hand, TACs have been set higher than scientific recommendations [3] and, on the other, there is a lack of sufficient enforcement to ensure perfect compliance with TACs [4,5]. These facts are closely related to uncertainty, social preferences and legitimacy of management institutions.

The paper develops a model of decision making based on the constraints that are typically encountered in fisheries management when deciding on the TAC. The purpose of the model is to analyse the differences in the outcomes when the decision making process is led by different decision making institutions. This allows us to clarify the factors that explain the outcome differences, and establishes the circumstances in which the different institutions are to be preferred. To achieve this goal, the paper adapts the model developed by Li, Rosen and Suen [8–10] about decision making processes in different situations to the particular case of fisheries management. An additional contribution of the paper is to introduce the role that social preferences and costs relate to the legitimacy that the management institution has during the TAC decision making process.

The remainder of the paper is organized as follows. First, we present motivation for why legitimacy should be included in the model. Then, we present the basic decision model. Thereafter, we discuss the information updating process. In this context, we establish the basic reference case, which is when the central authority decides on the TAC, followed by two particular cases, when the authority delegates the decision to a team of experts and when it delegates it to a stakeholder committee. Finally, a policy oriented discussion ends the paper.

2. Institutions and participation in the decision making process in fisheries

Every fishery needs to be managed, either by some authority or by its stakeholders. From authoritarian governments to democracies, some agent or institution has to make the decisions regarding fisheries management. Jentoft and MacCay [11] studied 11 countries and classified the type of fisheries administration depending on the degree of user participation in the decision making process, ordering them from one-way communication to co-management. The key lesson from their analysis is that user participation provides a *"two-way channel for communication of information and knowledge between industry and government [which] are a means of producing support and of sharing responsibility for hard decisions"* (p. 233). Moreover, the effectiveness of the system depends on how it is designed and implemented. Two key issues are raised by the authors, namely representation and scale. On one hand, if some group does not feel properly represented in the decision making process, there is a risk that the group boycotts or sabotages the regulations that have been decided. On the other hand, small-scale institutions are more homogeneous and allow more effective user participation, although they might be inappropriate for managing transient stocks and fleets. In the model presented in this paper, we concentrate on the first of these issues.

The question about who should be considered a stakeholder with the right to participate in the decision making process remains open. Naturally, fishermen are first-order candidates to be represented in the process, but they are a heterogeneous group with different preferences and goals. Moreover, other users, such as consumers and processing plants, may also claim that their welfare is affected by fish availability and therefore they have the right to have an opinion. Yet other relevant actors in all countries studied by Jentoft and McCay [11] were those that held scientific knowledge. Scientists usually give advice about decisions but they are not necessarily entitled to make the decision because *"it is a scientific question to determine the size of the biomass, but it is a political issue to decide how big it should be (by deciding the level of stock extraction)"* (p. 240).

The heterogeneity of the actors involved implies that their opinions about the optimal level of the TAC will probably diverge. In fact, the discussion about the optimal harvest, which continues among scientists [12–15], is partly due to the lack of agreement on the objectives at which fisheries should aim [16]. One of the reasons for these disagreements is the difference in goals and preferences of different stakeholders.

Ultimately, once the TAC is set, "fishermen control to what extent a management system will work or not, almost no matter how much government spends on policing" [11] (p. 241). If they set the TAC too low, fishermen would not only complain, but they might also overfish if enforcement is weak. Therefore, rational decision makers should consider legitimacy when setting the TAC, particularly under weak enforcement situations.

We define legitimacy as the extent to which agents recognize decisions made by the delegated authority as the right decision. The crucial point is that the more closely the delegated agent is perceived to share the preferences of the people he represents, the more legitimate will be his decisions. When stakeholders perceive that decisions are illegitimate, however, they may take actions that impose a social cost in the form of resources that society employs in response to these stakeholder actions. We call this the "legitimacy cost."

To fix ideas, we identify two types of costly actions stakeholders could take if they do not agree with the decision made by the authority. First, they could take direct actions against the decision, ranging from lobbying to public protests and manifestations. In the case of lobbying, the cost is reflected in suboptimal decisions taken by the authority and imposed on the society, while public protests and manifestations could directly affect the wellbeing of the population. The second type of action is non-compliance with the TAC, which reduces the probability of sustaining the stock over time. Although the main component of this cost is related to the biological cost of sustainability, an illegitimate decision-maker should be aware of this non-compliance behaviour and increase enforcement efforts, which implies direct costs to society.

These costs may be high enough to pressure the authority to affect society's net benefits from different types of management institutions. For example, when fishermen participate in the decisions (co-management), compliance appears to be higher than in fisheries without co-management [17,18]. The reason is that, in this scenario, fishermen should be ready to accept and follow regulations if they believe them to be fair. If they or their representatives participate in the decisions, this gives legitimacy to the decisions made by the authority, and creates an internal obligation for compliance. If stakeholders do not perceive that the decisions are fair or correct, they will be less prone to comply with the regulations.

To motivate the importance of legitimacy in the TAC decision process, let's consider some polar cases: at one extreme, a large and unsustainable TAC can be legitimate among fishermen if they all agree that a large quota is optimal to achieve their goals. At the other extreme, the government could try to induce lower TACs by delegating power to a team of "scientific experts". If fishermen do not agree with their decision, this might justify illegal behaviour on their side, based on the lack of legitimacy of the decision taken by the experts, creating social costs. Yet another possibility is that the government directly makes TAC decisions. In such case, one should expect that legitimacy costs should be lower than in the case of a "scientific expert" committee, because the government should be at least partially accountable to citizens[1] and therefore government preferences should somehow reflect preferences of voters. However, in our opinion, the real issue here is not the nature of the agent (government, fishermen, scientific expert), but the legitimacy he enjoys to make decisions about the quota. Non-legitimate decisions could impose a social cost through illegal fishing or other socially costly behaviour.

In summary, delegation of power might be associated with agency costs for the fisheries authority if these agents do not share the objectives and decisions of their principals. These agency costs might include information costs, decision making costs, operational costs, and monitoring, control and enforcement costs [18]. So, the delegation of quota-setting power to any stakeholder can be associated with different types of costs, which need to be taken into account when looking for the socially optimum institution.

3. Model

We analyse the decision about the Total Allowable Catch, TAC, in a binary world for a single species fishery: the decision can be either to increase or not to increase the TAC from its original level, T_0. The decision maker bases its choice on the state of nature, which can be either good (G) or bad (B). If the fishery is in a good state, the biomass is healthy and the ecosystem can bear an increase in the level of catch without reducing its stock size. If the fishery is in a bad state, the environmental conditions are bad for the biomass, the ecosystem will not be able to support an increase in TAC, and its stock size will be reduced.

The conservation state of the biomass delivers different values to different agents depending on their relationship with the fishery. A fisherman is much more concerned than consumers by the amount of fish catch because the former *"cannot shift as easily to other occupations as consumers can shift among goods"* [11] (p. 241). However, in both cases, a wrong decision about the TAC generates an opportunity cost. If the catch is increased today and

[1] Although governments are accountable to citizens through elections , this accountability is indirect, and it is not obvious that each measure taken by a government, such as defining the TAC, is controlled by the electors.

the state is bad, there may not be enough biomass in the future, but if the catch is not increased today and the state is good, it may be a waste of resources and consumer welfare. In statistics, the first situation is called type I error and the second, type II error. These errors are costly mainly from a biological perspective in the first case and from an economic perspective in the second. We denote the cost of the first error type for agent i by λ_b^i and the cost of the second error type by λ_e^i.

The trade-off between sustainability and economic efficiency will depend on preferences and on how impatient different agents are. Given any state of nature, everything else constant, a more impatient agent would prefer to increase the level of catch today, sacrificing future stocks more often than would less impatient agents.

Heterogeneity among agents may become the source of another cost, namely, a legitimacy cost. Any wrong decision – either increasing the TAC in a bad state or maintaining it in a good state – could induce non-compliance behaviour or even open manifestations against the decision by people who do not agree with that decision. This state of things can lead to increased enforcement costs and political costs for the authority. We denote this legitimacy cost by λ_p^i.

As a benchmark, let's consider that the TAC decision is delegated to agent i who does not take into account the legitimacy cost and has no contemporary information about the state of the fishery. In such a case, his decision about increasing the TAC or not depends on his belief about the probability of a good and a bad state. We denote the prior belief of agent i about the probability that the fishery is in a good state as γ^i, and the prior belief of agent i about the probability that the fishery is in a bad state as $(1-\gamma^i)$.

Under this assumption, on one hand, the expected cost of increasing the TAC is given by the probability of making that decision in a bad state of the fishery, times the expected biological cost, i.e. $(1-\gamma^i)\lambda_b^i$. On the other hand, the expected cost of not increasing the TAC is given by the probability of not doing so in a good state of the fishery, times the expected economic costs, i.e. $\gamma^i\lambda_e^i$.

Therefore, if agent i should make the decision with no contemporary information about the real state of the fishery, he would increase the TAC if and only if

$$(1-\gamma^i)\,\lambda_b^i < \gamma^i\lambda_e^i \qquad (1)$$

All the information in equation (*1*) refers to agent i. Hence, we summarize both prior beliefs and perceived individual costs of agent i in parameter k^i.

$$k^i \equiv \frac{\left(1-\gamma^i\right)\lambda_b^i}{\gamma^i \lambda_e^i} \quad (2)$$

This expression explains why a biologist would be less prone to increase quotas when compared to a fisherman. This will be the case if the biologist gives a higher value to the ecological cost than to the economic cost, when compared to a fisherman who has the same priors about the state of nature. Additionally, the same could happen if the biologist is more pessimistic about his beliefs about good and bad states of nature. In particular, fishermen and fish industry workers would probably suffer higher opportunity costs than sustainability costs, compared with biologists or ecologists, who would consider that lost sustainability is always more costly than the opportunity cost of production. Parameter k^i in equation (2) simplifies the analysis because it reduces all the information relative to the characteristics of the agent involved in the decision. Hence, for brevity, we shall refer to k^i as the parameter that summarizes individual preferences.

Using information on economic and biological cost, and priors for a good and bad state of nature, summarized in parameter k^i, we could order all the agents between the most and the least prone to increase TACs in this uncertain environment. Notice that, if no value is given to the conservation of the stock ($\lambda_b^i = 0$) or if only a good state is in the agent's beliefs ($\gamma^i = 1$), the agent will prefer to increase the quota in any state, and t $k^i = 0$. At the other extreme, if no values were given to the lost jobs and wealth from not increasing the quota ($\lambda_e^i = 0$) or if the agent believes that only bad states are feasible ($\gamma^i = 0$), the agent will never be willing to increase the quota, and therefore $k^i \to \infty$. Moreover, we could classify agents as TAC-keepers if parameter $k^i > 1$ and TAC-increasers if parameter $k^i < 1$. When $k^i = 1$, the agent is indifferent between increasing the TAC or not.

3.1 Information update

In this subsection, we assume that decision maker i observes a signal $y \in \mathbb{R}$ about the state of the fish stock. Intuitively, a fisherman knows how much fish he captures and has an idea about how much fish other fishermen capture; a biologist studies the size and quality of the biomass; and authorities hire their own experts and also observe the quantities reported by fishermen. For simplicity, we assume that all agents receive (or share) the same signal about the state of nature of the fish stock.[2] However, this observation is only a signal about the real state of nature. A lucky fisherman may capture a large amount of fish in a bad state of nature or a stock assessor may find few fish in a good state of nature.

In a good state of nature, signal y would follow distribution $f(y|G)$, while, in a bad state of nature, signal y would follow distribution $f(y|B)$. These distributions are known and shared by all agents. Moreover, assume that the density $f(y|S)$, with $S = \{B, G\}$, has the monotone likelihood ratio property (MLRP), such that the density ratio

$$l(y) \equiv \frac{f(y|G)}{f(y|B)} \tag{3}$$

is increasing in y, as in Milgrom [19].

The agent infers the real state of nature by considering both his prior γ^i and the signal y. Following Bayes' rule, the updated probabilities for each state of nature for agent i are

$$Pr^i[G|y] = \frac{\gamma^i \cdot f(y|G)}{\gamma^i \cdot f(y|G) + (1-\gamma^i) \cdot f(y|B)} \tag{4}$$

$$Pr^i[B|y] = \frac{\left(1-\gamma^i\right) \cdot f(y|B)}{\gamma^i \cdot f(y|G) + (1-\gamma^i) \cdot f(y|B)} \tag{5}$$

Hence, given a signal y, agent i would support an increase in the TAC if and only if the expected biologic cost of increasing the quota (EBC) is lower than the expected economic cost of not doing so (EEC).

$$EBC \equiv Pr^i[B|y] \cdot \lambda_b^i \quad < \quad Pr^i[G|y] \cdot \lambda_e^i \equiv EEC \tag{6}$$

$$\left(1-\gamma^i\right) \cdot f(y|B) \cdot \lambda_b^i \quad < \quad \gamma^i \cdot f(y|G) \cdot \lambda_e^i \tag{7}$$

$$l(y) \quad > \quad k^{\mathrm{i}} \tag{8}$$

Given that a higher signal y is more favourable to a good state of the fishery, agent i would be willing to increase the total allowed catch if and only if the signal is greater than a certain threshold $t^i \equiv l^{-1}\left(k^i\right)$. In fact, given a signal y, if equation (8) holds, the expected cost of increasing the TAC is lower than the expected cost of not doing it, and therefore an increase of the TAC should be the right decision.

[2] If every agent received a different signal, the revelation of this information would become a game in itself and would pose a methodological problem beyond the scope of this paper. See Li and Suen [16,18].

Let's define the function $F_G^i(t)$ as the accumulated posterior probability for agent i that the fishery is in a good state, given that signal y is lower than a certain threshold t, and the function $F_B^i(t)$ as the accumulated posterior probability for agent i that the fishery is in a bad state, given that the signal is higher than the threshold, as

$$F_G^i(t) = \int_{y<t} \Pr{}^i[G|y]\, dy \quad (9)$$

$$F_B^i(t) = \int_{y>t} \Pr{}^i[B|y]\, dy \quad (10)$$

Given that the decision is to increase the total allowable catch if the signal is above threshold t, and not to do it below that threshold, the expected cost that agent i has to bear is

$$EC^i(t) = \lambda_b^i \cdot F_B^i(t) + \lambda_e^i \cdot F_G^i(t) \quad (11)$$

In the Appendix, we prove that expected costs defined by equation (11) are single-peaked around t^i, i.e., the closer the decision threshold is to the preferences of agent i, the lower would be his expected costs of the TAC decision.

From the social point of view, let's consider that social preferences can be summarized in λ_b^s and λ_e^s as a representative agent s who values the costs of a wrong decision and has a prior belief about the state of the fishery γ^s. Beyond the issues pointed by Sen [20,21], this aggregation may consider any externalities or interactions among agents; it make sense because the decision depends on relative and not on absolute costs, i.e., on parameter

$$k^s \equiv \frac{(1-\gamma^s)\lambda_b^s}{\gamma^s \lambda_e^s} \quad (12)$$

In this case, the social optimum is to increase the TAC if and only if $l(y) > k^s$, or equivalently, when $y > t^s \equiv l^{-1}(k^s)$. The social expected cost is

$$EC^s(t^s) = \lambda_1^s \cdot F_B^s(t^s) + \lambda_2^s \cdot F_G^s(t^s) \quad (13)$$

3.2 Misalignment of Preferences

Consider that the decision of increasing the TAC or not is delegated to agent d with preferences given by $k^d \neq k^s$. She would increase the TAC if she observes a signal greater than $t^d \equiv l^{-1}(k^d)$. Without loss of generality, assume that $t^d < t^s$. If signal y is lower than t^d or higher than t^s, the delegated agent would take the socially optimal decision. However, if the signal falls between these two thresholds, $t^d < y < t^s$, the agent would increase the total allowed catch even if it would be too costly in expected terms for society. Under this situation, the society will face an *ex-ante* expected cost given by $EC^s(t^d)$, which is higher than the social optimum $EC^s(t^s)$. This loss arises because the delegated agent's preferences (reflected in k^d) are different from the social preferences (reflected in k^s).

This situation is depicted in Figure 1. Here, the expected biological cost of increasing the quota is given by the decreasing EBC curve for both agent d and the representative agent s, while the expected economic cost of not increasing the quota is given by the EEC^d curve for agent d and EEC^s curve for representative agent s. Notice that, to minimize the expected cost, society should increase the quota whenever the signal is over the threshold t^s and should not increase the quota when the signal is under this threshold. Nevertheless, if the decision is delegated to a stakeholder with $t^d < t^s$, he will increase the quota when $t^s < y < t^s$, contrary to social preferences. This is because this stakeholder has a higher economic expected cost schedule for every y-level as compared to society. In this situation, society will face an expected loss, given by the shaded area of Figure 1. This could be the case if, for example, the decision is delegated to a fishermen who values the economic cost relatively more than society when compared to the expected biological cost.

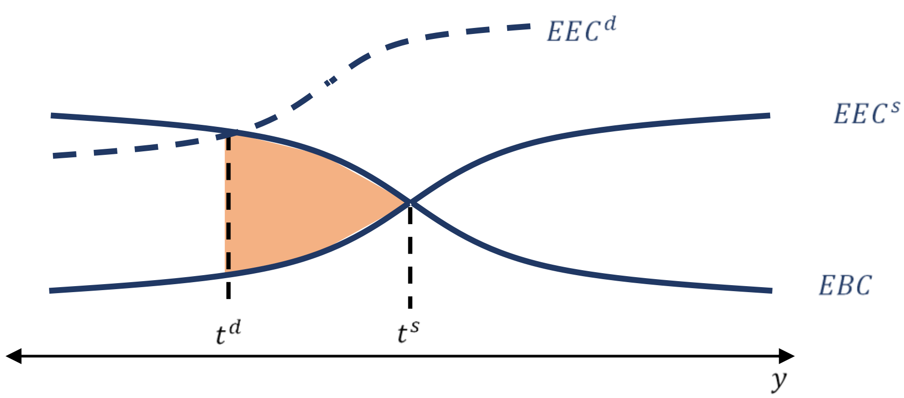

Figure 1: Misalignment cost when TAC decision is delegated to agent d.

3.3 Legitimacy

Assume now that there is a stakeholder group in society with its own preference structure and priors, such as a group of fishermen with interests in increasing the TAC. This group has the power to take a costly action for society if it disagrees with the decision made by the authority. As defined above, this costly action could take the form of increased non-compliance or public manifestations. To fix ideas, suppose that fishermen associate to lobby for an increase in the total allowed catch.[3] Define the preferences of this group by $k^g < k^s$, which defines its preferred policy threshold $t^g < t^s$. Moreover, consider that the TAC decision is made by the representative agent s.

Again, when signal y is lower than t^g or higher than t^s, both the fishermen and the authority agree on the decision. However, when $t^g < y < t^s$, the interest group would try to veto the decision. This could be done in several forms: they could lobby to change the decision with other power groups in society, they could organize strikes or riots, or they could simply ignore the quota limit, because they believe it is not fair or correct.

In any of these cases, there is an additional social cost of making the decision, related to the cost imposed by the lobby group through its reaction to the decision taken by the authority. This cost is not related to the fishery itself, but to the fact that the decision made by the authority is not considered legitimate. We define the expected legitimacy cost as ELC and the actual legitimacy cost as λ_p. Notice that this cost is realized only if the decision made by the authority is not considered legitimate, which happens only when $t^g < y < t^s$. In this case, given that the authority will not increase the TAC against the preferences of the pressure group, society would have to bear the opportunity cost if the state of the fishery was actually good λ_e^s, plus the legitimacy cost generated by the interest group λ_p. Therefore, under these conditions, the expected cost of not increasing the quota will be higher in this range of signals. Also notice that, if the authority takes into account the cost of this social pressure, it will be optimal for it to increase the quota under certain relatively good scenarios, and therefore its optimal threshold will be lower than when it does not take into account this social pressure.

This situation is depicted in Figure 2. The total expected cost of not increasing the quota (TEC) is given by the sum of the expected economic cost (EEC) and the expected legitimacy costs (ELC). If the authority does not take into account this legitimacy cost and only considers its private preferences, he will choose the same threshold as before, that is, t^s. In this case, the cost imposed by the pressure group creates a lower social expected welfare, given by the shaded area $(A + B + C)$. Nevertheless, if the authority considers the legitimacy cost in its decision, its optimal decision will be t^*, deciding to increase the quota when $t^* < y < t^s$, but not when $t^g < y < t^*$. In this situation, the total expected cost will be reduced, as shown in the upper-right

[3] The group of lobbyists could also be against the increase in the total allowable catch. The analysis is symmetrical.

triangle in Figure 2, denoted by A; this decision avoids some social pressure cost but accepts a higher expected biological cost (area B).

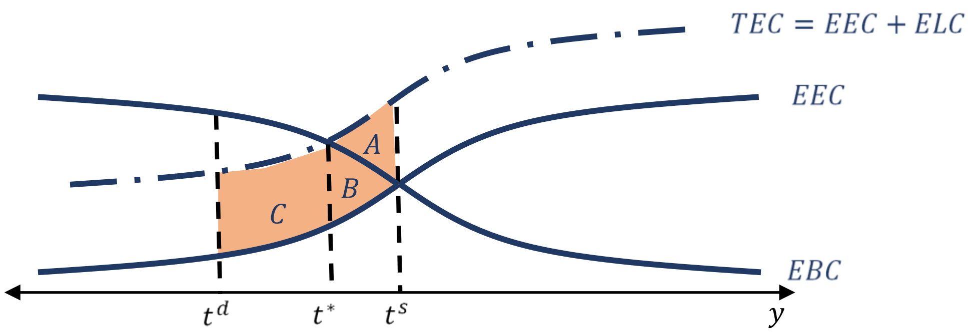

Figure 2: Legitimacy cost when interest group g does not recognize legitimacy of agent s.

4. Comparing institutions

Now that we have presented the biological, economic and political costs involved in decision making when setting a TAC, we are in a better position to analyse the different institutions commonly used to delegate the power to set the TAC and their consequences for social welfare. We distinguish the cases when the fishing authority delegates its decision to a committee of stakeholders (fisheries users) and a panel of scientific experts (external advisors). The principal difference between these institutions is that, on one hand, the decisions made by a committee composed of spokesmen for the interest groups in the fishery might be considered more legitimate by stakeholders because it can better represent their preferences. However, the way preferences are aggregated by the committee may not be aligned with the social optimum. On the other hand, a panel of scientific experts, with no vested interest in the fisheries, might better balance biological and economic costs and make decisions that correspond more closely to social preferences. Their decision might be nearer than that of the committee of stakeholders to the social optimum. Nevertheless, their decisions might not be considered legitimate in the eyes of the stakeholders and this could generate additional costs to society.

4.1 Committee of Stakeholders

Delegating a decision to a committee of stakeholders implies asking agents that have interests in the fishing sector to what extent they are willing to risk a reduction in the stock size by increasing the TAC. It is important to remember in this section that all agents receive the same signal about the state of nature, i.e., all the information gathered by any agent would be disclosed to all other agents. If this was not the case, members of the committee could act strategically (see, e.g., [8,10]).

Given that agents within the committee have different preferences, they need a mechanism to make a decision. The usual way a committee aggregates preferences is by voting whether or not to increase the quota: if the majority of agents support an increase of the quota, the quota is increased; if not, it is not increased. There exist other particular rules that shape the outcome of the committee in different ways. For example, some agent (e.g., the authority himself) can partially control the outcome of the committee by having veto power over any decision made by the committee; some members of the committee may be nominated by the authority; any decision may require qualified majorities (or supermajorities) to make it more difficult to change the status quo; or some members may have more power by having more votes.

However, to make the contrast between legitimacy and stakeholder preferences more transparent, in the following we assume that the committee's voting rule is "one member, one vote", independently of how the members are nominated. Every agent $i = 1, \ldots, N$ observes the same signal y and decides to vote for or against an increase in the TAC depending on his preferences. Because the decision is not made directly, but by aggregating several ballots, we need to identify who would vote for increasing the quota and who would vote for the *status quo*.

Given that expected costs are single peaked and that there are only two alternatives to vote on, the solution will be that the threshold over which the TAC is increased coincides with the threshold preferred by the median voter of the stakeholder group, m.

$$t^{com} = l^{-1}(k^m) \tag{14}$$

Therefore, if we consider the preferences of the representative agent, the expected social cost of leaving the decision in the hands of a committee of stakeholders is

$$EC^s_{com} = \lambda^s_b \cdot F^s_B(t^{com}) + \lambda^s_e \cdot F^s_G(t^{com}) \tag{15}$$

The loss for society of delegating power to a stakeholder committee will be

$$EC^s - EC^s_{com} = \lambda^s_b \cdot [F^s_B(t^s) - F^s_B(t^{com})] + \lambda^s_e \cdot [F^s_G(t^s) - F^s_G(t^{com})]$$
16)

If $t^{com} < t^s$, and assuming that prior beliefs are homogenous within the society, then

$$EC^s - EC^s_{com} = \int_{t^{com}}^{t^s} \frac{(1-\gamma^s) \cdot f(y|B)}{\gamma^s \cdot f(y|G) + (1-\gamma^s) \cdot f(y|B)} dy$$
17)

The closer the preferences of the median voter of the committee of stakeholders t^{com} is to the social preferences t^s, the lower will be the expected cost of delegating the TAC decision to the committee. Therefore, the main problem with the committee of stakeholders is that, if certain interest groups are over-represented, the decisions of the committee would be different from those of the representative agent and the social optimum, imposing a cost on expected welfare.

4.2 Panel of experts

The fishing authority can also delegate the decision to a panel of external experts to isolate interest groups' influence and make the decision as close to the social optimum as possible. Despite the fact that defining what "social optimum" means from a scientific perspective might be very difficult [12–15], we assume that the panel of experts actually knows what this optimum is. This clearly requires that scientific experts consider both economic and biological costs in their decisions and have priors similar to a representative agent.

As pointed out in the previous section, interest groups may not recognize that a panel of experts has the capacity to identify the social optimum, either because scientific procedures might not be fully transparent or because it is not in the interest of the stakeholders to follow the social optimum. Under this situation, interest groups may create legitimacy costs and push the authority not to take into account the external scientific advice.

Therefore, increasing the quota will be optimal when the signal is high enough, and keeping the *status quo* will be optimal otherwise; i.e., the TAC is increased when $y \geq t^s$.

If we assume that the panel of experts does not consider the legitimacy costs in its decisions and proposes the threshold t^s, the total expected cost of delegating the decision to a panel of experts is

$$EC^s_{pe} = \lambda^s_b \cdot F^s_B(t^s) + \lambda^s_e \cdot F^s_G(t^s) + |t^s - t^m| \cdot \lambda_p$$
(18)

This deviates from the social optimum by the last term of expression (18). The closer the preferences of the interest group t^m to the social preferences t^s, and the lower the legitimacy costs λ_p, the lower will be the expected costs of delegating the decision to a panel of experts.

5. Discussion

In this paper, we analysed the role of legitimacy and of stakeholder preferences in determining the TAC. We first discussed how the expected economic cost of not increasing the quotas must be balanced against the biological risk of increasing it, given a signal received about the state of the fishery under uncertainty. We introduced the concept of "legitimacy costs" as those that arise when users of the fishery do not accept the decision of the fishing authority and develop costly actions to force a change in the decision. We showed that authorities might either ignore these costs, which implies that society will need to face the cost imposed by pressure groups, or consider them in their decisions, balancing the biological risk of increasing the quota under relatively good scenarios against the expected cost imposed by the pressure groups. We then use the model to compare the effect of delegating the quota-setting responsibility to two specific institutions: a stakeholder committee that enjoys legitimacy, but that has preferences that diverge from the social ones, and a scientific expert committee whose preferences are aligned with society, but that lacks legitimacy with other stakeholders. Of course, in practice, there are many possible combinations of legitimacy and preference endowments among stakeholders that could range between these two polar cases. We use these two examples to analyse the role of legitimacy and preferences in the TAC decision process.

Our results suggest that both the lack of legitimacy and the misalignment of preferences in decision making committees generate solutions that are different from the socially optimal ones, generating costs to society. Additionally, we show that, when pressure groups exist that create political costs to the authority, it might be optimal for the authority to reduce total cost by accepting increases in the quota to avoid this political cost, accepting a biological risk that will be higher than in the absence of legitimacy costs.

Our results are useful to discuss policy implications for the design of TAC decision making committees when an authority faces high legitimacy costs and/or is not willing to face the political costs involved in making unpopular decisions. On one hand, the authority could delegate this decision to a stakeholders committee, which is a form of co-managing the fishery. In this case, the authority should design the composition of the committee members in such a way that the median voter of the group has preferences that are representative of the median voter in the society. International experience shows that institutions are migrating toward systems with increased participation, not only of the traditional actors but also of new interest groups [22,23].

On the other hand, the authority could delegate the decision making to a panel of experts, but this might create a risk of higher legitimacy costs when compared to the stakeholders committee. For this reason, it is important not only that the members of the scientific committee correctly consider both economic and biological costs, but also that they consider including participatory mechanisms in their decision procedures, such as information building and opinion recovery from other stakeholders, to increase their legitimacy. Transparency could be increased, e.g., by making public all committee meeting procedures and the reasons that determine their decision making, and making clear that they consider not only biological but also economic expected costs in their decisions. Other stakeholders' participation could also be encouraged by incorporating them in the process of gathering information and in public communications of the committee, with stakeholders exchanging their views of the state of the resources. This might reduce the legitimacy costs of any decision made by the committee, by reducing the predisposition to non-compliance behaviour or public manifestations when interest groups disagree with the TAC.

In any case, the design of institutions that reduce social costs when determining the TAC should focus on at least these two aspects: aligning the decision making body's preferences with the social ones, and increasing the legitimacy of the agent that defines the quota. In fact, increasing the participation of more agents in the decision making process in fisheries has two effects: first, it increases the number of interest groups represented in any committee of stakeholders, and, through this arrangement, it may reduce the misalignment costs of delegating the decision; and second, it reduces the potential legitimacy costs by incorporating the different interests of the agents in the decision process.

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Appendix

Single-peaked Expected Costs

Expected costs of agent i over threshold t are single peaked around t^i.

Proof

Expected costs defined by equation (11*)* are single-peaked, i.e., there exist t^i such that for every pair t' and t'' with $t'' < t' < t^i$ or $t^i < t' < t''$,

$$EC^i(t') < EC^i(t'') \tag{19}$$

Moreover, t^i is defined by the first order condition of the minimization of (11*)* with respect to t. This condition can be expressed in any of the three following equivalent forms:

$$\lambda_b^i \cdot Pr[B|t^i] \quad = \quad \lambda_e^i \cdot \Pr[G|t^i] \tag{20}$$

$$(1-\gamma^i)\lambda_b^i \cdot f(t^i|B) \cdot \eta \quad = \quad \gamma^i \lambda_e^i \cdot f(t^i|G) \cdot \eta \tag{21}$$

$$l(t^i) \quad = \quad k^i \tag{22}$$

where $\eta \equiv [\gamma^i f(y|G) + (1-\gamma^i) f(y|B)]^{-1}$.

The third relation establishes that the signal that equals the prior cost ratio to the density ratio minimizes expected costs. This signal defines the threshold value t^i. In other words, if the signal is higher than t^i, the agent agrees with the increase, and, if the signal is lower than t^i, the agent prefers to keep the *status quo*. Since MLRP holds, a more conservative agent (with a higher k^i) would require a higher signal for agreeing with the increase because t^i is increasing in k^i.

Expected costs are defined as single-peaked if, for any pair of thresholds t' and t'' such that either $t' < t'' < t^i$ or $t^i < t'' < t'$, $EC^i(t') > EC^i(t'')$.

Recall that preferences of agent i are

$$EC^i(t) = \lambda_b^i \cdot F_B^i(t) + \lambda_e^i \cdot F_G^i(t)$$

Consider any pair of thresholds t' and t'' such that $t' < t'' < t^i$ and notice that

$$EC^i(t') - EC^i(t'') = \lambda_b^i \cdot \left[F_B^i(t') - F_B^i(t'')\right] + \lambda_e^i \cdot \left[F_G^i(t') - F_G^i(t'')\right]$$

$$= \lambda_b^i \cdot (1-\gamma^i) \int_{t'}^{t''} f(y|B)\eta \, dy + \lambda_e^i \cdot \gamma^i \int_{t''}^{t'} f(y|G)\eta \, dy$$

$$= \int_{t'}^{t''} \lambda_e^i \cdot \gamma^i \cdot f(y|B)\eta \, [k^i - l(y)] \, dy$$

is always positive because $l(y)$ is increasing by MLRP and $t' < t'' < t^i$.

The same reasoning proves that $EC^i(t') > EC^i(t'')$ when $t^i < t'' < t'$.