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# Putting Foxes in Charge of the Hen-House: The Political Economy of Harvest Quota Regulations

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**Abstract** This paper considers a dynamic common agency model of natural resource harvest quota regulation in which both conservationists and harvesters vie to influence the regulator's quota allocations as well as the choice of regulator. Conservationists tend to benefit from the adoption of regulation since the regulator will reduce the aggregate harvest quota relative to the unregulated equilibrium. Harvesters, however, only support the adoption of regulation if the regulator places sufficient weight on their welfare. Because harvester's support of regulation is conditional while conservationist's support of regulation is unconditional, harvester's interests tend to be over-represented in the truthful Markov Perfect equilibrium.

**Keywords** Natural resources · Conservation · Political economy · Common agency · Truthful Markov perfect equilibrium

**JEL Classification** D72 · C73 · Q28 · Q38

## 1 Introduction

In 1995, the U. S. House of Representatives version of the reauthorization of the Magnuson Fishery Management Act would have allowed voting members on the federal fishery management councils to be "selected for their fisheries expertise as demonstrated by their academic training, marine conservation advocacy, consumer advocacy, or other affiliation with nonuser groups." However, the Senate version, which became law, required only that voting members "be individuals who, by reason of their occupational or other expertise, scientific expertise, or training are knowledgeable regarding the conservation and management, or the commercial

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or recreational harvest, of the fishery resources."[1] Regulatory agencies have been established for many natural resources that limit the total harvest and allocate quotas across harvesters.[2] The user groups represented on these bodies typically include harvesters-fishermen, whalers, oil producers, land- and resource-owners, etc.—and on occasion non-consumptive users such as conservationists. Conservation groups often complain that regulatory panels such as these are biased towards harvesters (e.g., Okey 2003; Eagle et al. 2003). Pontecorvo (1977) estimated that at the time of their formation, 57% of the U.S. regional Fishery Council Members represented commercial fishing, 22% represented recreational fishing, and only 21% represented the general public. Okey (2003, p. 193) found that this had not much changed in the succeeding years:[3]

> "In the United States, commercial fishing interests made up 49% of appointed voting members of the eight Regional Fishery Management Councils between 1990 and 2001; recreational fishing interests made up 33%, and all other interests combined made up 17%. Dominance of commercial fishing representation over the 'otherć6 group was statistically significant, and this unequal apportionment of interests remained statistically stable throughout the 12 years of reporting."

Indeed, in very few instances do conservationists seem to dominate harvesters in their representation on these regulatory bodies.[4] Why is this? Why do natural resource regulatory agencies show a preference for harvesting groups over conservation groups? And what effect, if any, does such a preference have on the sustainablility of the resource?

This paper considers a dynamic common agency model in which harvester and conservation groups compete to influence a regulator who chooses and allocates harvest quotas for a natural resource. Since the primary conservation issue in most natural resource problems

[1] Section 302(b) 16 U. S. C. 1852. (See Cloutier 1996 for a discussion of these bills.) The Audubon Society points out that the Atlantic States Marine Fisheries Commission "is composed of 19 individuals. Of these, 15 are associated with the fishing industry" (quoted in Horseshoe Crab Plan, November 1998, National Audubon Society, Washington, D.C.) See Okey (2003) for evidence that this pattern is true more broadly across the eight U.S. regional Fishery Management Councils.

[2] Other renewable resource examples include the Migratory Waterfowl Treaty, signed by Canada, the United States and Mexico in 1916 to allocates harvests of waterfowl across the three countries; the Colorado River Compact, signed by Arizona, California, Colorado, Nevada, New Mexico, Utah and Wyoming in 1921 to allocate water rights among the western states; the International Pacific Halibut Commission, formed in 1923 by the United States and Canada to allocate halibut harvests both across countries and fishery harvest gear types; the International Whaling Commission, formed in 1946 by forty whaling nations to allocate harvest quotas (it now has banned all harvests); the Convention on International Trade in Endangered Species, formed in 1973 and now signed by 150 countries to prohibit or control trade in many endangered species; and the Common Fishery Policy, enacted by the European Union in 1980 to allocate commercial harvests of fish. Examples dealing with exhaustible resources include unitized oilfields, where the regulator allocates extraction shares in commonly owned oil pools, and the Organization of the Petroleum Exporting Countries, which allocates production quotas across its members. In addition, many major environmental treaties such as the Montreal Protocol on ozone depleting substances and the Kyoto Agreement on greenhouse gases (if ratified) grant regulators with the power of determining the total quota and allocating that quota across various users. In almost all of these examples, quota regulations are used in lieu of price regulations.

[3] These authors argue that the harvesters have a conflict of interest in managing the resource, since "60% of appointed council members have a direct financial interest in the fisheries they manage and regulate" (Eagle et al. 2003, at p. 2). These arguments do not seem to be economic, as the councils are imbued with the power to regulate harvests, and harvesters should care about future harvests as well as present harvests. In addition, such views doe not appear to be empirically supported. Ostrom (1990), for example, provides a number of examples where those with "direct financial interests" in managing resources have done so in a sustainable manner.

[4] Conservationists dominate on the International Whaling Commission and the Convention on Trade in Endangered Species, and were influential in the Montreal Protocol and the Kyoto Agreements.

is the rate at which the stock is exploited over time, the model is dynamic. Each harvester's instantaneous welfare depends upon his own harvest quota, and each conservationist's welfare depends on the stock remaining after harvesting. The regulator cares about the gross welfare of both harvesters and conservationists, since their gross welfare translates positively into electoral support for the regulator or the regulator's overseers. However, since the regulator's quota allocations affects their welfare, harvesters and conservationists lobby the regulator via campaign contributions. The regulator benefits from campaign contributions, because they may be consumed directly[5] or used to influence uninformed voters.[6] The contributions paid by each interest group are in the form of contingency contracts specifying a payment that depends upon the harvest quotas chosen by the regulator. A key assumption is that neither the regulator nor the interest groups are able to commit to future actions. This assumption not only drives the solution technique (Markov perfection), but it also focuses attention on the "constitutional" restrictions one might expect to see in sustainable treaties, laws, and agreements.[7]

The common agency model was first developed by Bernheim and Whinston (1986) and adapted to political economy by Grossman and Helpman (1994). It has since been extended to a dynamic framework by Bergemann and Valimaki (2003). Laussel and LeBreton (1996) have derived the allocation of rents between the agent and the principals.[8] The harvesters and conservationists act as principals who each attempt to influence the common agent, the regulator, in the regulator's choice of the harvest quotas. As in Bergemann and Valimaki (2003), the strategy space of each agent is restricted to Markov decision rules, implying that the history of the game is reduced to the current state-the size of the resource stock. Following Bernheim and Whinston, the strategies employed by the principals are also required to be "truthful." Bernheim and Whinston show that restricting players to truthful strategies in common agency games involves no cost, since if other players behave truthfully, then a truthful strategy is always a best-response. Bergemann and Valimaki show that this holds in dynamic games as well.

The first objective of this paper is to derive and characterize the truthful Markov perfect equilibrium (TMPE) harvest quotas in a dynamic common agency model of the regulation of a natural resource that generates consumptive and non-consumptive use values to different groups.[9] The regulator solves the common property problem among the harvesting groups by restricting the harvest of each group relative to the common property equilibrium-a move that benefits both harvesters and conservationists in the long-run. However, the regulator also forces harvesters to internalize the stock externality they impose upon conservationists by restricting the aggregate harvest to a level never larger than that which maximizes the joint

5 Cloutier (1996, pp.134–140) discusses several examples where Fishery Management Council members may have been persuaded by financial inducements to alter the way they voted on regulations before the council.

6 The assumption that the regulator can use the contributions to influence uniformed groups is a key, but controversial, assumption in the common agency literature. See Coate and Morris (1995) for a criticism of the view that uninformed voters can be influenced by politicians. Ironically, even with the assumption that politicians are able to deceive uninformed voters, it is possible to obtain results that appear remarkably efficient (Dixit et al 1997).

7 Constitutional restrictions include boilerplate statements about conservation being the primary goal (included in most agreements), explicit statements about which members have which particular voting rights (e.g., the United Nations), and, in some instances, specific allocations of the resource (e.g., the Colorado River Compact).

8 Other applications of the common agency model include regulation of multinational firms (Bond and Gresik 1996), government tax policy (Dixit et al 1997), lobbying by capital and labor over labor policies (Rama and Tabellini 1998), supply of public goods (Persson 1998), and the internalization of environmental externalities (Aidt 1998).

9 Freeman (1992) reviews the literature on non-consumptive use values.

welfare of the harvesting groups. The share of the stock harvested in each period decreases as the effective political weight for the conservationists increases or as the effective political weight of the harvesters decreases. The effective political weights assigned to each group in the common agency equilibrium are increasing in the group's electoral importance to the regulator, decreasing in the transaction costs faced by the group in raising the contributions, and increasing in the intensity of the group's preferences.

The second objective of the paper is to address the question of when and in what form regulation is likely to occur. I address this question by asking how the welfare of each group is affected by adopting regulation, while varying the electoral importance of each group to the regulator. Because at the constitutional stage, a supermajority is required-which I model as unanimity-the regulation is supported by a principal only if the regulation provides net rents for each of the principals that are in excess of those the principals could obtain absent regulation. The constitutional restrictions take the form of allocations of memberships on regulatory bodies. Because harvesters have the most to lose from regulation—i.e., they could receive a harvest quota allocation of zero, whereas conservationists always benefit at least from the solution of the common property problem—harvesters fight harder than conservationists for representation on regulatory governing bodies.[10] Perhaps ironically, this occurs because conservationists benefit in net from regulation no matter what their electoral importance with the regulator. Harvesters, in contrast, are willing to support regulation only if the regulation provides rents in excess of what they earn absent regulation. Since this occurs only if the harvester's welfare is given sufficient weighting in the regulator's welfare function, harvesters gain extraordinary representation on regulatory bodies.

The remainder of the paper is organized as follows. Section 2 derives the truthful Markov perfect equilibrium for a simple dynamic common agency model. Section 3 derives the Markov perfect equilibrium for the unregulated case, and shows how this is affected by different property rights regimes. Section 4 examines the welfare effects, both on the individual interest groups, and for society as a whole, of adopting regulation. Section 5 concludes the paper with a brief discussion of the results.

## 2 The Quota Regulated Equilibrium

### 2.1 Assumptions

Let the set of principals (the interest groups) be denoted as $\Gamma = \Gamma_H \cup \Gamma_C$, where $\Gamma_H \equiv \{1, 2, \ldots, N\}$ is the set of $N$ harvesters and $\Gamma_C \equiv \{1, 2, \ldots, M\}$ is the set of $M$ conservationists. Throughout, I use the notation $\Gamma_{H\setminus h}$, $\Gamma_{C\setminus c}$, or $\Gamma_{\setminus j}$ to denote the set excluding harvester $h$, conservationist $c$, or group $j$. The instance where there is one harvesting group ($N = 1$) is taken to imply that private property rights exist for the stock, since with private property rights the harvesters will maximize the joint returns of the harvesting sector (Scott 1955).

Harvester $h$ exploits the resource, harvesting $Y_{ht}$ units in period $t$. The aggregate harvest in period $t$ is $Y_t \equiv \sum_{h\in\Gamma_H} Y_{ht}$. Let $Z_t = X_t - Y_t$, denote the stock remaining at the end of each harvest period, where $X_t \in [0, 1]$ is the stock beginning at period $t$. Harvester $h$ earns utility $u_h(Y_{ht}) = \nu_i \log(Y_{ht})$ in period $t$, and conservationist $c$ earns utility $u_c(Z_t) = \nu_c \log(Z_t)$ in period $t$. These functional forms imply that both types of principals' utility functions are

[10] This argument is independent of differences in free-riding costs for the two types of groups. It is difficult to reconcile the free-riding argument with the evidence: groups such as Greenpeace, the World Wildlife Fund, the Audubon Society, the Sierra Club, and the Environmental Defense Fund are exceptionally well organized. The Environmental Defense Fund holds a voting membership on the New England Fishery Management Council.

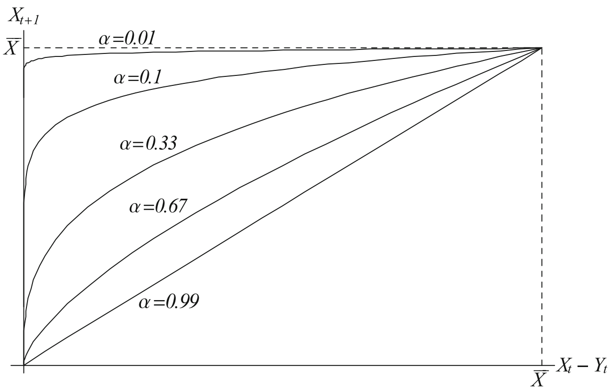


**Fig. 1** The Biological Growth Function

concave in the relevant arguments. In order for harvesters to earn positive utility absent regulation, it is assumed that the rents are infra-marginal, say due to heterogeneity (e.g., Johnson and Libecap 1982; Karpoff 1987). The parameters $\nu_h > 0$, $j \in \Gamma$, measures the relative *preference intensity* of group $j$. Both total and marginal utility are increasing in $\nu_j$, implying that the $\nu_j$ act as demand shifters.

The regulator, $R$, chooses a harvest quota for each harvester in each period.[11] In making this choice, the regulator considers how the harvest quotas affect the welfare of the harvester and conservation groups, and how the harvest quotas affects the contributions each group pays to the regulator (Bernheim and Whinston 1986; Grossman and Helpman 1994). The regulator cares about the welfare of the groups because the group's support for the regulator (e.g., votes, demonstrations, letter-writing campaigns, etc.) depends upon their utility level. The regulator cares about the contributions because she can use the funds either for herself or to convince uninformed voters to vote for her.[12] The contributions the regulator receives are incentive contracts that specify the contribution as a function of the current harvest quotas.

The model is dynamic, because the future stock is affected by the harvest decisions in the current period. Following Levhari and Mirman (1980), the equation of motion of the stock is given by

$$X_{t+1} = (X_t - Y_t)^{\alpha}, \quad t = 0, 1, 2, \ldots, \tag{1}$$

for some $\alpha \in [0, 1]$, with $X(0) = X_0$ fixed. This function has the property that the unexploited stock (i.e., where $Y_t = 0$ for all $t$) approaches $\bar{X} = 1$ in the steady-state. (See Fig. 1.) As the parameter $\alpha$ increases, the value of $X_{t+1}$ decreases for any $Z_t < 1$. Thus, lower levels of $\alpha$ correspond to faster growing biological populations. Indeed, as $\alpha \to 1$, the rate of growth approaches zero, so harvesting exhausts the resource (e.g., oil, minerals, or old growth forest). As $\alpha \to 0$, the resource renews itself to the same level ($X_t = \bar{X}$) each year, independent of the size of the remaining stock. Finally, when $0 < \alpha < 1$, the growth in the stock, $X_{t+1} - X_t$, is concave in $X_t$: i.e., $\frac{d[X_{t+1}-X_t]}{dX_t} = \alpha(X_t - Y_t)^{\alpha-1} - 1$, which may be positive or negative, and $\frac{d^2[X_{t+1}-X_t]}{dX_t^2} = (\alpha - 1)\alpha(X_t - Y_t)^{\alpha-2} < 0$. This occurs for

[11] I am assuming that the regulator adopts only harvest quota restrictions, which he may allocate across harvester groups. Other forms of regulation, such as tradable quotas, input restrictions, or limited entry are not considered. See Boyce (2004) for an analysis of these restrictions when the harvest quota is exogenous.

[12] I do not, however, explicitly model the process by which the regulator is selected. See Persson (1998).

resources such as ground and surface water and, to some extent, herring and shrimp, which are harvested after they spawn.

The objective of harvesters and conservationists is to maximize the present value of the stream of utility net of the costs of influencing the regulator. In each period, each principal observes the stock $X_t$, and then the principals simultaneously and non-cooperatively offer the regulator payment $b_j(\mathbf{s}_t)$, $j \in \Gamma$, contingent upon the vector of harvest quota shares $\mathbf{s}_t = \{s_{1t}, s_{2t}, \dots, s_{Nt}\}$ chosen by the regulator, where each harvester's allowable quota, $Y_{ht} = s_{ht} X_t$, is expressed as a share ($s_{ht}$) of the stock, $X_t$, the regulator allows harvester $h$ to harvest. The regulator, after observing the stock $X_t$ and the incentive contracts $b_j(\mathbf{s}_t)$, chooses the harvest quotas $\mathbf{s}_t$ to maximize her own utility. Thus, there exists a Stackelberg relationship between the interest groups and the regulator, with the interest groups moving first, but simultaneously with one another.

Following Bergemann and Valimaki (2003), the strategy space of the harvesters and conservationists is restricted to Markov strategies.[13] In addition, I use a variation on the methodology first developed by Levhari and Mirman (1980) to solve dynamic Markov games.[14] As the steady-state consumption levels in games with log utility and growth function (1) are constant shares of the stock, I shall conjecture that the shares are constant over all time, i.e., the future harvest shares, $s_{h\tau} = \theta_h > 0$, for $\tau = t+1, t+2, t+3, \dots$ where $\sum_{h \in \Gamma_H} \theta_h = \theta < 1$. Thus the aggregate harvest in period $t+1$ is $Y_{t+1} = \theta X_{t+1}$; the period $t+2$ aggregate harvest is $Y_{t+2} = \theta X_{t+2} = \theta[(1-\theta)X_{t+1}]^{\alpha}$, the period $t+2$ aggregate harvest is $Y_{t+3} = \theta X_{t+3} = \theta[(1-\theta)^{1+\alpha} X_{t+1}^{\alpha}]^{\alpha}$, and so on. Since the harvest shares in the future are independent of the stock size, the incentive contracts offered to the regulator by each harvester and conservationist do not change with the current stock size. Thus $b_j(\theta)$, where $\theta = \{\theta_1, \theta_2, \dots, \theta_N\}$, is a constant in each future period. This means that the only thing that evolves over time is the stock of the resource. I shall later verify that the equilibrium harvest shares in period $t$ are independent of the stock size.

Under these assumptions, after period $t$ the stock evolves according to:

$$X_{t+1+\tau} = (1-\theta)^{\sum_{v=1}^{\tau} \alpha^v} X_{t+1}^{\alpha^\tau} \quad \tau = 1, 2, 3, \dots. \tag{2}$$

Let $\beta \in (0, 1)$, denote the discounted present value of returns one period in the future. Thus from (2), at time $t+1$, the present value of the stream of utility to harvesters and conservationists, respectively, given stock $X_{t+1}$ can be written as

$$U_h(X_{t+1}) = \sum_{\tau=0}^{\infty} \beta^\tau \left[ \log(\theta_h X_{t+1+\tau}) - \frac{b_h(\theta)}{\kappa_h} \right] = \frac{\nu_h \log(X_{t+1})}{1-\alpha\beta} + A_h, \quad h \in \Gamma_H,$$
$$U_c(X_{t+1}) = \sum_{\tau=0}^{\infty} \beta^\tau \left[ \log[(1-\theta) X_{t+1+\tau}] - \frac{b_h(\theta)}{\kappa_c} \right] = \frac{\nu_c \log(X_{t+1})}{1-\alpha\beta} + A_c, \quad c \in \Gamma_C,$$

where $A_h$ and $A_c$ are constants which depend only upon the the discount and growth parameters and the fixed harvest shares $\theta$. Thus, the period $t$ utility functions for the harvesters and conservationists, respectively, are:

[13] This rules out punishment strategies such as the "trigger strategies" used by Cave (1987) and Hannesson (1997).

[14] Levhari and Mirman assumed that the harvest quotas are endogenously chosen only up to period $T$. After period $T$, the actions are fixed. This allows one to utilize backwards induction methods to solve the game beginning at some arbitrary period $T - t$. The steady-state is found by taking the limit as $t \to \infty$.

$$U_h(X_t, \mathbf{s}_t) = \nu_h \log(s_{ht} X_t) - \frac{b_h(\mathbf{s}_t)}{\kappa_h} + \frac{\alpha\beta\nu_h \log[(1-s_t)X_t]}{1-\alpha\beta} + \beta A_h, \quad h \in \Gamma_H, \tag{3}$$

$$U_c(X_t, \mathbf{s}_t) = \nu_c \log[(1-s_t)X_t] - \frac{b_c(\mathbf{s}_t)}{\kappa_c} + \frac{\alpha\beta\nu_c \log[(1-s_t)X_t]}{1-\alpha\beta} + \beta A_c, \quad c \in \Gamma_C, \tag{4}$$

where $s_t = \sum_{h\in\Gamma_H} s_{ht}$ is the aggregate share of the harvest in period $t$. The first two terms on the right-hand-side of (3) and (4) are the gross utility less the payment to the regulator in period $t$, while the third and fourth terms are the present value of the period $t+1$ forward actions, using (2) and the assumption that the harvest shares in future periods are constant. The non-transfer cost associated with payment $b_j(\mathbf{s}_t)$ is

$$\frac{b_j(\mathbf{s}_t)}{\kappa_j} - b_j(\mathbf{s}_t) = \left(\frac{1-\kappa_j}{\kappa_j}\right) b_j(\mathbf{s}_t). \tag{5}$$

As $\kappa_j \to 1$, the transactions costs to group $j$ of making transfer $b_j(\mathbf{s}_t)$ to the regulator approaches zero. However, as $\kappa_j \to 0$, the transactions costs become prohibitively large. Thus, $\kappa_j$ serves as a parametric measure of the lobbying ability of principal $j$ to influence policy via transfers to the regulator. As $\kappa_j$ increases, group $j$'s costs of raising $b_j(\mathbf{s}_t)$ decreases, thus $\kappa_j$ is a measure of the *lobbying effectiveness weight* for group $j$ (e.g., Olson 1965; Aidt 1998).

Let us now turn to the regulator. Following Grossman and Helpman (1994), let the regulator's utility be a linear function of the utility and contributions of the harvesters and conservationists:

$$\begin{aligned} U_R(X_t, \mathbf{s}_t) = {} & \sum_{h\in\Gamma_H} \gamma_h \nu_h \log(s_{ht} X_t) + \sum_{c\in\Gamma_C} \gamma_c \nu_c \log[(1-s_t)X_t] + \sum_{j\in\Gamma} b_j(\mathbf{s}_t) \\ & + \left(\frac{\alpha\beta}{1-\alpha\beta}\right) \sum_{j\in\Gamma} \gamma_j \nu_j \log[(1-s_t)X_t] + \beta \sum_{j\in\Gamma} \gamma_j A_j, \end{aligned} \tag{6}$$

where the $\gamma_j$ parameters measure the value to the regulator of the welfare of the interest groups. Since groups with larger voting populations may receive a larger $\gamma_j$ (cf., Denzau and Munger 1986), $\gamma_j$ is denoted as the *electoral importance weight* the regulator places on the gross welfare of group $j \in \Gamma$.

## 2.2 The Markov Perfect Common Agency Equilibrium

The Markov common agency game in period $t$ proceeds as follows. From Proposition 1 of Grossman and Helpman (Lemma 2 of Bernheim and Whinston 1986), the regulator chooses the harvest quotas $s_{ht}$ to maximize $U_R(X_t, \mathbf{s}_t)$, taking the incentive contracts $b_j(\mathbf{s}_t)$ of the interest groups as given. Thus:

$$\frac{\gamma_h \nu_h}{s^*_{ht}} - \frac{\gamma_c \nu_c}{1-s^*_t} + \sum_{j\in\Gamma} \frac{\partial b_j(\mathbf{s}^*_t)}{\partial s_{ht}} - \frac{\alpha\beta \sum_{j\in\Gamma} \gamma_j \nu_j}{(1-\alpha\beta)(1-s^*_t)} = 0. \tag{7}$$

Therefore, the regulator takes into account how an increase in $s^*_{ht}$ affects both present and future utilities of each of the groups as well as how it affects the contingency payments from each group.

Similarly, Grossman and Helpman's Proposition 1, which Bergemann and Valimaki (2003) show holds in general dynamic games, implies that the harvest quota must also maximize the joint welfare of the regulator and each interest group individually, i.e., $\mathbf{s}^*_t$ maximizes

$U_R + U_j$, $j \in \Gamma$. However, since (7) implies $\partial U_R/\partial s_{ht} = 0$, maximization of $U_R + U_j$ implies $\partial U_j/\partial s_{ht} = 0$, for each $j \in \Gamma$. Thus

$$\begin{aligned}
\frac{\partial b_h(\mathbf{s}_t^*)}{\partial s_{ht}} &= \frac{\kappa_h \nu_h}{s_{ht}^*} - \frac{\alpha\beta\kappa_h\nu_h}{(1-s_t^*)(1-\alpha\beta)}, \quad h \in \Gamma_H \\
\frac{\partial b_j(\mathbf{s}_t^*)}{\partial s_{ht}} &= -\frac{\alpha\beta\kappa_j\nu_j}{(1-s_t^*)(1-\alpha\beta)}, \quad j \neq h \in \Gamma_H \\
\frac{\partial b_c(\mathbf{s}_t^*)}{\partial s_{ht}} &= -\frac{\kappa_c\nu_c}{(1-s_t^*)(1-\alpha\beta)}, \quad c \in \Gamma_C.
\end{aligned} \tag{8}$$

These conditions imply that the contributions are locally truthful: At the margin, the change in the contribution from group $j$ as $s_{ht}$ increases equals the change in value to group $j$ of a unit of additional harvest quota given to harvester $h$. In general, an increase in the harvest quota to harvester $h$ reduces the payment from other harvesters and conservationists, reflecting the externality the group imposes on these other groups. For a self-replenishing resource such as ground or surface water, where $\alpha = 0$, it follows that $\partial b_j^*/\partial s_{ht} = 0$, for $h \neq j, h, j \in \Gamma_H$. Thus, other harvesters are unaffected by an increase in $h$'s harvest quota.[15] However, conservationists are affected even when $\alpha = 0$, since their utility depends upon the quantity of water left in the reservoir at the end of each period. For any resource for which tomorrow's stock depends upon today's harvest quotas (i.e., $\alpha > 0$), both the other harvesters and the conservationists will oppose an increase in harvester $h$'s quota. Finally, note that a decrease in the lobbying ability of group $j$ (an increase in $j$'s transaction costs) diminishes the ability of group $j$ to offer an effective incentive contract. Indeed, in the limit as $\kappa_j \to 0$, the marginal contribution vanishes, and the group has no influence over the regulator other than through the electoral weight, $\gamma_j$ the regulator places on the group's utility.

Let us now characterize the common agency equilibrium in period $t$. Combining (7) and (8) yields:

$$\frac{\omega_h}{s_{ht}^*} = \frac{\omega_C + \alpha\beta\omega_H}{(1-s_t^*)(1-\alpha\beta)}, \quad h \in \Gamma_H, \tag{9}$$

where $\omega_j \equiv (\gamma_j + \kappa_j)\nu_j$, $j \in \Gamma$, are the *effective political weights* assigned to the harvesters and the conservationists in the political equilibrium, and where $\omega_H \equiv \sum_{h\in\Gamma_H} \omega_h$ and $\omega_C \equiv \sum_{c\in\Gamma_C} \omega_c$ are the *aggregate* effective political weights the regulator places on harvesters and conservationists, respectively, as a group. The effective political weight for each group is increasing in the group's electoral importance weight, $\gamma_j$, increasing in the group lobbying effectiveness weight, $\kappa_j$, and increasing in the group's preference intensity weight, $\nu_j$. In addition, these weights also implicitly depend upon the number of harvester and conservationist groups.

Solving the system of Eq. (9) for the share of the stock the regulator allows harvester $h$ to harvest in the truthful Markov perfect equilibrium yields

$$s_h^* = \frac{(1-\alpha\beta)\omega_h}{\omega_H + \omega_C}, \quad h \in \Gamma_H. \tag{10}$$

[15] This assumes that the pumping costs are unrelated to the stock size. In a more general model where the utility of harvesters also depends upon the stock remaining, this would not be true.

Hence the aggregate share of the stock that is harvested is

$$s^* = \sum_{h\in\Gamma_H} \frac{(1-\alpha\beta)\omega_h}{\omega_H+\omega_C} = \frac{(1-\alpha\beta)\omega_H}{\omega_H+\omega_C}. \tag{11}$$

As conjectured, the shares $s_h^*$ and $s^*$ are independent of the size of the stock in period $t$. Thus, in what follows, I have dropped the time subscript on the harvest shares, writing them as $s_h^*$ and $s^*$, respectively.

The equilibrium harvest share of harvester $h$, $s_h^*$, is increasing in his own effective political weight, $\omega_h$, and is decreasing in the aggregate political weight of the other harvesters and of conservationists. The aggregate equilibrium harvest share of the stock, $s^*$, is increasing in $\omega_H$ and decreasing in $\omega_C$. However, in the limit as $\omega_H \to \infty$ (or, equivalently, as $\omega_C \to 0$), $s^*$ approaches $1-\alpha\beta$. We shall see below that this limit corresponds to the harvest rate that maximizes the joint welfare of the harvesters.

## 2.3 Truthful Contributions

In order to consider the welfare properties of this model, I need to solve for the equilibrium contributions, $b_j(\mathbf{s}^*)$. The necessary conditions (8), however, only tie down the marginal properties of the contribution functions, so there are any number of contribution functions that satisfy (8). But Bernheim and Whinston (1986) show that if we restrict ourselves to contribution functions that are globally truthful, denoted as $b_j^T(\mathbf{s}^*)$ (where the superscripted '$T$' indicates "globally truthful") then unique contribution functions exist. These are also a best-response when the other players behave truthfully, and are coalition proof, implying neither an individual principal nor any group of principals can improve their lot by deviating.

A truthful contribution by principal $j \in \Gamma$ is one such that $j$ pays exactly the difference between his gross utility in equilibrium and his gross utility to he contributes zero. Let $\mathbf{s}^{-j}$ denote the policy chosen when $b_j^T(\mathbf{s}^{-j}) = 0$. In order for the regulator to choose policy $\mathbf{s}^*$, she must be indifferent between $\left(\mathbf{s}^*, \{b_j^T(\mathbf{s}^*)\}|_{j\in\Gamma}\right)$ and $\left(\mathbf{s}^{-j}, \{0, b_k^T(\mathbf{s}^{-j})\big|_{k\in\Gamma_{\setminus j}}\}\right)$, where the $j$th contribution has been replaced with zero. No principal wishes to contribute more than $b_j^T(\mathbf{s}^{-j})$, since his net utility is decreasing in $b_j^T(\mathbf{s}^{-j})$. Thus, for harvester $h$, the regulator's indifference implies

$$\begin{aligned} b_h^T(\mathbf{s}^*) = &\sum_{j\in\Gamma_H} \gamma_j\nu_j \log\left(\frac{s_j^{-h}}{s_j^*}\right) + \sum_{c\in\Gamma_C} \gamma_c\nu_c \log\left(\frac{1-s^{-h}}{1-s^*}\right) \\ &+ \frac{\alpha\beta}{1-\alpha\beta}\sum_{j\in\Gamma}\gamma_j\nu_j \log\left(\frac{1-s^{-h}}{1-s^*}\right) + \sum_{j\in\Gamma_{\setminus h}} \left[b_j^T(\mathbf{s}^{-h}) - b_j^T(\mathbf{s}^*)\right] \quad h\in\Gamma_H. \end{aligned}$$

If the other contributions are globally truthful, then

$$b_j^T(\mathbf{s}^{-h}) - b_j^T(\mathbf{s}^*) = \kappa_j\nu_j \log\left(\frac{s_j^{-h}}{s_j^*}\right) + \frac{\alpha\beta\kappa_j\nu_j}{1-\alpha\beta}\log\left(\frac{1-s^{-h}}{1-s^*}\right), \quad j\in\Gamma_{H\setminus h},$$

and

$$b_c^T(\mathbf{s}^{-h}) - b_c^T(\mathbf{s}^*) = \frac{\alpha\beta\kappa_c\nu_c}{1-\alpha\beta}\log\left(\frac{1-s^{-h}}{1-s^*}\right), \quad c\in\Gamma_C.$$

Therefore,

$$b_h^T(\mathbf{s}^*) = \gamma_h \nu_h \log\left(\frac{s_h^{-h}}{s_h^*}\right) + \frac{\omega_C + \alpha\beta(\omega_{H\backslash h} + \gamma_h \nu_h)}{1-\alpha\beta} \log\left(\frac{1-s^{-h}}{1-s^*}\right) + \sum_{j \in \Gamma_{H\backslash h}} \omega_j \log\left(\frac{s_j^{-h}}{s_j^*}\right), \quad h \in \Gamma_H, \tag{12}$$

where

$$\omega_{H\backslash h} = \sum_{j \in \Gamma_{H\backslash h}} \omega_j, \quad s_h^{-h} = \frac{(1-\alpha\beta)\gamma_h \nu_h}{\omega_C + \omega_{H\backslash h} + \gamma_h \nu_h}, \quad h \in \Gamma_H,$$

$$s_j^{-h} = \frac{(1-\alpha\beta)\omega_j}{\omega_C + \omega_{H\backslash h} + \gamma_h \nu_h}, \quad j \neq h \in \Gamma_H, \text{ and } s^{-h} = \frac{(1-\alpha\beta)(\omega_{H\backslash h} + \gamma_h \nu_h)}{\omega_C + \omega_{H\backslash h} + \gamma_h \nu_h}.$$

By a similar process, the truthful equilibrium transfer to the regulator by conservationist $c$ is

$$b_c^T(\mathbf{s}^*) = \frac{\omega_{C\backslash c} + \gamma_c \nu_c + \alpha\beta\omega_H}{1-\alpha\beta} \log\left(\frac{1-s^{-c}}{1-s^*}\right) + \sum_{j \in \Gamma_H} \omega_j \log\left(\frac{s_j^{-c}}{s_j^*}\right), \quad c \in \Gamma_C, \tag{13}$$

where

$$\omega_{C\backslash c} = \sum_{j \in \Gamma_{C\backslash c}} \omega_j, \quad s_h^{-c} = \frac{(1-\alpha\beta)\omega_h}{\omega_{C\backslash c} + \omega_H + \gamma_c \nu_c}, \quad \text{and } s^{-c} = \frac{(1-\alpha\beta)\omega_H}{\omega_{C\backslash c} + \omega_H + \gamma_c \nu_c}.$$

Thus, when principal $j$ does not contribute to the regulator, it is as though their effective political weight becomes $\gamma_j \nu_j$, which, as Grossman and Helpman (1994) observe, is the weight group $j$ would receive in the political welfare function if it were unorganized—i.e., if $\kappa_j = 0$.

The equilibrium truthful contributions given by (12) and (13) do not depend upon $X_t$. Thus, equating $s_h^* = \theta_h$ and $s^* = \theta$ in (2) implies that this equilibrium holds for *all* $t$. This verifies that the assumed constant harvest shares hold in equilibrium.

**Proposition 1** *In the regulated equilibrium, a constant proportion of the stock is harvested each period, and payments by each interest group to the regulator are also constant, depending only upon the shares of the stock harvested by each harvester.*

Thus, in the Markov common agency equilibrium, each harvester removes a constant portion of the stock $s_h^* = \frac{(1-\alpha\beta)\omega_h}{\omega_H + \omega_C}$, $h \in \Gamma_H$. The proportion of the stock harvested by harvester $h$ is an increasing function of the effective welfare weight given to harvester $h$, and a decreasing function of the effective welfare weight to other harvesters and conservationists. In addition, harvester $h$'s harvest quota share is decreasing in $\alpha$, which is inversely proportional to the growth in the stock, and is decreasing in one-period ahead discount factor, $\beta$. The share of the stock harvested in aggregate, $s^* = \frac{(1-\alpha\beta)\omega_H}{\omega_H + \omega_C}$, is an increasing function of the harvester's effective welfare weights, a decreasing function of the conservationist's effective welfare weight, and a decreasing function of both $\alpha$ and $\beta$. Thus, the increase in $h$'s aggregate harvest due to an increase in $\omega_h$ is greater than the decrease to the other $N-1$ harvester's aggregate harvest due to an increase in $\omega_h$. The proportion of the stock remaining at the end of each period, $1 - s^* = \frac{\omega_C + \alpha\beta\omega_H}{\omega_H + \omega_C}$, is an increasing function in $\omega_C$, a decreasing function in $\omega_H$, and an increasing function in both $\alpha$ and $\beta$.

Also appearing in the $b_j^T(\mathbf{s}^*)$, $j \in \Gamma$, functions are the harvest shares of the stock when either one of the harvesters or one of the conservationists does not contribute to the regulator. Harvester $h$'s share when he does not contribute is $s_h^{-h} = \frac{(1-\alpha\beta)\gamma_h \nu_h}{\omega_C+\omega_{H\backslash h}+\gamma_h\nu_h}$, $h \in \Gamma_H$. Since $s_h^*$ is increasing in $\omega_h$, harvester $h$'s share decreases when harvester $h$ does not contribute to the regulator: $s_h^{-h} < s_h^*$. However, when harvester $h$ does not contribute, the other harvesters' shares, $s_j^{-h} = \frac{(1-\alpha\beta)\omega_j}{\omega_C+\omega_{H\backslash h}+\gamma_h\nu_h}$, $h \neq j, h, j \in \Gamma_H$, increases: $s_j^{-h} > s_j^*$. In addition, when harvester $h$ does not contribute, the aggregate harvest quota share $s^{-h} = \frac{(1-\alpha\beta)(\omega_{H\backslash h}+\gamma_h\nu_h)}{\omega_C+\omega_{H\backslash h}+\gamma_h\nu_h}$, $h \in \Gamma_H$, is smaller than when $h$ does contribute: $s^{-h} < s^*$. Therefore, the reduction in harvester $h$'s quota share is greater than the increase in all other harvester's quota shares. Therefore, $1-s^{-h} > 1-s^*$ implies that the proportion of the stock remaining at the end of each period when $h$ does not contribute is smaller than when $h$ does contribute, which makes conservationists' worse off when $h$ contributes. Similarly, if conservationist $c$ does not contribute, then $s_h^{-c} = \frac{(1-\alpha\beta)\omega_h}{\omega_{C\backslash c}+\gamma_c\nu_c+\omega_H}$, and $s_h^{-c} > s_h^*$, since $s_h^*$ is decreasing in $\omega_C$. If conservationist $c$ does not contribute, the aggregate harvest quota share, $s^{-c} = \frac{(1-\alpha\beta)\omega_H}{\omega_{C\backslash c}+\gamma_c\nu_c+\omega_H}$, is greater than $s^*$, since $s^*$ is decreasing in $\omega_C$. It follows that $1-s^{-c} < 1-s^*$, so that all conservationists are worse off when conservationist $c$ does not contribute.

In harvester $h \in \Gamma_H$'s equilibrium truthful contribution to the regulator $b_h^T(\mathbf{s}^*)$ given in (12), the second and third terms represent compensation to the regulator for the costs harvester $h$ imposes on the regulator through lost contributions from other harvesters for reductions in their current harvest and from other harvesters and other conservationists for the reduction in future harvests. The first term, however, is negative, and represents the additional value the regulator places on an increase in the harvest share to harvester $h$. The equilibrium truthful contribution to the regulator, $b_c^T(\mathbf{s}^*)$, by conservationist $c \in \Gamma_C$ given by (13) equals the costs conservationist $c$ imposes on each harvester $h$ due the the reduction in each harvester's present share of the stock, less the increase in each harvesters' and conservationists' utility from an increase in the stock remaining in the future.

Thus we may write the equilibrium utility of a harvester or of a conservationist, starting with stock $X$, as

$$U_h^*(X) = \frac{\nu_h \log(X)}{1-\alpha\beta} + \frac{\nu_h \log(s_h^*)}{1-\beta} + \frac{\alpha\beta\nu_h \log(1-s^*)}{(1-\beta)(1-\alpha\beta)} - \frac{b_h^T(\mathbf{s}^*)}{(1-\beta)\kappa_h}, \quad h \in \Gamma_H \tag{14}$$

$$U_c^*(X) = \frac{\nu_c \log(X)}{1-\alpha\beta} + \frac{\alpha\beta\nu_c \log(1-s^*)}{(1-\beta)(1-\alpha\beta)} - \frac{b_c^T(\mathbf{s}^*)}{(1-\beta)\kappa_c}, \quad c \in \Gamma_C. \tag{15}$$

## 2.4 The Regulated Steady-State Equilibrium

When the resource is renewable (i.e., whenever $\alpha < 1$), the steady-state stock equals

$$X^* = \left(\frac{\omega_C + \alpha\beta\omega_H}{\omega_C + \omega_H}\right)^{\frac{\alpha}{1-\alpha}}, \quad \text{for } \alpha < 1. \tag{16}$$

Thus, the steady-state stock shares the same qualitative properties as the stock remaining at the end of each harvest period: It is increasing in the aggregate effective political weight of conservationists and decreasing in the effective political weight of harvesters. When $\omega_H = 0$, the welfare of conservationists is maximized, and the individual and aggregate harvest quota share, $s^*$, equals zero. In this case the stock reverts to its natural steady-state value $X^* = 1$.

We shall see below that when $\omega_C = 0$, the harvest quota share equals $s^* = 1 - \alpha\beta$, which maximizes the joint welfare of harvesters.

## 3 The Common Property Equilibrium

In this section, I solve for the equilibrium payoffs for the case where there is no regulation. This is the case considered by Levhari and Mirman (1980). These results are used in the next section both to assess the conditions under which regulation will be voluntarily adopted and to determine when regulation is welfare-improving, relative to the unregulated equilibrium. The assumption maintained throughout is that the public good nature of the conservation benefits prevents conservation groups from purchasing the stock. Thus, even if harvesters enjoy private property rights to the stock, they will still impose an externality on the conservationists. In addition, the structure of the harvesting sector, here taken to be the number of harvesting groups, $N$, is exogenous.

Suppose as before that in all future periods a constant share, $0 < \theta < 1$, of the stock is harvested and that each harvester's share of the stock to be harvested is $\theta_h$, where $\sum_{h\in\Gamma_h} \theta_h = \theta$. Then, using (2), harvester $h$'s objective in period $t$ is to chose $s_{ht}$, taking as given the vector of shares harvested by the other harvesters, $\{s_{1t}, s_{2t}, \ldots, s_{h-1t}, s_{h+1t}, \ldots, s_{Nt}\}$, to maximize

$$U_h(X_t, s_{ht}) = \nu_h \log(s_{ht} X_t) + \frac{\alpha\beta\nu_h \log(Z_t)}{1-\alpha\beta} + \beta A_h, \quad h \in \Gamma_H.$$

Thus the period $t$ Nash equilibrium has solution

$$s_h^{\#} = \frac{N(1-\alpha\beta)}{N(1-\alpha\beta)+\alpha\beta}, \tag{17}$$

which does not depend upon $X_t$ and is therefore independent of time. Therefore, setting $\theta_h = s_h^{\#}$ confirms that this solution works for all $t$. From (17), the aggregate harvest share is $s^{\#} = \frac{N(1-\alpha\beta)}{N(1-\alpha\beta)+\alpha\beta}$. Hence, the share of the stock remaining at the end of each period is $1 - s^{\#} = \frac{\alpha\beta}{N(1-\alpha\beta)+\alpha\beta}$, which is decreasing in $N$ and increasing in $\alpha\beta$.

Hence, the utility of a harvester or conservationist in the unregulated equilibrium is

$$U_h^{\#}(X) = \frac{\nu_h \log(X)}{1-\alpha\beta} + \frac{\nu_h \log(s_h^{\#})}{1-\beta} + \frac{\alpha\beta\nu_h \log(1-s^{\#})}{(1-\beta)(1-\alpha\beta)}, \quad h \in \Gamma_H \tag{18}$$

$$U_c^{\#}(X) = \frac{\nu_c \log(X)}{1-\alpha\beta} + \frac{\alpha\beta\nu_c \log(1-s^{\#})}{(1-\beta)(1-\alpha\beta)}, \quad c \in \Gamma_C. \tag{19}$$

As the number of harvesting groups grows, the aggregate share of the stock that is harvested approaches unity. Thus, in the limit as $N \to \infty$, the stock is completely consumed in the first period. Conversely, when there is only one harvesting group ($N = 1$), the share of the stock harvested in each period equals $s^{\#} = 1 - \alpha\beta$, so the harvest quota share maximizes the welfare of fishermen. This is what occurs if private property rights are well defined for the stock.

In the event that the resource is renewable (i.e., $\alpha < 1$), the unregulated steady-state stock equals

$$X^{\#} = \left(\frac{\alpha\beta}{N(1-\alpha\beta)+\alpha\beta}\right)^{\frac{\alpha}{1-\alpha}}, \quad \text{for } \alpha < 1. \tag{20}$$

Taking the limit as $N \to \infty$, the steady-state stock vanishes. In contrast, in the private property equilibrium ($N = 1$), the steady-state stock equals $X_H^{\#} = (\alpha\beta)^{\frac{\alpha}{1-\alpha}}$, which is greater than $X^{\#}$ since $X^{\#}$ is decreasing in $N$.

It is now possible to show the effect regulation has on the share of the stock that is harvested, and, for the case where $\alpha < 1$, on the steady-state stock:

**Proposition 2** *With regulation, the aggregate share of the stock harvested is never larger, and the aggregate share of the stock that remains after each harvest period is never smaller, than that which occurs absent regulation.*

*Proof* From the definitions of $s^*$ and $s^{\#}$,

$$s^{\#} - s^* = (1 - s^*) - (1 - s^{\#}) = \frac{(1 - \alpha\beta)[N\omega_C + (N - 1)\alpha\beta\omega_H]}{(\omega_C + \omega_H)[N(1 - \alpha\beta) + \alpha\beta]} \geq 0, \qquad (21)$$

and this holds with strict inequality whenever $N > 1$ or $\omega_C > 0$. □

In the event that $\omega_C = 0$, the regulated aggregate harvest quota share is $s^* = 1-\alpha\beta$, which corresponds to the aggregate harvest quota share that maximizes harvesters' joint welfare. In the event that $\omega_H = 0$, the regulated aggregate harvest quota share is $s^* = 0$, which corresponds to the aggregate harvest quota share that maximizes conservationists' joint welfare. These suggest that when $\omega_C$ and $\omega_H$ are each greater than zero, the regulated harvest quota share maximizes the joint welfare of harvesters and conservationists. However, this is not necessarily the case. The equilibrium harvest quota share that maximizes the joint welfare of harvesters and conservationists equals $\frac{(1-\alpha\beta)\sum_{h\in\Gamma_H} \nu_h}{\sum_{h\in\Gamma_H} \nu_h + \sum_{c\in\Gamma_C} \nu_c}$. Thus, the regulated harvest quota share $s^*$ maximizes the joint welfare of harvesters and conservationists, if and only if, the effective political weights are all in the same relative proportions as the harvest intensity parameters, i.e., when $\omega_j = \delta\nu_j$ for all $j \in \Gamma$ for some $\delta > 0$. The regulator, however, is weighting each group's preference intensity by the sum of its electoral plus lobbying ability weights, $\omega_j = \nu_j + \kappa_j$. In the event that the electoral plus lobbying ability weight is equal across groups, the regulator maximizes aggregate welfare because that maximizes the possible contributions she can extract. However, in general, there is no reason for these weights to be equal across interest groups.

## 4 Net Welfare Effects from Regulation

This section examines two issues: When is regulation is likely to be voluntarily supported? And When is regulation socially beneficial, relative to the un-regulated case? The first question is important for understanding the "constitutions" under which regulation is adopted. An important conclusion from this analysis is that harvesters voluntarily support regulation only if their interests are given sufficient weight by the regulator. Thus, harvester's welfare will be given greater weight than that of conservationists in successful regulations. The second question raises the issue that socially beneficial regulation might not be adopted if the regulator takes too large of a proportion of the surplus.

### 4.1 Net Benefits of Regulation to Conservationists

Define $\Delta U_c(X) \equiv U_c^*(X) - U_c^\#(X)$ as the *net* change in welfare to conservationist $c$ from adopting regulation, relative to the no-regulation case.

$$\Delta U_c(X) = \frac{\nu_c}{(1-\beta)(1-\alpha\beta)} \log\left(\frac{1-s^\#}{1-s^*}\right) - \frac{b_c^T(\mathbf{s}^*)}{(1-\beta)\kappa_c}, \quad c \in \Gamma_C. \tag{22}$$

The first term in $\Delta U_c(X)$ is the gross increase in the present value of welfare to conservationists from the adoption of regulation and the second term is the present value of the cost of raising contributions $b_c^T(\mathbf{s}^*)$. This condition is not affected by the starting stock $X$, since neither the contributions $b_c^T(\mathbf{s}^*)$ nor the harvest quota shares $s^*$ and $s^\#$ depend on $X$. By Proposition 2, we know that $1 - s^* \geq 1 - s^\#$. Thus, the gross benefits of regulation are always positive to conservationists. The question is when will the gross benefits outweigh the costs of regulation to conservationists, which is the cost of influencing policy, $b_c^T(\mathbf{s}^*)$?

Suppose that conservationist group $c$ is completely unorganized in the sense that $\kappa_c = 0$. Since group $c$'s cost of contributing even a penny becomes prohibitive, $c$'s contributions vanish. But if this is so, then $c$ will be willing to support regulation no matter what the current state of the property rights, since its gross welfare change from the adoption of regulation is positive whenever $\omega_C > 0$. Indeed, this point can be extended to the case where $\omega_c = 0$ for all $c \in \Gamma_C$. In this event, every conservationist's contributions vanish. However, by (27), $\Delta U_c(X)$ is determined entirely by the change in group $c$'s gross welfare, which is non-negative (and is strictly positive for $N > 1$). Thus:

**Proposition 3** *Conservationists benefit from the adoption of regulation when their own welfare is given zero political weight in the regulator's effective welfare function.*

The intuition behind this result is that regulation reduces the over-harvesting from the common property equilibrium. Conservationists benefit from this because they care only about the stock of the resource.

Next, suppose harvesters are given zero effective weight in the regulated equilibrium, i.e., $\omega_H = 0$. Then no harvest is allowed even if conservationist $c$ does not contribute (indeed, even if none of the conservationists contribute), so long as the regulator places positive electoral weight on the welfare of at least one conservationist (i.e., so long as $\omega_c > 0$ for some $c \in \Gamma_C$). Then, each conservationist contributes zero, since no conservationist affects the outcome (i.e., $s^* = s^{-c} = 0$). Therefore, conservationists clearly benefit from regulation when the regulator cares only about their interests. This suggests that conservationists support a regulator such as the International Whaling Commission, which has placed a permanent moratorium on whaling, not just because the regulator cares more about their interests than those of the harvesters, but also because the regulator can not credibly extract rents from the conservationists groups. Thus

**Proposition 4** *Conservationists benefit from the adoption of regulation when harvesters welfare is given zero effective political weight.*

Next, suppose that the weight the regulator places on the welfare of harvesters is independent of the number of harvesters, so that $\omega_H$ is fixed, but $N$ may vary. Then, as $N$ increases, the change in the gross welfare to conservationist $c$ is

$$\frac{\partial}{\partial N}\left[\log\left(\frac{1-s^*}{1-s^\#}\right)\right] = \frac{1-\alpha\beta}{(1-s^*)\alpha\beta} > 0.$$

Thus, the change in gross welfare to conservationists as regulation is adopted is increasing in $N$. Furthermore, since $\omega_H$ is independent of $N$, there is no corresponding increase in $b_c^T(\mathbf{s}^*)$. This implies

**Proposition 5** *The net benefit conservationists receive from the adoption of a harvest quota regulation is increasing in $N$.*

Since the gross welfare change to conservationists is increasing in $N$, consider the case where private property rights exist, so $N = 1$. Expanding (20) by explicitly considering the contributions yields:

$$\Delta U_c(X) = \frac{\nu_c}{(1-\beta)(1-\alpha\beta)}\log\left(\frac{1-s^{\#}}{1-s^*}\right) - \frac{\omega_{C\backslash c} + \gamma_c\nu_c}{1-\alpha\beta}\log\left(\frac{1-s^{-c}}{1-s^*}\right)$$
$$-\sum_{h\in\Gamma_H}\omega_h\left[\frac{\alpha\beta}{1-\alpha\beta}\log\left(\frac{1-s^{-c}}{1-s^*}\right) + \log\left(\frac{s_h^{-c}}{s_h^*}\right)\right] \quad c \in \Gamma_C.$$

The terms on the first line are positive in total, and represent the gross increase in welfare to conservationist c plus the increase in welfare to conservationists as a group of the incremental increase in the remaining share of the stock due to conservationist $c$'s contribution $(1-s^*) > (1-s^{-c})$, given that regulation is in place. The terms on the second line represent the present value of the costs each conservationist $c$ imposes on the (sole) harvester due to $c$'s contribution, given that regulation is in place. Since $s^{-c} > s^*$, the first expression on the second line is positive, but the second is negative. Thus, so long as the cost to harvester is not too great, the net change in welfare to conservationists is positive, even when there is no common property problem with the use of the stock. This occurs because in the regulated equilibrium the share of the stock harvested decreases (see 20). Furthermore, since the contributions by each conservationist are reduced by the amount of benefit they create for other conservationists, there is no free-rider effect among conservationists in the dynamic common agency equilibrium.

## 4.2 Net Benefits of Regulation to Harvesters

Now consider the condition under which harvesters support regulation. Let $\Delta U_h(X) \equiv U_h^*(X) - U_h^{\#}(X)$ be the net change in welfare to harvester $h \in \Gamma_H$ of adopting regulation. Thus

$$\Delta U_h(X) = \frac{\nu_h}{1-\beta}\log\left(\frac{s_h^{\#}}{s_h^*}\right) + \frac{\alpha\beta\nu_h}{(1-\beta)(1-\alpha\beta)}\log\left(\frac{1-s^*}{1-s^{\#}}\right) - \frac{b_h^T(\mathbf{s}^*)}{(1-\beta)\kappa_h}, \quad h \in \Gamma_H. \tag{23}$$

The first two terms are the present-value of the gross welfare change to harvester $h$ of adopting regulation, and the third term is the present value of the cost of contributing $b_h^T(\mathbf{s}^*)$ into perpetuity. As with the conservationists, whether harvester $h$ will prefer regulation is independent of $X$.

Let us begin by supposing that private property rights exist to the stock. This is equivalent to letting $N = 1$. Since the share of the stock harvested in each period absent regulation maximizes the harvester's gross utility, and since the equilibrium regulated share $s^*$ declines as $\omega_C$ increases, the harvester's gross utility of adopting regulation is unaffected when $\omega_C = 0$ and is reduced when $\omega_C > 0$. Furthermore, since the regulator captures part of the rents in the form of the equilibrium payment $b_h^T(\mathbf{s}^*)$, which is strictly positive when $\omega_C > 0$ for $N = 1$, the (sole) harvester's welfare is unambiguously reduced by the adoption of regulation when $\omega_C > 0$, and is unaffected when $\omega_C = 0$. This implies the following:[16]

**Proposition 6** *If well-defined private property rights exist for the resource, then the adoption of a harvest quota regulation will not create positive net benefits harvesters, and it will make harvesters worse off if the weight the regulator places on conservationists' welfare is positive.*

In contrast, when the resource is owned in common among $N$ harvesters it is possible that the harvesters will benefit from regulation, since regulation will resolve the common property problem. Suppose that $\omega_C = 0$, so that conservationists are given zero weight in the effective political welfare function, and assume that the effective political weight on each harvester is identical in the sense that $\omega_h = \frac{1-\alpha\beta}{N}$, for all $h \in \Gamma_H$, so each harvester gets share $1/N$ of the optimal harvest quota in the regulated equilibrium. Then the change in the gross utility of to the $h$th harvester of adopting regulation is

$$\Delta U_h(X) = \frac{\nu_h}{1-\beta}\log\left(\frac{N(1-\alpha\beta)+\alpha\beta}{N}\right) + \frac{\alpha\beta\nu_h}{(1-\beta)(1-\alpha\beta)}\log\left[N(1-]alpha\beta)+\alpha\beta\right], \quad h \in \Gamma_H.$$

This expression vanishes for $N = 1$, and it is increasing in $N$, i.e.

$$\frac{\partial \Delta U_h(X)}{\partial N} = \frac{\nu_h}{1-\beta}\left(\frac{(N-1)\alpha\beta}{N(1-\alpha\beta)+\alpha\beta}\right)$$

Thus, the change in gross utility to harvesters is positive for $N > 1$. Furthermore, under these conditions, $s^{-h} = s^*$, since conservationists are ignored, and $s_h^{-h}/s_h^* = \frac{N}{N(1-\alpha\beta)+\alpha\beta}$. Thus, $b_h^T(\mathbf{s}^*) = \nu_h \log\left(\frac{N}{N(1-\alpha\beta)+\alpha\beta}\right)$, which is decreasing in $N$. Thus,

**Proposition 7** *When harvesters in a common property resource are homogeneous and the regulator places zero weight on conservationists, the net benefit to harvesters from adopting a harvest quota regulation is positive.*

However, violation of either the homogeneity or zero weight on conservationists' welfare assumptions may cause harvesters to oppose regulation, since the contributions will be positive and the gross change in welfare may be negative under these circumstances.

Next, note that in the limit as $N \to \infty$, the share to harvester $h$ approaches zero, the harvester will clearly oppose regulation (i.e., the limit of $\log(s_h^{-h}/s_h^*)$ approaches negative infinity). Thus,

**Proposition 8** *A necessary condition for harvesters to benefit from the adoption of a harvest quota regulation is that the regulator values their welfare with significant enough weight.*

This could explain why whaling countries such as Norway and Japan have considered withdrawing from the International Whaling Commission.[17]

[16] This will also occur in a model where harvesters care about the stock (see note 11, *supra*), since the adoption of regulation will increase the stock.

[17] See Johnson and Libecap (1982), Libecap and Wiggins (1985), Karpoff (1987), and Boyce (2004) for discussions of the effect of heterogeneity on common property resource regulations.

### 4.3 Net Benefits of Regulation to Society

Next, consider the conditions under which social welfare is improved by regulation. The key to this analysis is that when regulation exists, the regulator cares about the gross welfare of the groups only because their welfare translates positively into electoral support. Thus, absent regulation, the regulator does not care about the group's welfare in any meaningful way. This means that in what follows, I set $\gamma_j = 0$ for all $j \in \Gamma$. Nevertheless, such a regulator still receives contributions from the harvesters and conservationists. Counting the contributions to the regulator as pure transfers, the cost of regulation is then in the non-transfer cost of the payments made to the regulator. Recalling (5), these non-transfer costs are $\frac{1-\kappa_j}{\kappa_j} b_j^T(\mathbf{s}^*)$.

Let $\Delta \hat{U}_j(X)$ denote the change in gross utility to interest group $j$ less the transactions costs associated with the contributions:

$$\Delta \hat{U}_h(X) = \frac{\nu_h}{1-\beta} \log\left(\frac{s^*}{s^\#}\right) + \frac{\alpha\beta\nu_h}{(1-\beta)(1-\alpha\beta)} \log\left(\frac{1-s^*}{1-s^\#}\right) - \left(\frac{1-\kappa_h}{\kappa_h}\right)\frac{b_h^T(\mathbf{s}^*)}{1-\beta}, h \in \Gamma_H \tag{24}$$

$$\Delta \hat{U}_c(X) = \frac{\nu_c}{(1-\beta)(1-\alpha\beta)} \log\left(\frac{1-s^*}{1-s^\#}\right) - \left(\frac{1-\kappa_c}{\kappa_c}\right)\frac{b_c^T(\mathbf{s}^*)}{1-\beta}, c \in \Gamma_C. \tag{25}$$

Since $\Delta U_j(X) - \Delta \hat{U}_j(X) = \frac{b_j^T(\mathbf{s}^*)}{1-\beta} > 0$, if both harvesters and conservationists support regulation, then regulation is clearly welfare-improving. However, since both harvesters and conservationists perceive the contributions as a cost, when they are not social costs, it is possible that regulation that improves welfare is not voluntarily adopted.

The net welfare change to society is

$$\Delta W(X) = \sum_{h\in\Gamma_H}\left(\frac{\nu_h}{1-\beta}\right)\log\left(\frac{s^*}{s^\#}\right) + \sum_{j\in\Gamma}\left(\frac{\nu_j}{(1-\beta)(1-\alpha\beta)}\right)\log\left(\frac{1-s^*}{1-s^\#}\right) - \sum_{j\in\Gamma}\left(\frac{1-\kappa_j}{\kappa_j}\right)\frac{b_j^T(\mathbf{s}^*)}{1-\beta}. \tag{26}$$

I have already shown that as $\kappa_j \to 0$, the cost of the contributions vanish for both conservationists and harvesters, since producing political pressure becomes prohibitively costly. The same thing occurs here. Indeed, if all groups are unorganized in the sense that $\kappa_j = 0$ for all $j \in \Gamma$, then no group contributes in equilibrium. Similarly, the transactions costs also vanish if $\kappa_j \to 1$ for all $j \in \Gamma$. Thus, the transactions costs associated with the contributions vanish in either case. In both of these extreme cases, regulation is welfare improving.

Two other special cases are interest. First, we saw above that as $\omega_h \to 0$ for $h \in \Gamma_H$, the welfare loss to harvesters grew extremely large. Thus, for $\omega_h$ small enough, social welfare is clearly made worse off by the adoption of regulation. Therefore, for regulation to be socially beneficial—as well as for it to get the support of harvesters—it is necessary that the regulator place sufficient weight on the welfare of the harvesters. In contrast, suppose that $\omega_c \to 0$ for all $c \in \Gamma_C$, and that each harvester is identical, so that $\omega_h \equiv \bar{\omega} > 0$, for all $h \in \Gamma_H$. We saw above that this resulted in support for regulation both from harvesters and conservationists. Thus, when $\omega_C = \infty$, social welfare is improved, except in the instance where there exists private property, in which case regulation has no effect. Therefore,

**Proposition 9** *In order that the adoption of a harvest quota regulation to benefit society, it is necessary that the effective weight on harvesters in the regulator's welfare function be sufficiently high. The adoption of a harvest quota regulation is socially beneficial even when conservationists receive zero effective weight in the regulator's welfare function.*

This occurs because harvesters, like conservationists, value the stock, but conservationists, unlike harvesters, place no value on the harvests.

Finally, there exists an interesting parallel between common agency and bidding (Bernheim and Whinston 1986; Laussel and LeBreton 1996). Suppose the regulator places zero electoral weight on each interest group. In this case, each harvester earns zero net utility in equilibrium, since failure by harvester $h$ to pay results in $h$ receiving zero harvest quota. By (15), each harvester pays the regulator for the cost harvester i imposes on the other $N-1$ harvesters for the reduction in their harvest quota, and the cost imposed on conservationists and harvesters of the increase in the total harvest. In contrast, conservationist $c$ receives positive utility in equilibrium, since he only has to pay for the net reduction in the harvest quota from $s^{-c}$ to $s^{*}$. From (16), the equilibrium contribution is the sum of the costs imposed on each harvester for the reduction in their harvest quota less the value of the increase in the stock due to the overall reduction in the harvest quota. If both harvesters and conservationists face zero transactions costs ($\kappa_j = 1$ for all $j \in \Gamma$), then the allocation maximizes social welfare in the standard sense. However, if, as is more likely, the conservationists face positive transactions costs, then the allocation will be skewed towards harvesters. Nevertheless, since harvesters earn zero net rents under an auction, one would not expect to see auctions very often. Indeed, the most common form of auctions occurs with resources not currently available, such as the newly exploited parts of the radio spectrum and new oil and gas leases.

## 5 Conclusions

This paper has examined a dynamic common agency model in which harvester and conservation groups compete over the exploitation of a natural resource, where the rate of that exploitation is regulated by a public agency. The equilibrium concept employed is that of a truthful Markov perfect equilibrium (Bernheim and Whinston 1986; Grossman and Helpman 1994; Bergemann and Valimaki 2003). Simple logarithmic utility functions are assumed for both the harvesters and conservationists, and the regulator's utility is additively linear in the utility and contributions of the interest groups. These assumptions give sufficient concavity to make the results relatively general, and they ensure that the results are tractable and transparent.

In the truthful Markov perfect equilibrium, the regulator solves the common property problem and forces harvesters to internalize the stock externality imposed on conservationists by maintaining an aggregate harvest quota that is less than that which maximizes the joint welfare of the harvesters. For regulation to be supported by harvesters, it is necessary that the no-regulation status quo involve common-property rent dissipation among the harvesters and that the effective political weight for harvesters under regulation be sufficiently high. However, conservationists unconditionally support regulation, since the gross change in conservationists' welfare is always non-negative and the regulator cannot fully capture the rents earned by them. As the transactions costs associated with rent-seeking approach zero or become arbitrarily large, the equilibrium contributions vanish, and regulation is more likely to be socially beneficial and to be supported by each group. Regulation is socially beneficial if the weight given to harvesters is sufficiently large relative to that given to conservationists. This occurs because harvesters, like conservationists, value the stock, but conservationists, unlike harvesters, place no value on the harvest. The regulator is more likely to place significant weight on the welfare of harvesters than that of conservationists, since conservationists' support of regulation is unconditional, whereas harvesters' support of regulation is conditional.

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