COLLOQUIUM PAPER

On the use of group performance and rights for environmental protection and resource management

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Environmental and natural resource (ENR) policies that focus on group outcomes are common but have received relatively less attention from economists than policies based on individual behavior. Existing research tends to focus on particular contexts, such as water or air quality, fisheries, or land use. This paper discusses unifying themes of group performance policies, along with their advantages and disadvantages. We discuss a range of specific policy instruments, including group-based taxes, subsidies, and fixed penalties. We show how, in principle, group-based policies can be designed to achieve efficient provision of group-level environmental performance; however, in some cases, group policies can lead to suboptimal outcomes. We discuss the incentives for collaboration that can arise when regulators impose group performance policies, and the role that it can play in promoting efficient outcomes. We argue that the success of group-based policies will depend both on how the policy is designed (i.e., the external rewards and penalties) and on how the group operates. This implies potential complementarities between "top-down" regulatory interventions based on group performance and "bottom-up" within-group incentives for self-governance. Our discussion suggests that group performance policies should play a more prominent role in the suite of policy instruments considered by scholars and policymakers concerned with ENR management.

group performance policies | collective approaches | self-regulation

A large body of scholarly literature within economics studies the design of environmental and natural resource (ENR) policies with the goal of understanding the advantages and disadvantages of alternative approaches (1). Most of the focus is on policies geared toward individual pollution sources or individual resource users. Examples includes policies to reduce emissions of air pollutants or discharges into water bodies from specific facilities, to reduce deforestation by individual landowners, or to limit harvests of fish stocks or harmful bycatch by individual fishing vessels. In many cases, however, ENR policies are applied at the group level, whereby rewards or penalties are triggered by group rather than individual performance, or rights are allocated to a group rather than to individuals. For example, entire industries have been threatened with costly regulations or taxes if they fail to meet pollution control objectives voluntarily (2); the imposition or stringency of regulations to protect air or water quality can be based on ambient rather than individual pollution (3); payments for ecosystem services are often made to collectives or communities rather than individual landowners (4); and the total allowable catch (TAC) or an aggregate bycatch limit is often allocated to a group of vessels rather than individual vessels (5–7).

In some contexts, group approaches have been suggested or used because individual actions are difficult and hence costly to observe, while indicators of group performance can be more easily monitored. For example, it might be difficult for a regulator to monitor all of the activities undertaken by individual farmers that affect ambient water quality in a nearby water body, but relatively easy for the regulator to monitor and measure the water body's ambient water quality (8). More generally, the use of a group approach might lower transaction costs. When seeking to promote ecosystem services such as deforestation, a government agency or other organization might face lower transaction costs when contracting with a group rather than many individual landholders (9). Moreover, in contexts where there is limited information or uncertainty about the impacts of individual actions, such as fishing and bycatch, group approaches can promote information sharing (10) and the pooling of risks across individuals within a group (6, 11).

Although group approaches are used, or have been suggested, in a wide variety of contexts, the scholarly literature lacks a general inquiry on these mechanisms as a form of ENR management. Existing research separately examines group approaches to agricultural nonpoint source pollution (12), hazardous waste management (13), land conservation (9), fisheries (14), and payments for ecosystem services (4, 15). However, papers in these areas are generally quite distinct with little cross-fertilization. We believe that many of the fundamental economic issues relating to the design and use of group policies are very similar across these different areas of ENR management, and that researchers focused on one area could benefit from familiarity with the literature in other areas. In particular, despite some obvious differences (both physically and institutionally), we believe there are unifying principles that apply across these contexts.

A fundamental feature of group approaches is the creation of regulatory interdependency among group members. This interdependency is distinct from other ways that the profits or well-being of group members might be interrelated through, for example, price-related market channels or physical interdependencies due to congestion or joint production. This policy-induced interdependency is akin to the creation of a "local public good" for the group itself. This follows because, when any member of a group contributes to improved group performance, it generates benefits for all other group members in the form of, say, lower taxes, higher subsidies, or avoidance of penalties. Notice that these within-group benefits differ from any associated benefits to society of improved environmental quality or natural resource management. Nonetheless, the fact that group policies create a group-level, local public good means that they are also susceptible to many of the well-known challenges of providing public goods, such as the potential for free riding.

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In this paper, we focus primarily on two distinct but related questions: (*i*) Can group policies be designed to promote efficient provision of environmental quality or use of a natural resource, thereby addressing the externality that group members impose on society, and, if so, (*ii*) will they do so cost-effectively, that is, in a way that maximizes returns to the group given the level of overall group performance? To answer these questions, we begin by presenting a simple modeling framework that underlies most of the existing theoretical literature across the various contexts in which these policies have been studied. The model captures the fundamental structure of group approaches noted above. We then examine several specific regulatory approaches based on group performance, including proportional taxes or subsidies, fixed penalties, and a combination of both. We summarize properties of these mechanisms, such as their ability to meet ENR goals and to do so cost-effectively. We show how, in principle, group-based policies can be designed to achieve efficient provision of group-level environmental performance; however, in some cases, group policies can lead to suboptimal outcomes. We discuss the incentives for collaboration that can arise when regulators impose group performance policies, and the role that it can play in promoting efficient outcomes. We argue that the success of group-based policies will depend both on how the policy is designed (i.e., the external rewards and penalties) and on how the group operates. This implies potential complementarities between "top-down" regulatory interventions based on group performance and "bottom-up" within-group incentives for self-governance.

A Simple Framework for Characterizing Group Performance Mechanisms

As noted above, a key feature that distinguishes mechanisms based on group performance from those based on individual performance is the interdependence of payoffs that the group approach creates. When all members of a group are rewarded or penalized based on the performance of the group as a whole, each member's own costs, benefits, or both depend not only on its own actions but also on the actions of all other group members.

We capture this key feature of group approaches in a simple and stylized model that can be used to examine the incentive effects of various group mechanisms across a variety of contexts. Suppose there are two "firms" (which could represent two companies, landowners, or vessel owners, for example), denoted $i = 1,2$. In the absence of a group policy, we assume the two firms operate independently. Each firm makes a decision on the level of x_i to maximize its net benefit function $W_i(x_i)$. This function could represent a firm's net profit or an individual's overall well-being, and x_i could represent its emissions or discharges of a given pollutant, disposal of hazardous waste, applications of fertilizer, or fishing effort. The fact that, in the absence of policy, each firm's payoff depends only on its own choice means that for now we ignore any within-group externalities based on market or physical interdependencies (e.g., use of a common property resource).

Suppose the firms' decisions combine to determine an outcome that is detrimental to others (i.e., "society"), but not to themselves. This implies the existence of a negative "externality" from the firms' decisions. We denote the measure of this outcome or the group's "performance" as $y(x_1,x_2)$, which is assumed to increase when either firm increases its value of x_i. This function may represent something like aggregate emissions of greenhouse gases, ambient air or water pollution, some risk of spill or contamination from hazardous waste disposal, or harmful ecosystem damages (e.g., bycatch or habitat destruction) from fish harvesting. We assume initially that the relationship between the firms' decisions and the outcome of interest is deterministic, although later in the paper we consider the implications of introducing uncertainty.

The detrimental impact of y on others is captured by the function $W_3(y(x_1,x_2))$, which represents the well-being of others and is assumed to decrease as the level of y increases. Note that a special case is where the well-being of others depends solely on the aggregate level of the firms' actions, that is, $y = x_1 + x_2$. This would apply, for example, if the outcome that generates damages is simply aggregate greenhouse-gas emissions. A slightly more general case is $y = y_1(x_1) + y_2(x_2)$, implying that the impacts of the two firms are additively separable, as may occur when y represents aggregate bycatch from the harvesting effort of each boat in a fishing fleet.

It is well known that the choices of firms will be inefficient in settings where firms impose negative externalities on the rest of society (16). This means that the firms' choices will not maximize aggregate societal well-being, often referred to as "social welfare," which here consists of the sum of the well-being inside and outside the group: $W_1(x_1) + W_2(x_2) + W_3(y(x_1,x_2))$. The inefficiency occurs because firms have no incentive to account for the negative impacts of their own actions on the well-being of others. Formally, this can be seen by comparing the choices that maximize the individual versus social net benefits. The privately optimal decisions, denoted $\hat{x}_i$, will satisfy $W_i'(x_i) = 0$ for both i, yielding group performance of $\hat{y} = y(\hat{x}_1,\hat{x}_2)$, while the socially optimal decisions, denoted x_i^*, will satisfy:

$$W_i' + W_3' \frac{\partial y(x_1,x_2)}{\partial x_i} = 0 \text{ for } i = 1,2 \qquad \textbf{[1]}$$

and lead to a level of group performance $y^* = y(x_1^*,x_2^*) < \hat{y}$.

The divergence between privately and socially desirable decisions provides a possible rationale for regulatory intervention. An individual policy approach, whether it involves penalties, rewards, or rights, would be based directly on each firm's choice of x_i, assuming it can be observed (or perhaps y_i if there were observability and additive separability). A group performance policy, in contrast, would be based only on the value of aggregate y.

Group performance policies can take several forms. One possibility is a tax imposed on both firms that is proportional to y. If τ is the tax rate, then under this group performance mechanism each firm faces a tax payment of $\tau y(x_1,x_2)$. Alternatively, firms could face the tax only when y exceeds a certain level, say $\bar{y}$. This mechanism is equivalent to granting firms a collective right to generate y for free up to a point (e.g., freely allocating to the group a fixed number of pollution permits or a given harvest or bycatch quota), but penalizing them proportionately for exceeding the limit or requiring them to purchase additional rights in excess of the granted amount. Another alternative is that all firms in the group could face a fixed penalty when the level of y exceeds the group's limit, where the magnitude of the penalty is the same regardless of the amount by which the limit is exceeded. In such cases, the actual regulatory action may not be imposition of a monetary fine but could be some action that imposes monetary costs (or losses) on firms within the group. An example would be closure of a fishery when the fleet-level bycatch limit is reached or exceeded. A group performance policy might also involve subsidies or payments when y is below a specified level, as for example with payments to communities for reductions in deforestation.

The primary question we examine below is whether group performance policies can induce efficient outcomes. Specifically, we consider whether a group policy instrument can ensure that group performance is at the desired level, y^*, and whether it does so cost-effectively, namely, with x_1^* and x_2^*. As we discuss below, the answer to this question depends on both the specific policy design and the internal rules by which the group operates.

Proportional Group Performance Taxes

Consider first the case of a proportional tax imposed on y. This is perhaps the closest analog to the concept of a Pigouvian tax on individual polluters (e.g., a carbon tax), which economists often tout as the "gold standard" for environmental policy design. The question is whether, when applied to group performance rather than individual performance, the tax rate can be set by the regulator at a level that provides an incentive for the group to achieve y^*, and for each member of the group to reduce x_i to the socially optimal level, as determined by [**1**]. Under this policy, each firm chooses its action to solve the following:

$$\max_{x_i} W_i(x_i) - \tau y(x_1,x_2). \quad \textbf{[2]}$$

This setup differs from one with no policy in place in an important way. Here, the (after-tax) net benefits for each firm depend not only on its own decision but also on the decision of the other firm. That is, the group tax creates a policy-induced interdependence. Note that, although each firm bears the full cost of its own reduction in x_i, both firms will benefit from that reduction (through a lower tax payment). In this sense, a reduction in x_i is a local public good for all firms subject to the tax. Although this creates the potential for shirking or free riding in the provision of reductions [analogous to the standard free-riding result that arises in team production (17)], by setting the tax rate appropriately, this incentive can be eliminated. To see this, note that, if the firms' choices are a Nash equilibrium (18), then they will satisfy the following:

$$W_i' - \tau \frac{\partial y(x_1,x_2)}{\partial x_i} = 0 \text{ for } i = 1,2. \quad \textbf{[3]}$$

Comparing this expression to [**1**], it is straightforward to see that setting the tax rate equal to the efficient level of the marginal damages to society generated by additional y, that is, setting $\tau^* = -W_3'(y(x_1^*,x_2^*))$, will induce each firm to choose x_i^*. Hence the tax provides incentives for the firms to make decisions that provide the desired level y^* in a cost-effective way. In addition, the efficient solution is the only Nash equilibrium under a proportional group tax structured in this way.

Although the proportional tax can be designed to create efficient incentives for firms when they act independently, it also creates an incentive for firms to collude to reduce their tax payments (19), an effect that does not arise when taxes are applied based on individual behavior. In other words, under the group tax, if the firms join together and collude to make the decisions that maximize their joint net benefits, they will choose to "overabate," that is, reduce x_i below the efficient level. While it might be tempting to think that the additional reduction in y would be socially beneficial, it is not, since firms would lower pollution beyond the point where the social benefits of further reductions exceed the associated costs. Note, however, that the inefficiency from collusion stems from the fact that the tax rate τ^* was derived assuming firms make decisions independently, that is, they do not collaborate. If it is known that the members of the group will collaborate (collude) to maximize their combined after-tax net benefit, then the regulator should set $\tau^* = -0.5W_3'(y(x_1^*,x_2^*))$, and, faced with this tax, the members of the group would collaboratively make efficient decisions. Thus, the efficiency of the proportional tax depends on both how the tax rate is set and how the group makes decisions. This suggests that the design of the group policy should reflect any internal decision-making rules that the group has or establishes in response to the policy. We assume throughout our discussion of specific policies below that members of the group make decisions independently (and hence focus on policies designed to induce efficiency under a Nash equilibrium) but return to this point in our discussion of incentives for collaboration below.

The proportional group tax described here effectively gives the group no right to generate any amount of y free of charge, since the tax would be levied on all units of y. In this sense, it is consistent with the "polluter-pays-principle" (20). The implied property rights are therefore consistent with a standard Pigouvian tax. A potential downside, however, is that the approach can lead to very large tax payments for a firm (21). Unlike with a standard Pigouvian tax, a tax on group performance implies that each firm pays not only for its own contribution to y, but for the contribution of other firms as well. Thus, while a proportional group tax creates efficient incentives under a Nash equilibrium, it could be very costly for firms, especially if the number of group members is large. In addition to imposing a substantial burden on firms, this could also inefficiently drive some firms out of business because of the excessive tax burden. Note that, when firms act independently, this potential problem cannot be solved by simply dividing the total tax burden of $\tau^* y(x_1,x_2)$ among the firms, since doing so would reduce the effective tax rate for each firm and thereby reduce the policy's effectiveness.

Proportional Tax with an Allowable Group Limit

To address concerns about its total cost to firms, the proportional tax policy can be modified so that the tax is paid only when y exceeds some limit $\bar{y} > 0$. In this case, the tax payment would be $\tau^*[y(x_1,x_2) - \bar{y}]$, and it would only be paid if $y(x_1,x_2) > \bar{y}$. This approach embodies an assignment of property rights that is "intermediate" in the sense that the group has the right to freely engage in activities that are damaging to others, but only up to a certain point. Beyond that point, each firm would face a penalty or fine, where the magnitude is proportional to the exceedance. Alternatively, we could interpret the approach as granting the group a collective limit of $\bar{y}$ for free, but allowing the purchase of an exceedance from the regulator at a given price. This interpretation is similar to the notion of a price-based safety valve with the allocation of emissions permits (22, 23), or the payment of "deemed values" for exceeding harvest quotas for fish (24).

To understand the implications of penalizing or charging only when y exceeds some limit, consider some special cases for $\bar{y}$. At one extreme, when $\bar{y} = 0$, we have the tax mechanism described in the previous section. At the other end of the spectrum, if the limit is set at a level firms would meet with no adjustment to their behavior, that is, $\bar{y} = \hat{y}$, then the policy will have no effect.

An intermediate possibility is to set the limit at the socially desirable level, that is, $\bar{y} = y^*$. Under this policy, with $\tau = \tau^*$ both firms still make efficient choices that yield y^* in a cost-effective way. Moreover, these choices are the only Nash equilibrium under the policy, that is, the equilibrium is unique (25). It also means that in equilibrium no tax payment will need to be made because group performance will exactly meet the aggregate limit. Thus, rather than paying a potentially high tax bill as under the previous policy, this policy induces efficient choices without any actual tax payment in equilibrium. In addition, because tax payments would already be reduced to zero if the firms make efficient decisions, when the threshold is set at the efficient level, there is no incentive for firms to collude to reduce their tax liability. If the threshold is set below the efficient level of y, then setting the tax rate at τ^* will still create efficient incentives for the firms (as a unique Nash equilibrium), but in this case each firm would pay the tax on the difference $y(x_1^*,x_2^*) - \bar{y}$ and an incentive to collude would once again exist (19). Thus, setting the threshold at the efficient level of y eliminates both the tax payments in equilibrium and the incentive to collude. If, however, the relationship between the firms' choices and the level of y is affected by random factors such as weather, then even with $\bar{y}$ set at the expected value of the socially efficient level, the firms will sometimes face positive tax payments, since efficient choices will no longer ensure that the target is always met. We return to this issue in the discussion of combined tax–subsidy policies below.

Group Performance Subsidies/Payments

We have considered approaches based on either the polluter-pays-principle or an intermediate approach where some rights are freely allocated. However, a group approach could alternatively be based on a "beneficiary-pays-principle," whereby firms receive payments when their actions benefit others. These payments are analogous to government subsidies designed to promote beneficial actions, although payments need not come from the government and can instead come from the private sector or nongovernmental organizations (26). Subsidies or payments based on group performance are common in ENR management. Many schemes for the payment of ecosystem services are structured in this way. As noted above, payments are frequently used to incentivize communities to reduce deforestation below a baseline level (9). Similarly, carbon offsets may apply at the group level and consist of payments for reducing emissions below what is considered a "business-as-usual" (BAU) baseline. Indeed, many carbon offset programs are themselves based on reducing deforestation for purposes of carbon sequestration (27).

We now consider the implications of using a subsidy approach based on group performance. Let s denote the subsidy paid to both firms for each unit of y below a threshold level $\bar{y}$. Thus, when $y<\bar{y}$, both firms would receive a payment of $s\,[\bar{y}-y(x_1,x_2)]$. Assuming firms are receiving the subsidy, a reduction in x_i by either firm increases the subsidy payment for all firms within the group, thereby providing a local public good for all group members. Conversely, an increase in x_i by either firm generates a cost for all firms since it increases y and therefore reduces the total subsidy payment that each firm receives. At the margin, this cost is analogous to an increased tax payment that all firms would have to make when one firm increases its level of x_i under the tax policies. Thus, it is not surprising that an appropriately designed subsidy can lead to efficient choices, and that the subsidy rate that achieves this is the same as the corresponding tax rate τ^*. In other words, with $s=\tau^*$ and an appropriate choice of $\bar{y}$, the choices that induce y^* cost-effectively will be a Nash equilibrium, with each firm receiving a subsidy payment of $\tau^*\,[\bar{y}-y(x_1^*,x_2^*)]$. However, despite this parallel between the collective tax and subsidy approaches, the two approaches differ in some ways that can have potential implications beyond simply the difference in implied property rights.

First, the incremental impact of a subsidy policy with $s=\tau^*$ depends critically on how the threshold is set. Unlike in the tax case, if the threshold under the subsidy policy is set at y^*, the policy will be ineffective, that is, it will not induce any change in behavior. This follows from the fact that under this threshold, any reduction in y between $\hat{y}$ and y^* is costly but generates no subsidy payment, while any reduction below y^* costs more than the firms would receive in subsidy payments. As a result, the firms would be better off simply continuing to do what they would have done otherwise, that is, following BAU. In order for the policy to be effective, it must generate changes in behavior. For example, with payments for ecosystem services, those payments will only be effective if they induce additional provision of services beyond the BAU level (28). This requires that $\bar{y}$ be set above $y(x_1^*,x_2^*)$. However, to avoid paying for BAU decisions, the threshold also needs to be set at or below the BAU level, $\hat{y}$, that is, we need $y^*<\bar{y}\le\hat{y}$.

In addition, when the threshold is set at or below the BAU level and the subsidy rate is set optimally assuming firms make decisions independently, the subsidies can actually create an incentive for firms to collude (inefficiently) to increase their subsidy payments (29). This can again lead to overabatement. Perhaps more importantly, it can also lead to multiple equilibria. Although efficient behavior is a Nash equilibrium (and the only equilibrium under which the firms' choices are efficient and they receive subsidy payments), it is not the only possible Nash equilibrium. The BAU outcome can also be an equilibrium, which is a possibility that does not arise under a similar subsidy policy applied to individuals. The possibility for multiple equilibria, and its relationship to the potential benefits of self-coordination within the group, is a topic to which we will return later in more detail.

Finally, subsidies paid by governments require that funds be raised for this purpose, typically through distortionary taxes such as income or sales taxes. The need to fund government payments in some way can add an additional cost to the use of a subsidy approach that does not exist for a corresponding tax policy. Moreover, the effect is amplified in the context of payments based on group performance because each firm is receiving a payment based not only on its own reductions, but on the reductions of other firms as well (21). Thus, the total payments would be higher under the group policy than under a corresponding policy based on individual performance and therefore require a higher level of distortionary taxation.

A Combined Tax–Subsidy Approach

Although we have discussed the proportional tax and subsidy policies separately, they can also be combined into a policy that imposes a tax on firms when $y(x_1,x_2)>\bar{y}$ and pays the firms a subsidy when $y(x_1,x_2)<\bar{y}$ (8). If the tax and subsidy rates are equal, then each firm will have an incentive to choose its level of x_i to solve the following:

$$\max_{x_i} W_i(x_i)-\tau\,[y(x_1,x_2)-\bar{y}], \qquad [4]$$

where τ now represents both the tax and the subsidy rate and the bracketed term is either positive or negative, depending on whether y is greater or less than $\bar{y}$, respectively. The setup is consistent, for example, with a mechanism where the group is allocated a fixed number of pollution permits for free, but is then able to buy additional permits or sell back unused permits to the regulator at a fixed price. The combined policy has several advantages. One is that the incentive for each firm to reduce its level of x_i does not depend on the threshold $\bar{y}$. Thus, although the threshold has distributional consequences, it does not affect the firms' marginal incentives or the resulting level of y. This means that, when the tax and subsidy rates are set at τ^*, the outcome under which firms choose efficient effort levels and thereby ensure y^* is a cost-effective, unique Nash equilibrium. This can be seen from the conditions defining the Nash equilibrium, which are the same as those for the proportional tax given in [**3**]. Thus, the combined tax–subsidy creates the same incentives as the pure tax policy (where $\bar{y}=0$), but without the excessive cost burden on firms. Nevertheless, as with the proportional subsidy, the subsidy component of the combined approach can still create incentives for inefficient collusion when the tax rate is set assuming non-cooperative behavior (30).

The combined tax–subsidy approach also has advantages if the model is extended to account for uncertainty. In many circumstances, unpredictable or unknown factors introduce uncertainty in the relationship between firms' choices and the resulting level of y. For example, uncertain weather events and delivery coefficients will impact the way that farm-level pesticide applications ultimately affect ambient water quality (8). Similarly, the bycatch associated with fishing effort in a particular location will depend on the spatial distribution of the bycatch species, which is not observable and hence not known with certainty (11), and even polluting firms may not be able to completely control their emissions (31). We can easily incorporate a measure of uncertainty into the model by writing y as a function of firm choices and a random variable, that is, by writing the group outcome as $y(x_1, x_2, \varepsilon)$, where ε is a random variable reflecting the uncertainty.

A key implication of uncertainty is that, even if they want to, the firms cannot guarantee that they will meet a given group performance standard $\bar{y}$. In other words, even if firms take actions to reduce y and meet the threshold, the presence of random factors means they may still exceed it. Conversely, even if the firms make little effort to meet the standard, they may get "lucky" and meet it anyway. Either way, the combined tax–subsidy approach treats these randomly occurring outcomes symmetrically, imposing a tax for exceeding the limit and a subsidy for being below it. This means that, despite the uncertainty about whether the allowable limit will be met given the firms' decisions, the limit itself does not affect firm incentives. To see why, we need only replace $y(x_1, x_2)$ in **[4]** with $\mathbb{E}[y(x_1, x_2, \varepsilon)]$. However, it can be shown that such symmetry does not apply to the policies discussed in previous sections, which include only a tax or subsidy (based on a given threshold) but not both. Thus, unlike under the previous policies, coupling the tax with the subsidy ensures that even with uncertainty, private incentives align with social incentives, regardless of where the threshold is set. In addition, if the threshold is set at the expected efficient level, that is, $\bar{y} = \mathbb{E}y(x_1^*, x_2^*, \varepsilon)$, then tax payments and subsidy receipts will balance each other out on average.

Fixed Penalties

In the collective policies discussed so far, the penalty or reward (i.e., tax or subsidy) is proportional to the amount by which the group outcome is above or below the group threshold. Alternatively, a fixed penalty can be imposed on each group member when y exceeds a limit. Often these penalties are costly regulations rather than monetary fines (perhaps because the regulator does not have authority for the latter). For example, all firms in a given industry could face the imposition of a costly regulation if the industry as a whole does not meet some regulatory objective (32). Similarly, an entire fishery could be closed for the remainder of the season if aggregate bycatch exceeds an allowable level (14), thereby imposing a fixed cost in the form of lost profit for all fleet vessels. In these cases, the penalty of foregone profits may differ across firms, but such heterogeneity simply means that firms face different fixed penalties.

Under a fixed penalty, which we assume for simplicity is the same for both firms, each firm would incur a fixed cost F if $y(x_1, x_2) > \bar{y}$. The key to understanding the effect of a fixed penalty is to recognize that there are many different combinations of x_1 and x_2 that can generate $\bar{y}$ and, unlike under some of the policies discussed above, under a fixed penalty multiple combinations can be Nash equilibria. This means that it is possible to have an equilibrium where one firm "does what it takes" to ensure the threshold is met and the other firm free rides on the efforts of that firm. To see this, note that, under a binding policy firms face a choice between choosing $\hat{x}_i$ or some lower level to avoid paying the fine. The minimum value of x_i that a firm would be willing to choose to avoid the penalty is defined implicitly by the expression $W_i(x_i^{\min}) = W_i(\hat{x}_i) - F$, from which it is clear that the minimum value decreases as F increases. To eliminate BAU as a Nash equilibrium, the penalty must be sufficiently high that one of the firms is still willing to do what it takes to avoid the penalty even if the other firm does nothing, that is, $y(x_i^{\min}, \hat{x}_j) \leq \bar{y}$ for at least one firm. However, even if the penalty is high enough for this condition to hold, and even if the threshold is set at the socially optimal level of $\bar{y} = y^*$, multiple equilibria where the threshold is met can still arise. This follows because the set of x_1 and x_2 combinations that are greater than each firm's minimum value and that satisfy $y(x_1, x_2) = \bar{y}$ are all Nash equilibria. This result is analogous to results on nonuniqueness of the equilibrium for voluntary provision of a threshold public good when contributions to the public good are continuous (33). It also provides an explanation for why fixed penalties or "forcing contracts" often do not perform well in laboratory settings (30, 34). In addition, as with subsidies and some proportional tax policies, a fixed penalty policy can lead to incentives for collusion if there is uncertainty about whether the threshold will be met (35).

Finally, and importantly, the possibility of multiple equilibria raises the possibility that the desired level of environmental protection or resource exploitation y^* will be met but not in a way that is cost-effective. Minimizing the costs of a reduction in y requires that the foregone marginal net benefits expressed in terms of y be equated across firms. This "equimarginal" condition for cost minimization will hold at the equilibrium where firms meet the target y^* by choosing x_1^* and x_2^*, but not if they meet it through some other equilibrium combination of effort levels. This constitutes a form of free riding within the group regarding each firm's contribution to meeting the target, since one firm contributes more than its efficient level while the other firm contributes less (thereby free riding on the efforts of the other firm). Furthermore, it generates a type of rent dissipation, since aggregate profits for the group would be higher if the target were met through efficient effort levels. For example, in fisheries permit holders governed by collective limits on harvest of target species or bycatch often engage in a rent-dissipating race-to-fish in an effort to claim a greater share of the allowable catch or bycatch (36). This raises the possibility of gains from collaboration, a topic to which we now turn.

Incentives for Collaboration

We have seen that group policies can implement the efficient level of group activity, y^*, although such a result is not guaranteed and depends on policy design. In addition, we have identified at least two ways in which firms might have an incentive to collaborate when faced with a group policy, neither of which arise with policies based on individual performance. First, the group may benefit from colluding if, by doing so, it can reduce aggregate tax payments or increase aggregate subsidy payments, thereby increasing joint profits for the group. This incentive can arise when the design of the group policy (e.g., the magnitude of the penalties or rewards) is based on an assumption of noncooperative behavior. In this case, collaboration benefits the group but can be detrimental overall if it leads to an inefficient level of y. However, as noted above, the inefficiency arises because the penalties or rewards do not reflect the actual decision-making rules of the group. If the regulator anticipates the incentive for collaboration (and perhaps even encourages it), then the policy can (and should) be designed to eliminate this inefficiency. In other words, in such cases, collaboration can still be beneficial for both the group and society provided the regulator anticipates it and designs the group policy accordingly.

Second, we saw that fixed penalties can give rise to rent-dissipating equilibria among firms. In circumstances where such inefficiencies occur, the outcome for both firms and society as a whole could be improved if some mechanism is found for reaching the "good" equilibrium where y^* is met with each firm making efficient choices (thereby eliminating any shirking or free riding within the group). This suggests that firms can mutually benefit through various forms of collaboration or self-governance intended to reach an equilibrium that is most favorable for members of the group. In other words, the top-down policy based on group performance can create complementary incentives for self-governance designed to "manage" group performance. Thus, although the top-down group policy is designed to reduce detrimental impacts to society, by making group performance a local public good for the group itself, it can also create the opportunity for benefits from collaboration within the group.

Of course, just because the group would benefit from collaboration does not guarantee that it will be able to solve the associated within-group collective action problem. The circumstances that give rise to successful bottom-up collective action to meet a group target are likely to be similar to those leading to successful cooperation and self-governance of common-pool resources, where much of the research focuses on the key factors or "design principles" that lead to effective self-governance (37, 38), along with the challenges and opportunities for contracting among individuals to establish their own set of property rights (39, 40).

A key consideration is how, if at all, the group organizes itself, that is, the internal rules it uses to govern effort choices within the group. For example, the group could have an organizational structure that entails either centralized or decentralized decision making within the group (6, 41). Under centralized decision making, the firms delegate decisions to a central decision maker who makes decisions on behalf of the whole group and distributes the resulting benefits to members according to some agreed-upon rules. For example, the Chignik salmon cooperative in Alaska was allocated a share of the fishery's TAC and managed that share through a centralized body, with all members of the cooperative sharing in the resulting profits (42). A fully centralized structure ensures that the aggregate target or cap is met in a manner that maximizes profits for the group. Alternatively, members of the group could continue to act independently but establish rules within the group for simultaneously enhancing benefits for all members. Specifically, firms within the group would have an incentive to set up an internal system under which the aggregate allowable limit for the group is allocated across group members through some mechanism, after which mutually beneficial trades are allowed to occur within the group. This happened in the cooperatives that were established in the New England groundfish fishery. These cooperatives (called "sectors") were given a share of the fishery's TAC and then allocated those harvest rights to individual vessels within the sector, who were then free to trade their allocated quotas. Thus, these cooperatives essentially set up their own decentralized individual transferable quota systems within their groups (43). A similar decentralized system was established by the Alaskan weathervane scallop cooperative (36). Whether decision making is centralized or decentralized will affect the magnitudes of the penalties or payments needed to induce firms to make efficient decisions. In general, decentralized decision making will imply the need for higher penalties than under centralized decision making to offset the greater free-rider incentives (41).

Another factor that is likely to influence self-organization and whether group members are able to individually coordinate is the presence of strong leadership and the extent of preexisting social capital among members (44). Social capital refers to the relationships among individuals that help promote individual or collective action through reciprocity, trust, and norms. While the extent of social capital may affect the initial equilibrium, it may also affect a group's capacity for coordination after imposition of a new policy (15). Regulators may seek to target interventions in places where such capacity appears to exist, and should also recognize that new policies themselves may affect social norms that could encourage or discourage the capacity for coordination (45).

Other important factors that can affect the likelihood of successful group collaboration include communication, group size, and heterogeneity of group members, as well as the ability of the group to internally monitor and sanction members of the group (through, for example, fines, peer pressure, or exclusion) (37, 38, 46). For example, the existence of mandatory on-board observers and formal contracting have been keys to success of fishing cooperatives formed in response to collective caps (6, 36).

The Role of Within-Group Externalities

Our primary interest here is in situations where group members make decisions that can negatively impact society. For this reason, we have so far ignored the possibility that, even in the absence of a group performance policy, the choices that one firm makes might affect the well-being of other firms within the group, that is, that in addition to the externality imposed on society, there are preexisting within-group externalities. For example, fishing vessels can impose negative externalities on each other through congestion or stock effects, while at the same time imposing externalities outside the group through bycatch or habitat degradation. Likewise, under imperfect competition, the choices by one polluting firm can affect market prices and hence the profits of another polluting firm in the group. Positive within-group externalities are also possible, due, for example, to information spillovers or group brand recognition.

The existence of within-group externalities can create possible gains from collaboration in addition to those identified above and can also affect optimal policy design. In particular, research suggests that group policies can be efficient in addressing externalities both inside and outside of the group, although rewards and punishments would need to be adjusted to reflect the additional externality (41, 47, 48). In addition, somewhat counterintuitively, the existence of a within-group externality creates the possibility that group members could benefit from a top-down policy that would otherwise be viewed as costly. For example, a tax on group emissions could actually increase the profits of group members. With common-pool resources, this possibility has been referred to as a "free lunch in the commons" (49), building on an earlier result applied to firms that have market power (50). The underlying intuition is that the tax policy can effectively serve as a mechanism to enforce profitable (and socially beneficial) collusion, the benefits of which may be greater than the cost of the tax itself. This means, for example, that a tax on bycatch in a fishery will reduce fishing effort, but the reduction in congestion of the commons can be more valuable to the fishing fleet than having to pay the higher taxes. This result is important because it identifies a potential incentive for the group to support group-regulation, namely, greater profits.

The Potential for Risk Pooling

Another possible incentive for collaboration arises when the relationship between firm decisions and the performance measure is uncertain, due, for example, to random factors or incomplete knowledge. As noted above, in the presence of uncertainty, firms cannot perfectly predict the level of y that will result from their choices. Hence they cannot know with certainty whether the allowable limit will be met. This would be true not only under group limits, but under individual limits as well. For example, if fishing vessels are allocated individual harvest or bycatch quotas, but there is uncertainty about how effort (e.g., number of days at sea) will affect actual harvest or bycatch, then vessel managers cannot know for sure whether their choices will result in meeting or exceeding the quotas. The same would be true for firms with pollution permits when emissions cannot be completely controlled. This type of uncertainty suggests that, even if individual limits are feasible (because individual contributions can be observed through monitoring), there might be some advantage to the firms of "pooling" their quotas and thereby pooling their risks (51). That is, by combining their individual allocations into a shared pool, they might be able to reduce the risk of incurring penalties for exceeding the overall allowable limit. The use of a collective cap is another form of risk pooling across vessels (41). In fact, the benefits of risk pooling across fishing vessels has been viewed as one advantage of a group approach, and risk pools have been used for bycatch management in several fisheries (6, 11).

When risk pools are formed, either voluntarily through pooling individual quotas or through the imposition of a top-down group-level cap, members of the group have an incentive to work together in their attempt to avoid exceeding their combined limit. However, it is important to note that pooling risk does not necessarily reduce the probability of exceeding limits. For example, depending on the underlying distribution of the random factors affecting actual levels and the magnitude of the limits, the probability that an individual firm will exceed its individual limit can be greater than, equal to, or less than the probability that the group would exceed the group limit if the individual limits were pooled (41).

Endogenous Group Formation

Throughout the previous discussion, we have focused on group performance policies where the group itself is exogenously determined. An exogenous definition of the group occurs naturally in many settings. Groups may be exogenously determined based on geographical or physical boundaries, or on political or industry delineations. Examples include farmers in a watershed, boats in a fishery, power plants in a region, firms in an industry, or members of a community that collectively owns and manages land. Alternatively, a regulator may have flexibility in defining the policy-relevant group, or subgroups. A fisheries regulator could, for example, allocate an aggregate catch limit to the entire fleet, or it could allocate shares to subgroups within the fishery. These subgroups could be defined exogenously, or they could form endogenously, as is often the case with fishing cooperatives (e.g., refs. 36, 42, and 43).

It is well-known that management of common property resources, where within-group externalities create benefits from collaboration, can lead to endogenous group formation, even in the absence of any external regulatory policy (37). However, here we are primarily interested in cases where groups might form endogenously in response to policy. Fishing cooperatives are one example, but there are others as well. For example, endogenous group formation can occur in the context of voluntary pollution control under the threat of regulation (52, 53). A regulatory threat can provide incentives for voluntary participation in a group of firms that seek to preempt or forestall the regulation. For example, the threat to impose pollution regulations led some firms to join the Environmental Protection Agency's Strategic Goals Program (2) and the US Department of Energy's Climate Challenge program (54). These are both cases of government-sponsored programs where participation was voluntary. Programs like these create a "threshold" public good for the industry as a whole. Voluntary reductions must meet a threshold level or provision point to avoid the establishment of a regulation and all firms in the industry would benefit from avoiding regulation, including those outside the group who took no voluntary action to reduce their discharges or emissions (55). In much the same way that we saw previously for the fixed penalty based on group performance, voluntary programs to preempt or forestall a regulation can give way to multiple equilibria (32, 56). This again raises potential concerns about cost-effectiveness and within-group free riding. Indeed, empirical research shows evidence of such free riding but also finds that some firms do in fact voluntarily reduce pollution despite the free riding of others (53).

While the two previous examples were government-sponsored programs, group formation that leads to self-regulation can also arise in response to market incentives (57, 58). For example, voluntary certification programs for environmental performance (e.g., "green" certification programs) are commonly used in ENR management. Prominent examples are the US Energy Star program for the energy efficiency of appliances and the Sustainable Forestry Initiative certification of the American Forestry and Paper Association. Participating firms voluntarily agree to meet a standard of environmental performance that is above and beyond what government regulations require, and the reason for participation is the perceived signaling benefit of affiliation with the program's green certification. A recent strand of the literature identifies voluntary programs of this type as "green clubs" (59, 60). They are clubs because they provide nonrival and excludable reputation benefits to participating firms (through membership or certification), and they are green because they have the additional consequence of providing environmental benefits to those outside the club. A key feature of such club design is balancing the environmental and reputation benefits, along with a negative congestion externality within the club as membership grows large. The congestion may arise, for example, because of less product differentiation when too many firms are certified. Nevertheless, much like the approach to group performance considered previously, green clubs provide a mechanism for using within-group incentives (e.g., reputation) to address outside the group market failures (e.g., pollution).

Conclusion

Policies that focus on group performance are common in ENR management, yet economic analysis of ENR policy instruments has typically focused on policies applied at the individual rather than group level. Research that does exist on group performance policies tends to focus on particular areas of management, such as water or air quality, fisheries, or land use. Missing from the literature—and what has been one of our aims here—is a more general inquiry on unifying themes of group performance policies, along with a discussion about their advantages and disadvantages. In some cases, as when individual performance is not observable, a group-based policy might be the only viable policy option. However, even when policies can be applied at the individual level, an important question for policy is whether they should be, that is, whether a group performance approach might have advantages.

We consider several specific policy instruments based on a group's performance that have been discussed in the literature, but typically only in specific contexts, and show how they can be applied across a variety of ENR settings. In this sense, we provide a more general characterization of these policy approaches. The specific instruments we consider include proportional taxes with and without an allowable limit, proportional subsidy payments that depend on an established baseline, a combined tax and subsidy approach, and fixed penalties or fines. Although each of these policies has an analog based on individual performance, when applied to group performance, they raise a number of interesting and important considerations about interactions within the group.

In particular, we show how each of the group policies we consider can be designed to ensure that the group as a whole provides an efficient level of environmental protection or conservation. They do this by creating a local public good shared among group members. This is both an advantage and a disadvantage of group approaches. It means that, although policies can be designed such that meeting the desired goals in a cost-effective way is a possible equilibrium, this is not guaranteed. In some cases, incentives for collusion to reduce aggregate tax payments or increase aggregate subsidy payments can undermine efficiency if the policy design does not anticipate the group's incentives to act cooperatively in response to the policy. In other cases, multiple equilibria can arise that, as with the provision of public goods more generally (61), entail free riding or shirking among individual members of a group and lead to rent dissipation. When this occurs, members of the group (as well as society as a whole) would benefit from collaboration within the group and there are numerous examples where group policies have prompted a collaborative response by the regulated parties. Moreover, the circumstances that contribute to successful collaboration may be similar to those that arise in the context of self-governance in other common pool resource management contexts. The success of group-based policies will, therefore, depend critically on how the policy is designed (i.e., the rewards and penalties established by a specific policy) as well as the internal operating rules of the group itself. In particular, using group performance policies both to address external impacts of the group's behavior and to promote within-group collaboration can lead to better ENR management when regulators understand and anticipate within-group behavior and incentives.

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