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Group Incentives for Environmental Protection and Natural Resource Management

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Abstract

Group incentives can and have been used to address a range of environmental and resource problems. These schemes base individual penalties and/or rewards on the performance of a group of individuals or firms who contribute to the environmental or resource problem. The economics literature on team incentives and public goods, as well as the literature specifically on environmental and natural resource management, provides insights into the design of group incentives. This article reviews the literature on group incentives in the context of environmental protection and natural resource policy. This literature suggests that group incentives can be effective and even efficient as environmental policy tools. However, the outcomes under group incentives will likely depend on a combination of the policy design and the nature of the internal group interactions. Within-group interactions are likely to be particularly important when policies involve thresholds so that coordination is needed to reach a cooperative equilibrium.

1. INTRODUCTION

Many human activities lead to the degradation of air, water, or land or the overexploitation of renewable resources such as forests and fisheries. Typically, these impacts represent negative externalities, since they are borne by people other than those whose activities generate them. Controlling these externalities is a key rationale for adoption of natural resource management or environmental protection policies. Typically, these policies are applied at the level of the party engaging in the offending activity. For example, environmental taxes, regulations, and subsidies target firms engaging in polluting activities based on the level of their activities, and harvest or bycatch quotas can be allocated to individual vessels or firms. However, in some contexts, an alternative approach might be possible, namely, policies that involve group incentive schemes. Group incentives have long been used to incentivize team production in other contexts such as workplaces, where the actions of a number of individuals (team or group members) combine to determine an outcome that is valuable to the team or the owners of the firm (Bloom & Van Reenen 2011, Friebel et al. 2017).[1] Examples include team bonuses, profit sharing (e.g., in law firms or medical practices), and employee ownership schemes.

In the context of environmental protection and natural resource management, group incentives could take a variety of forms (Kotchen & Segerson 2018, 2020). For example, a group of farmers could be taxed (or receive subsidies) based on ambient water quality, which is determined by the combined actions of all farmers in the watershed, rather than on their own individual discharges (which might not be easily monitored). Likewise, a contract to make payments for ecosystem services (PES) could base those payments on the collective performance of a group of landowners, or a fisheries manager could allocate harvest or bycatch quota to a group of vessels (e.g., a cooperative or an entire fleet) rather than to individual vessels and then penalize the group as a whole (typically through closure of the fishery) if the group fails to comply with the aggregate limits. A regulator might also threaten an entire industry with costly regulation if it does not improve its collective performance (e.g., by sufficiently reducing industry-wide emissions). In all cases, the key feature is that each individual within the group faces rewards and/or penalties that are based on group performance rather their own individual performance.

There are a number of reasons for using a group incentive rather than individual incentives for addressing environmental externalities (e.g., Swallow & Meinzen-Dick 2009; Kerr et al. 2014; Kotchen & Segerson 2018, 2020; Holland 2018).

1. The joint production function determining the group's output may not be separable into independent individual contributions;
2. Monitoring or contracting on individual contributions or performance may be difficult or very costly;
3. The resource that needs to be managed may be collectively owned by, for example, a village or community;
4. Group incentives may foster spatial or temporal coordination among group members that is needed to manage a resource efficiently; or
5. Group incentives may allow members of a group to pool risks when outcomes are uncertain.

In all of these cases, a group incentive might be either the only feasible way to structure rewards or punishments or possibly the preferred way to do so.

[1] Other contexts in which group incentives have been used include team projects in education (Hansen 2006), microfinance in developing countries (Armendáriz & Morduch 2005, Giné & Karlan 2014), joint and several liability (Miceli & Segerson 1991), and group punishment (Miceli & Segerson 2007). See Babcock et al. (2015) for discussion of other examples.

A key concern with the use of group incentives, however, is that they will lead to shirking or free-riding by group members who do not "do their part" (e.g., Prendergast 1999). Broadly speaking, group incentives create collective action problems, and it is well known that collective action problems can lead to underinvestment in effort when benefits are shared by the group but the associated cost is borne by individual group members (e.g., Olson 1965, Sandler 2015). The challenge is to try to design the incentive scheme to overcome the potential for free-riding that might otherwise arise.

This review provides an overview of the economic literature on the use of group incentives in environmental and natural resource policy design. The focus is on contexts in which a regulatory body can design and impose a policy that creates incentives for individual members of a group based on the group's overall performance. As noted above, such policies would include taxes and/or subsidies based on ambient water (or air) quality, collective PES, industry-wide regulatory threats, and fleet-wide fisheries harvest or bycatch quotas. I begin in Section 2 with a discussion of terminology and scope, which is intended to clarify where the scope of this review falls within a broader literature on incentive schemes involving groups. Because group incentives create collective actions problems, I then turn in Section 3 to a brief overview of the key characteristics of collective actions problems. Section 4 presents a brief discussion of the related literatures in the contexts of public goods and employee compensation. Section 5 then overviews the theoretical literature on the use of group incentives in environmental and natural resource economics, starting with a stylized model of group incentives that further clarifies the nature of how group incentives can be structured and then turning to a discussion of policy design. This is followed in Section 6 by an overview of the empirical literature on the use of group incentives in this context, which draws from both laboratory and field experiments as well as observational studies. Finally, Section 7 provides concluding comments.

2. A NOTE ON TERMINOLOGY AND SCOPE

The literature on groups (or teams) and collectiveness, both within and outside of economics, uses a variety of terms that are often not clearly distinguished and are sometimes used inconsistently (Castañer & Oliveira 2020). These include collective action, collective choices/decisions, coordination, cooperation, collaboration, and collusion. For example, the seminal work by Olson (1965) and follow-up work by Ostrom (1990, 2000) and others use the term collective action to refer to problems where the payoffs of individuals are interdependent and such that the choices that maximize net benefits to individuals deviate from those that maximize joint (or social) net benefits or, more precisely, where the Nash equilibrium is not socially efficient, typically because the problem is a Prisoner's Dilemma. Sandler (2015, p. 196) uses a broader definition that includes any situation where "the efforts of two or more individuals or agents (e.g., countries) are required to accomplish an outcome," or, in other words, any situation where there is "team production." This definition includes not only Prisoners' Dilemmas but also other types of interactions (e.g., chicken, assurance, or coordination games), including problems where the (or at least one) Nash equilibrium is socially efficient (see Sandler & Arce 2003). Under both definitions, the focus is on problems where the decision-making unit is an individual (or individual firm or country) and on the incentives faced by those individuals (including possible free-riding incentives). In these contexts the notion of a group or collective is relevant only in that it defines the set of individuals who contribute to team production and/or have interdependent payoffs. Cooperation is then simply the outcome where individuals make decisions that consider these interdependencies and are socially efficient even (especially) when those decisions are not a Nash equilibrium. A key focus is thus on the incentives for cooperation and the circumstances under which it might or might not emerge.

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It is important to note that, because of the focus on individual decision making, the economic models of collective action/cooperation noted above fall under the heading of noncooperative game theory (rather than cooperative game theory), where individual players (rather than coalitions) make strategic decisions. In other words, despite the use of the term collective action, the actions (or decisions) studied in these models are not made collectively, i.e., by the group to which the individuals belong. There is a large body of literature on collective decisions/choices (sometimes included as part of collective action or choice, following Oliver 1993 and Stasser & Abele 2020), where the decision-making body or unit is the collective or group; i.e., a group must make a single decision or choice for or on behalf of all members of the group (see footnote 3). Such choices are often (but not always) made through some form of collaborative process where group members work together toward some agreed-upon goal.

In addition, as defined above, cooperation is distinct from coordination. The term coordination has a very specific meaning when used in the context of a coordination game (Weidenholzer 2010) but is sometimes used more broadly as a synonym for cooperation. For example, in a coordination game, the payoffs are such that the players benefit from coordinating on (i.e., choosing) the same strategy (such as driving on the right side of the road) and, once coordination is achieved, there is no incentive for individuals to deviate. In addition, there are often multiple Nash equilibria, and the goal is to ensure that individuals coordinate on the good or better equilibrium, as, for example, in an assurance game (Isaac et al. 1989).

This article adopts the broader definition of collective action used by Sandler (2015), where individual decision makers (e.g., consumers, landowners, or firms) who are members of an identifiable group face payoffs that are interdependent, but allowing for scenarios (e.g., policy designs) where that interdependency does not necessarily imply inefficient Nash equilibria. The term cooperation is then used to refer to the outcome where the decisions made by individuals consider those payoff interdependencies and are socially efficient, even if there is no explicit interaction among individuals (beyond the interdependence of payoffs). In this sense, it is the outcome that is cooperative rather than the process of reaching that outcome. Coordination, on the other hand, will be used to refer to an unspecified process by which a group (collaboratively or otherwise) determines and implements a means for achieving an agreed-upon group-level goal.

Based on this terminology, the group incentives discussed here are policies or schemes that create (or in some cases compound) a collective action problem that might or might not induce individual-level cooperative behavior (possibly, but not necessarily, through coordination and/or collaboration). I emphasize this to clearly define the scope of the review. However, even within this scope, there can still be different types of specific policy contexts (see, e.g., Engel 2016, Hayes et al. 2019). Here, I focus primarily on group incentive schemes where (*a*) the scheme is externally designed and imposed (e.g., by a regulator) rather than being decided upon by the group; (*b*) rewards/punishments are triggered by the level of overall group performance; (*c*) once triggered, the magnitudes of those individual reward/punishment are also based on group rather than individual performance; (*d*) those rewards/punishments are specified for each individual as part of the policy design (i.e., reward/punishments are at the individual rather than group level); and (*e*) individuals (rather than groups) make decisions (i.e., the game is noncooperative). In particular, I do not consider contexts in which there is no externally imposed policy,[2] decisions are made by

[2]This includes common property problems where there are no externalities imposed outside the group and no external management body (e.g., Ostrom 1990, 2000; Tarui et al. 2008), as well as global collective action problems, where no central authority exists for imposing policies on nations (Sandler 2004).

groups,[3] rewards/punishments are paid to/by the group rather than individual group members,[4] or where the incentive scheme depends in some way on (observable) individual behavior.[5] (This latter category includes schemes based on comparisons of individual performance across group members, such as tournaments and relative performance standards.[6])

3. KEY CHARACTERISTICS OF COLLECTIVE ACTION PROBLEMS

As noted above, group incentive schemes create collective action problems. They thus share many of the characteristics of other collective action problems, which can arise from a variety of scenarios. The canonical context is the existence of a public good whose provision generates benefits for all members of a group. In this case, the benefit of provision is public while the associated costs are private. As a result, each group member has an incentive to undercontribute relative to the socially efficient level, resulting in underprovision of the good. The dual of the public good collective action problem is the common property (or commons) problem (Sandler & Arce 2003), where use of a given resource by members of a group generates private benefits for those members but also imposes public costs on other members (because the available resource is limited or because of congestion/crowding costs). In this case, individual group members have an incentive to overuse the resource relative to the socially efficient level, resulting in either overexploitation of the resource or, in the case where a finite amount is available, inefficient exploitation (e.g., a race to fish). Both the public good and the common contexts are, of course, specific examples of the more general context where decisions by one group member impose externalities (either positive or negative) on other members of the group (Cornes & Sandler 1996).

In all cases, the collective action problem hinges on the existence of an identifiable group with interdependent payoffs. However, these groups can be formed in a variety of ways (e.g., Kerr et al. 2014). In some cases, the group will be exogenously defined, based on, for example, physical interdependencies. For instance, the owners of all fishing vessels that fish for a given species in a particular waterbody or area may form a natural group if species abundance and space are limited in the fishing grounds and those vessels compete for the limited resource. Other examples of natural groups include a group of farmers in a watershed, firms in an industry, power plants in a region, or landowners in a given community. Alternatively, group membership can be defined endogenously, as when individuals or firms choose to join a group specifically for the benefits of group

[3]For discussions of group decisions, see, e.g., Charness & Sutter (2012) and Cason et al. (2019). Group-level decision making is also relevant in the context of collective PES programs, where the land being enrolled in the program is collectively managed (Hayes et al. 2019). See also Gatiso et al. (2018).

[4]Under such schemes the regulator leaves it to the group to determine how a collective penalty/reward is to be distributed within the group (e.g., Collins & Maille 2011, Engel 2016, Hayes et al. 2019).

[5]If individual choices can be monitored, it is possible to have an individual's payment linked to their own contributions. For example, improved monitoring to allow payments to vary with individual contributions has been suggested as a means for addressing the nonpoint source pollution problem (e.g., Xepapadeas 2011, Palm-Forster, et al. 2019, Balmford et al. 2021). Policies that allow for firms to avoid the negative consequences of group failures through their individual effort have also been used to reduce greenhouse gas emissions (e.g., Dijkstra & Rübbelke 2013). For studies comparing individual versus collective payments, see Narloch et al. (2012), Midler et al. (2015), Gatiso et al. (2018), and Moros et al. (2019).

[6]For general discussions of tournaments and related contests, see, e.g., Lazear & Rosen (1981), Holmstrom (1982), Nalbantian & Schotter (1997), Prendergast (1999), Che & Yoo (2001), and Connelly et al. (2014). For discussions of relative performance standards specifically in the context of environmental performance, see Zabel & Roe (2009) and Mullins (2018). Tan et al. (2021) and Wang & Lei (2021) describe examples of environmental tournament-style schemes in China.

membership. Clubs and cooperatives are good examples. In some cases, endogenously formed groups will develop organically; i.e., individuals will come together to form a group on their own. For example, firms that seek green certification might form a green club aimed at promoting an eco-friendly reputation for member firms (Potoski & Prakash 2013, van't Veld & Kotchen 2011, Kotchen 2013). In other cases, a third party (such as a regulator) can establish a group and allow (or even invite) individuals to join. For example, in an effort to better regulate the New England groundfish fishery, fisheries managers allowed the creation of sectors that would operate as collectives and self-manage collective quotas, where individual vessel owners could then choose whether or not to join a given sector (Holland & Wiersma 2010). Similarly, many government-run voluntary environmental programs invite participation into an endogenously formed group of participants (e.g., Borck & Coglianese 2009). Of course, regulators can also establish groups where participation is mandatory rather than voluntary. For example, in the case of the fleet-wide sea turtle bycatch quota for the Hawaiian swordfish fleet, all vessels within the fleet automatically became members of the group subject to the overall bycatch limit (Chan & Pan 2016). Whether participation is mandatory or voluntary can have implications for self-selection, which can in turn impact group performance (e.g., Deacon et al. 2008, 2013). Finally, groups can emerge from interactions in imperfectly competitive markets. Those markets could be created by regulators (e.g., through establishment of a cap-and-trade system) or simply through supply side characteristics (such as economies of scale or access to limited resources). In this case, the group is the set of firms whose decisions are strategically interdependent. Relevant to this review are cases where that strategic interdependence has implications for environmental quality or resource use.

In addition to the nature of the interdependencies and how the group is formed, collection action problems can also differ in how individual decisions combine to determine the overall outcome for the group. The standard aggregator function for determining the group outcome or performance metric from individual actions is a simple summation function, whereby, for example, group contributions are simply the sum of individual contributions. For instance, total emissions (or emissions reductions) by firms in a given region are simply the sum of the emissions (emissions reductions) of those firms. However, other aggregator functions are possible, based on different characterizations of the public good (see, e.g., Hirshleifer 1983, Cornes 1993, Sandler 2015). These include aggregators representing weakest-link public goods (where the total group outcome is determined by the smallest or worst individual contribution), best-shot public goods (where the overall outcome is determined by the effort or success of the best member), and threshold public goods (where the benefits for the group only materialize once contributions by group members reach a certain level). Although the relevant aggregator function might be determined by the physical nature of the public good, in the context of public goods created through the use of group incentives, the relevant function might also be determined by policy design [e.g., based on the metric used for group performance and how the associated group rewards or punishments are designed (Hirshleifer 1983)]. For example, policies that punish a group when total emissions exceed a given standard effectively define group performance as a threshold public good, since avoided emissions must reach a certain level before the benefits of avoided punishment are realized.

Finally, it is important to distinguish whether, absent any group incentive mechanism, the actions by members of the group impose externalities only on other group members or they impose externalities outside the group. This determines the motivation for group incentives. In the former case, group incentives could be used to help the group solve the internal collective action problem that stems from intragroup externalities. This is the typical case for groups seeking to manage common property resources. In the latter case where the group imposes externalities on nongroup members (e.g., farmers collectively pollute a downstream waterbody), the group incentive mechanism would presumably be designed to address these third-party externalities. In this case, the collective action problem is created by the use of a group incentive. Here, I focus on this latter case, recognizing that, regardless of what generates the collective action problem, many of the insights about its implications and solutions will be the same.

4. RELATED LITERATURE

4.1. Group Incentives and Public Goods

It is clear from the discussion above that the use of group incentives in environmental and natural resource management is closely related to the theory of public goods. Under a group incentive scheme, group performance becomes a public good for the group (Kotchen & Segerson 2018). Although a review of the voluminous literature on public goods is beyond the scope of this article, a key part of this literature is the focus on free-rider incentives and the resulting underprovision of the public good. Thus, a key question of interest is how to solve the free-rider problem to ensure efficient provision (Cornes & Sandler 1996). The remedies that have been proposed for public goods include, for example, demand-revelation mechanisms (e.g., Healy & Jain 2017) and bundling/packaging of public and private goods or the creation of clubs (Kotchen 2013, Dixit & Olson 2000). These proposed solutions are not based on group incentives. However, at least for discrete public goods, the free-rider problem can also be solved through use of a mechanism under which the public good is provided if and only if total group contributions exceed the cost of provision. These mechanisms are sometimes termed provision point mechanisms (e.g., Rondeau et al. 2005). They yield multiple equilibria, not all of which are efficient, and can thus lead to coordination failures (Bagnoli & Lipman 1989, 1992; Bagnoli & McKee 1991).[7] Nonetheless, they constitute a form of group incentive mechanism (based on a threshold public good) that is similar to those discussed below.

A key focus of much of the literature on free-riding is the role of group size, i.e., whether increases in group size increase free-rider incentives. In general, this depends on the nature of the public good, and in particular, whether an increase in group size reduces the marginal benefit of individual contributions.[8] For example, there is no impact on this marginal benefit if the good is a pure public good, but marginal benefits decrease with group size for impure public goods that are shared or subject to congestion (e.g., Isaac & Walker 1988, Sandler 2015). Thus, free-rider incentives may be unaffected by group size in the former case but increase with group size in the latter case. In the case of a threshold public good, an increase in group size could reduce the marginal benefit of contribution (and thereby increase free-riding) if it makes an individual feel that her contribution is less pivotal in reaching the target that secures provision of the public good (Dixit & Olson 2000). As discussed in more detail below, with group incentive schemes, the scheme can be designed so that the efficient outcome is a Nash equilibrium for any group size. Nonetheless, for schemes that have multiple equilibria, group size could affect the ability to coordinate on the efficient equilibrium.[9]

[7] Interestingly, the results of Cachon & Camerer (1996) and Feltovich et al. (2012) suggest that coordination can be affected by whether payoffs take the form of losses or gains (due to loss aversion), implying that coordination might be easier for group incentives based on penalties than analogous schemes based on rewards. See also Bougherara et al. (2011).

[8] The effect of group size also depends on its impact on the marginal cost of contribution (Esteban & Ray 2001) and the specific aggregator function that characterizes the public good (Sandler 2015).

[9] Weber (2006) shows that coordination can be sustained in large groups if the group starts small, establishes a history of coordination, and then grows over time. This is consistent with evidence that the history of a group's

4.2. Group Incentives in Employee Compensation

While there are clear parallels with the public goods literature on free-rider incentives, the economic literature on the use of group incentives in environmental and resource management has its roots primarily in the theoretical literature on team production in industrial organization. As noted in Section 1, group incentives have been (and continue to be) used frequently in employment contexts, and economists have studied alternative schemes for compensating employees for group production (Prendergast 1999). The seminal article by Holmstrom (1982) examined the incentive effects of alternative schemes and identified the basic inefficiency that arises from any sharing rule that allocates the value of group output across group members (whereby the marginal costs of individual effort are borne fully by the individual while the marginal benefits are divided among the group). This is analogous to the inefficiency arising from free-riding in the context of contributions to public goods.[10] However, Holmstrom also showed that group bonuses (or penalties) can lead to a Nash equilibrium that is efficient, although the threshold nature of these types of forcing contracts leads to multiple equilibria that are vulnerable to slight mistakes (Nalbantian & Schotter 1997).[11]

5. GROUP INCENTIVES IN ENVIRONMENTAL AND NATURAL RESOURCE ECONOMICS: THEORETICAL LITERATURE

The principal-agent models that lie at the heart of the literature on team production have been adapted to a number of environmental or resource management problems, where the principal is society (or regulators acting on behalf of society), and the agents are individuals whose decisions lead to the production of a joint output related to environmental quality or resource use. This parallel was first noted in the context of nonpoint source pollution, where often group performance (e.g., ambient water quality) is observable while individual contributions are not. Drawing on the team production literature, theoretical work on nonpoint pollution control sought to design group incentives based on ambient water quality that could induce efficient pollution abatement as a Nash equilibrium. Early work developed tax and/or subsidy policies as well as fixed rewards/penalties that would be faced by individuals (e.g., farmers) but based on ambient water quality (relative to a baseline) (Meran & Schwalbe 1987, Segerson 1988). Such policies create a collective action problem for the group that is subject to the policy, since the payoff of each now depends on the group's overall performance, which in turn depends on the actions of all members of the group. Nonetheless, as the early work showed, by appropriately setting tax/subsidy rates or fixed penalties, the cooperative (first-best) outcome could be generated as a Nash equilibrium.

5.1. A Stylized Model of Group Incentives

To see this, consider the following stylized context in which a group incentive might be used (Kotchen & Segerson 2018). Suppose there are two agents (e.g., individuals, firms, or landowners),

coordination can be an important determinant of future coordination (Nalbantian & Schotter 1997) and with the experimental literature on the use of group incentives for resource management discussed in Section 6.

[10]Although there are many similarities between group incentives in an employment context and the incentives for contributions to public goods, there are also some important differences. See, e.g., the discussion by Nalbantian & Schotter (1997).

[11]The standard literature on employee compensation assumes workers are motivated only by monetary payments. However, evidence suggests that other factors, such as identity, i.e., the feeling of belonging to an identifiable group, can also affect effort or contribution decisions. The extent to which identity does or does not foster cooperation is an interesting area of research. See, e.g., Akerlof & Kranton (2000, 2005), Charness et al. (2014), and Camera & Hohl (2021).

each of whom makes a decision x_i, where $i = 1, 2$ and denotes the two agents. For example, x_i could represent emissions or discharges of a given pollutant, fertilizer applications, fishing effort, or the clearing of forested land. Suppose for simplicity that, absent a group incentive policy, there are no intragroup externalities; i.e., the payoff for each agent (W_i) depends only on her own decisions, implying $W_i = W_i(x_i)$. Suppose, however, that the actions of the two agents combine to determine an outcome $y = y(x_1, x_2)$ that impacts a third party whose payoff is given by $Z(y)$. Note that there are various forms that the y function could take, including:

1. Simple summation: $y = x_1 + x_2$;
2. Additively separable summation: $y = y_1(x_1) + y_2(x_2)$;
3. Threshold: $y = \max(0, \tilde{y} - \bar{y})$ where $\tilde{y} = x_1 + x_2$ or $\tilde{y} = y_1(x_1) + y_2(x_2)$;
4. Weakest-link: $y = \min(x_1, x_2)$; and
5. Best-shot: $y = \max(x_1, x_2)$.

The nature of the problem determines the appropriate form for this production function. For example, as noted above, the simple summation form might be appropriate when y simply represents total emissions of a pollutant such as sulfur dioxide or carbon dioxide. In contrast, additive separability might be more appropriate when y represents aggregate bycatch across two fishing vessels, where the bycatch of each vessel depends on its fishing effort, or when x_i represents an polluting input and y_i is the resulting pollution level for that party. It could also represent ambient water quality in a lake, where the impact of fertilizer use by the two farmers depends on their proximity and land characteristics. The threshold good representation would apply, for example, when there is some assimilative capacity and third-party damages only occur when that capacity is exceeded.

Each of the two players seeks to maximize her own payoff. Absent any policy and assuming differentiability and suitable regularity conditions and interior solutions, the equilibrium choices are given by the solutions to

$$\frac{dW_i}{dx_i}(x_i) = 0 \text{ for } i = 1, 2. \qquad 1.$$

Without a group incentive policy in place, if the two players do not impose externalities on each other, they do not face a collective action problem.[12] However, their choices are inefficient because of the externality imposed on the third party. Social efficiency is defined by the solutions to

$$\frac{dW_i}{dx_i}(x_i) + Z'(y)\frac{\partial y}{\partial x_i}(x_i, x_j) = 0 \text{ for } i = 1, 2. \qquad 2.$$

Comparing Equations 1 and 2 shows the inefficiency that can result when private decisions do not factor in third-party impacts.[13] The divergence between the equilibrium and efficient outcomes provides the motivation for policy intervention. The set of feasible policies depends on what is observable. If only y is observable, i.e., x_i and y_i are not observable, then only policies based on the observed group outcome (performance) are feasible. For example, if regulators

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[12] In a standard collective action problem of the type discussed by Olson (1965) and Ostrom (1990, 2000), the payoffs for each depend on not only their own choices but also an outcome determined by the choices of all members of the group; i.e., $W_i = \tilde{W}_i[x_i, y(x_1, x_2)] \equiv W_i(x_i, x_j)$.

[13] This specification again assumes differentiability and suitable regularity conditions. In particular, it assumes $y(x_1, x_2)$ is differentiable, which is not true for certain aggregator functions, such as weakest-link and best-shot. Nonetheless, the comparison of Equations 1 and 2 is useful for illustrating the general point regarding the potential inefficiency of the equilibrium in cases of third-party externalities. Here, the inefficiency takes the form of an inefficient level of y. However, as discussed below, for threshold public goods, inefficiency can also arise when the efficient level of y is produced but not in a least-cost way.

cannot observe or easily monitor individual farmer actions or contributions to the water quality in a lake but they can observe the lake's water quality, then policies based on ambient water quality will be feasible while individual (farm-level) policies will not. However, if x_i or y_i is observable, then policies based on individual decisions or performance (such as input taxes, emissions taxes, or individual PES contracts) are feasible. Nonetheless, for reasons discussed in Section 1, group incentives might still be used. In this case, the group incentive might be based on group performance y but could also involve individual actions or performance (x_i or y_i), as, for example, with relative performance standards such as tournaments or rewards/punishments determined by comparisons with the average performance within a given group (see footnotes 5 and 6).

Under group incentives of all types, each agent realizes an additional positive or negative payoff $T_i = T_i(x_i, x_j)$ that depends on both her own actions and those of others. Her total payoff then becomes $W_i^T(x_i, x_j) = W_i(x_i) + T_i(x_i, x_j)$. When the group incentive T_i depends directly on group performance y, i.e., $T_i = \tilde{T}_i[y(x_i, x_j)]$, this implies that the agents now face a collective action problem.[14]

5.2. Efficient Policy Design

Although the purpose of the group incentive is to address the third-party externality, as noted, it generates within-group externalities that in turn generate a collective action problem. A key question is how to design the incentive scheme to address both potential distortions. Consider, for example, a simple group incentive where each of two farmers pays a tax that is proportional to ambient water pollution. In terms of the notation above, this implies that $T_i = \tau \cdot y(x_1, x_2)$, where y would represent ambient water pollution, and τ is the ambient tax rate. When faced with this tax, each individual's payoff becomes $W_i(x_i) - \tau \cdot y(x_1, x_2)$ and the Nash equilibrium is then defined by

$$\frac{dW_i}{dx_i}(x_i) - \tau \cdot \frac{\partial y}{\partial x_i}(x_1, x_2) = 0 \text{ for } i = 1, 2. \qquad 3.$$

Comparing this to Equation 2 shows that if the regulator sets $\tau = -Z'(y^*)$, where $y^* = y(x_1^*, x_2^*)$ is the efficient pollution level, then $(x_1{}^*, x_2{}^*)$ will be a Nash equilibrium. Moreover, with an additive or additively separable aggregator function, it will also be a unique dominant strategy. Thus, despite the collective action nature of the problem, efficient cooperation will emerge as a Nash equilibrium.

Other policy designs can yield the efficient choices as a Nash equilibrium as well (see Segerson 1988, Spraggon 2002, Kotchen & Segerson 2018). These include:

1. An ambient tax on water pollution above a threshold level $\bar{y}$, given by $T_i = \tau \cdot [y(x_1, x_2) - \bar{y}]$ when $y(x_1, x_2) > \bar{y}$ (and zero otherwise), where $0 \leq \bar{y} < \hat{y}$ and $\hat{y}$ is the prepolicy level;[15]
2. A proportional subsidy when water pollution is below a given threshold $\bar{y}$, given by $T_i = -s \cdot [\bar{y} - y(x_1, x_2)]$, when $y(x_1, x_2) < \bar{y}$ (and zero otherwise), where $y^* < \bar{y} < \hat{y}$;[16] and

[14]Note that more generally the reward or payment can be based on a chosen aggregator function that differs from the production function $y(x_1, x_2)$, as, for example, under a payment scheme where members of a group receive payments only if all members take a desired action (e.g., plant a given crop), implying use of a weakest-link aggregator function in the policy design, even when the total environmental outcome, i.e., the actual production function, depends on the summation of individual actions (e.g., total acreage planted).

[15]One possibility is to set $\bar{y} = y^*$. This specification has a number of advantages (see Kotchen & Segerson 2018).

[16]Alternatively, the subsidy can be paid when ambient pollution is below y^*, i.e., with $\bar{y} = y^*$, if it is coupled with an additional fixed subsidy payment (Spraggon 2002).

3. A combined tax/subsidy policy given by $T_i = \tau \cdot [y(x_1, x_2) - \bar{y}]$, under which individuals pay a proportional tax when ambient pollution exceeds $\bar{y}$ and receive a proportional subsidy when it is below $\bar{y}$.

Note that, regardless of the form of the aggregator function for y, the threshold $\bar{y} > 0$ creates a threshold public good (or bad), where costs or benefits for the group as a whole are realized only when group performance reaches that threshold.[17] Nonetheless, all of these policies can avoid free-rider incentives and thereby lead to a cooperative outcome by setting the appropriate tax or subsidy rates. These policies can also induce efficient behavior when used as regulatory threats. For example, Segerson & Wu (2006) show that efficient abatement can be induced voluntarily if ambient taxes are not imposed initially but used as a regulatory threat for failure to meet a given water quality standard. Moreover, in related work, Suter et al. (2010) show that the resulting Nash equilibrium is unique if the threat is set endogenously based on group performance under the voluntary action.

Under all of the abovementioned policies, the magnitudes of the rewards or punishments change proportionately with changes in group performance. However, efficient behavior can also emerge from a group incentive under which each group member is rewarded or punished based on whether overall group performance exceeds or falls short of a given threshold, where the associated reward/punishment is fixed, i.e., does not vary proportionately with performance. In the case of a group penalty, $T_i = \bar{T}$ when $y(x_1, x_2) > \bar{y}$ (and zero otherwise), where $\bar{T} > 0$ is the fixed penalty faced by all members of the group. Under a group reward (or bonus or subsidy), $T_i = -\bar{S}$ when $y(x_1, x_2) < \bar{y}$ (and zero otherwise), where $\bar{S} > 0$ is the fixed reward (Meran & Schwalbe 1987, Segerson 1988, Spraggon 2002). These policies are equivalent to the forcing contracts considered by Holmstrom (1982) and Nalbantian & Schotter (1997). Although they can be applied in contexts like nonpoint pollution where only group performance is observable, they can also represent policies that impose collective quotas or a performance standard on a group of firms even though individual choices can be observed. One example is when a regulator threatens imposition of a firm-level tax or costly regulation on the entire industry if it fails to self-regulate and thereby adequately control emissions voluntarily (Dawson & Segerson 2008).[18] In this case, the penalty is the imposition of the costly policy when group performance is inadequate. Another example of this type of policy is group-level quotas on fishery harvest or on fleet-level or cooperative-level bycatch (Deacon et al. 2008, 2013; Abbott & Wilen 2009; Holland & Wiersma 2010; Deacon 2012; Abbott et al. 2015; Chan & Pan 2016; Zhou & Segerson 2016; Holland 2018). Under collective quotas, once the cap is reached, the fishery is typically closed for the remainder of the season (or the members of the collective can no longer fish),[19] which imposes a fixed cost (in the form of lost profit) on those fishing vessels. The use of collective quotas has been justified based on the view

[17] A key difference between this scenario and the standard scenario for contributions to a threshold public good relates to refundability. In the standard contribution context, contributions can be refunded if the threshold is not met. However, in the context here, contributions (in the form of pollution abatement effort) are sunk once they are made and the associated costs cannot be refunded.

[18] Dawson & Segerson (2008) show that industry-wide regulatory threats can yield an equilibrium in which some subset of firms ensures that the performance needed to thwart the threat is achieved, despite the free-riding of other firms. For similar results in the context of financial disclosures, see Suijs & Wielhouwer (2019).

[19] Alternatively, if groups can purchase additional quota once the limit is reached (see, e.g., Stewart & Leaver 2016), then this policy operates like a proportional tax above a given baseline determined by the collective cap. This type of policy approach is analyzed by Zhou & Segerson (2016).

that they promote risk pooling/sharing (Holland 2010, 2018; Deacon 2012; Holland & Jannot 2012) and can foster cooperation that can address within-group externalities.[20]

5.3. Issues in Policy Design

Despite the ability of group incentives to generate efficient Nash equilibria, the literature has recognized a number of issues that need to be considered when designing group incentives.

5.3.1. Role of uncertainty. In many cases, the relationship between individual inputs and group performance depends on stochastic factors such as weather or market shocks. In this case, the general aggregator function takes the form $y = y(x_1, x_2, \varepsilon)$, where ε is a random variable (or a vector of random variables). This could reflect uncertainty regarding individual productivity [as, for example, if $y = y_1(x_1, \varepsilon_1) + y_2(x_2, \varepsilon_2)$], or it could reflect uncertainty about how group effort translates into group performance [e.g., $y = y(x_1 + x_2, \varepsilon)$]. Using weather as an example, the former could arise when weather and land characteristics affect how much of the fertilizer applied by a given farmer runs off into a nearby stream, while the latter would arise if weather and local conditions in the stream affect how total fertilizer loadings affect its water quality. In either case, individuals cannot fully control their performance (including whether a given target $\bar{y}$ is met) through their choices. This can have implications for the design of efficient group incentives. For example, although the presence of uncertainty does not necessarily change the optimal design of a proportional ambient tax/subsidy policy (Segerson 1988), it changes the optimal tax rate under an ambient tax policy that includes a baseline $\bar{y}$. It also complicates the policy design if individuals make multiple decisions that can affect group performance and the impact of group performance (e.g., the external damage that results) is strictly convex, or if firms are risk averse (Horan et al. 1998, 2002). In this case, efficiency can be achieved by using a state-dependent tax rate equal to marginal damages or a nonlinear tax based on total damages (Hansen 1998, Horan et al. 1998, Suter et al. 2008). Efficiency can also be impacted by imperfect information or asymmetric beliefs (Cabe & Herriges 1992).

Moreover, as noted above, uncertainty raises the possibility that pooling individual quotas (effectively creating a group limit or risk pools) would be advantageous (Mrozek & Keeler 2004; Holland 2010, 2018; Holland & Jannot 2012). However, risk pooling will not necessarily reduce the probability of exceeding limits. For example, Zhou & Segerson (2016) show that, depending on the underlying distributions of the random factors and the magnitudes of the limits, it is possible that the probability that a group exceeds its collective limit can be greater than the probability that an individual limit would be exceeded.

5.3.2. Budget-balancing and entry/exit incentives. A key feature of the group incentive schemes discussed above is that they are typically not budget-balancing; i.e., the total penalties (or rewards) paid (or received) by the group do not generally equal the external cost (or benefit) of their collective actions (see Xepapadeas 2011).[21] Moreover, they can entail high costs for the group members (for penalty-based schemes) or for regulators (for subsidy-based schemes), which

[20]These can include both congestion externalities and market externalities arising from price responses to the timing of supply. However, the use of collective rather than individual quotas can also create a race to fish as vessels compete for shares of the limited quota that is collectively available. See, e.g., Abbott & Wilen (2009).
[21]Holmstrom (1982) identified budget balancing as a key consideration in the design of incentives for efficient team production in firms. He showed that breaking the budget-balancing constraint was key to being able to design compensation schemes that provide efficient incentives, arguing that this need provides a rationale for the role of firm owners or managers.

can affect not only the political feasibility of these schemes but also entry/exit incentives. However, $\bar{y}$ can be adjusted to reduce these costs and under some schemes even yield an outcome where no payments are made or received in equilibrium (or on average, if there is uncertainty) (Segerson 1988, Kotchen & Segerson 2018). Alternatively, costs can be reduced (and efficiency achieved with a balanced budget) through a scheme under which penalties are imposed on a randomly chosen group member (rather than on all group members), at least if group members are sufficiently risk averse (Xepapadeas 1991, Herriges et al. 1994).

5.3.3. Incentives for collusion and the importance of within-group decision-making rules. The efficiency properties of the group incentive schemes discussed above assume Nash behavior, where group members individually choose actions that maximize their own payoffs. However, some of these schemes are not collusion-proof; i.e., they create incentives for group members to work together and collude (typically overabate) to raise the payoffs for all members of the group (by reducing their penalties or increasing their rewards). This can arise under policies that involve subsidies (Hansen 1998, Spraggon 2002) but also arises under a tax policy that is efficient (under Nash behavior) but that in equilibrium entails positive tax payments (Suter et al. 2008).

Of course, the problem with collusion arises when the incentive scheme is derived under a behavioral assumption (Nash behavior) that turns out to be incorrect once the scheme is put in place. This highlights the importance of understanding the decision-making environment when designing the group incentive scheme. If it is known that members within the group make decisions collectively (based on joint payoffs), then the incentive scheme can be adjusted accordingly to ensure efficient decisions in this decision environment (Zhou & Segerson 2016, Kotchen & Segerson 2018). Alternatively, a scheme that is both efficient under Nash behavior and collusion-proof can be used, such as a proportional tax policy with a baseline $\bar{y}$ set at the efficient group performance level y^* or a fixed group penalty (Spraggon, 2002). Under either of these schemes, in a Nash equilibrium tax payments are zero and therefore group members have no incentive to collude to reduce those payments.

5.3.4. Existence of multiple equilibria. Although the group incentive schemes discussed above induce efficient behavior as a Nash equilibrium, in some cases that equilibrium is not unique. This is particularly true for schemes based on fixed penalties (or rewards) but can also arise with proportional subsidies. These policies effectively create a threshold public good and generate something similar to an assurance problem.[22] In addition to the efficient equilibrium, no contribution (or no abatement) can also be a Nash equilibrium. Moreover, even when the threshold level is met in equilibrium, it is possible for it to be met in an infinite number of ways, as when there are an infinite number of combinations of inputs that yield $\bar{y}$ and still generate a net gain for all group members (Sandler 2015). This implies that, even though the target is met and in this sense there is no underprovision of the public good, there could still be an inefficiency because the contributions would not necessarily be distributed efficiently across group members (Segerson & Wu 2006, Dawson & Segerson 2008, Suter et al. 2010, Kotchen & Segerson 2018).

5.3.5. Within-group externalities. The original collective action literature (e.g., Olson 1965, Ostrom 1990, Ostrom et al. 1994) focused on problems where the interdependence of payoffs stemmed from the nature of the problem itself (e.g., the existence of a pure public good or

[22] However, a key distinction between a threshold public good and an assurance or standard coordination game is that in the former, as long as others step up to ensure provision of the good, there is no incentive for an individual to also do so.

a common property resource) rather than on a policy-induced interdependence created by the imposition of a group incentive scheme. In this case, the group as a whole benefits from self-regulation, even if self-regulation is not an equilibrium outcome. Moreover, the use of a group incentive adds a second collective action problem to the preexisting one that stems from within-group externalities. For example, a fishery that is a common property resource will face the usual within-group externalities (e.g., from congestion, stock, or price effects) and thereby face a collective action problem even in the absence of any externally imposed regulatory action (assuming Nash behavior). If in addition a regulator imposes a group incentive such as a fleet-wide total allowable catch or bycatch limit, this adds an additional dimension to the collective action problem that should be considered in the design of an efficient group incentive scheme and highlights the importance of understanding within-group decision making when designing group incentives (Zhou & Segerson 2016).

5.3.6. Dynamics and stock pollutants. The literature discussed above focuses on static problems (or one-shot games). Dynamics can arise, for example, when group performance involves a stock variable such as a stock pollutant (Xepapadeas 1992) or when the regulator can adjust the group incentive scheme over time in response to group performance (Karp 2005). In general, with appropriate adjustments, the group incentives discussed above can be efficiently applied in these contexts as well.

6. GROUP INCENTIVES IN ENVIRONMENTAL AND NATURAL RESOURCE ECONOMICS: EMPIRICAL LITERATURE

As noted in Section 1, there is considerable empirical literature regarding employee compensation showing that group incentive schemes can have positive impacts on labor productivity and firm performance (e.g., Nalbantian & Schotter 1997, Bloom & Van Reenen 2011, Friebel et al. 2017). A literature on the performance of group incentives in environmental and natural resource management contexts has emerged mainly over the last two decades. Although there have been some field experiments and observational studies, much of what is known about the efficiency and effectiveness of group incentives for environmental and natural resource management comes from lab experiments, which allow researchers to test alternative incentive schemes more easily.

6.1. Laboratory and Field Experiments

Much of the experimental literature on the use of group incentives has been motivated by an interest in ambient-based group policies to control nonpoint source pollution (for surveys, see Shortle & Horan 2001, 2013; Xepapadeas 2011; Giordana & Willinger 2013). Most of these studies involve laboratory experiments that use students as subjects.[23] In general, the results of these lab experiments have been consistent with the predictions of the theory (Giordana & Willinger 2013). An early paper by Spraggon (2002) and subsequent literature (e.g., Alpízar et al. 2004, Cochard et al. 2005, Suter et al. 2008, Cason & Gangadharan 2013, Suter & Vossler 2014, Miao et al. 2016, Palm-Forster et al. 2019) suggest that ambient-based policies can be not only effective but also efficient, at least in the aggregate. Those based on proportional taxes (by themselves or in combination with proportional subsidies) tend to perform better than schemes

[23] In addition, most (but not all) assume that the direct benefits of environmental or resource use improvements do not go to members of the group but rather to third parties. In other words, absent the incentive scheme, there are no within-group externalities associated with the behavior of interest. Exceptions to this are discussed by Cochard et al. (2005), Narloch et al. (2012), Midler et al. (2015), Kaczan et al. (2017), and Moros et al. (2019).

with fixed penalties or rewards (where there are multiple equilibria and efficient behavior is not a dominant strategy), although even when thresholds are met, some amount of free-riding (underabatement by some) often still occurs (Spraggon 2002).

The experimental literature also shows that the efficiency of these schemes can be increased through the use of social nudges (Wu et al. 2021) or direct communication to increase the likelihood of cooperation (e.g., Poe et al. 2004, Vossler et al. 2006, Suter et al. 2008). However, for some schemes, communication can also increase incentives for collusion, which can in turn reduce efficiency (through overabatement) (Poe et al. 2004, Vossler et al. 2006). This occurs when there is some chance of improving private payoffs through collusion, as, for example, with proportional subsidies (Hansen 1998) or with fixed fines in the presence of uncertainty (Vossler et al. 2006) or fixed or proportional taxes when the threshold is not set at the efficient level (Suter et al. 2008). In contrast, in the absence of uncertainty, a pure tax mechanism with a threshold set at the socially efficient level yields efficient outcomes under both noncooperative and cooperative (collusive) behavior (Suter et al. 2008, 2010). Thus, depending on the policy design, communication can lead to coordinating on either a good equilibrium or a bad equilibrium. The literature has also examined the role of other factors that might affect efficiency, such as cost and spatial heterogeneity (Spraggon 2004, 2013; Suter et al. 2009; Cason & Gangadharan 2013; Miao et al. 2016), risk preferences (Camacho-Cuena & Requate 2012), and the provision of detailed information about marginal incentives and payoffs (Spraggon & Oxoby 2010).

As noted, the studies discussed above rely on experiments conducted in laboratories using students as subjects. Although less numerous, other studies have conducted "lab in the field" controlled experiments of policy impacts where the subjects are individuals in the relevant field (e.g., farmers or miners). The majority of these studies test the impact of collective payments for the provision of ecosystem services and thus focus on collective rewards rather than collective penalties.[24] Study populations in these experiments include farmers in the United States, Ethiopia, Peru, Bolivia, Colombia, and Tanzania (Taylor et al. 2004, Reichhuber et al. 2009, Collins & Maille 2011, Narloch et al. 2012, Suter & Vossler 2014, Midler et al. 2015, Kaczan et al. 2019, Moros et al. 2019), coffee mill operators in Costa Rica (Alpízar et al. 2004), artisan gold miners in Colombia (Saldarriaga-Isaza et al. 2015; Rodriguez et al. 2019, 2021), participants of a PES program in Mexico (Kaczan et al. 2017), local villagers in Cambodia, Mexico, Tanzania, and Uganda (Travers et al. 2011, Kerr et al. 2012, Gatiso et al. 2018), and forest users across a range of other developing countries (Andersson et al. 2018). The results are generally consistent with those from the studies described above, showing that group incentives can be effective in inducing (more) efficient behavior[25] but that coordination can be difficult with fixed rewards and proportional subsidies can lead to collusion (e.g., Reichhuber et al. 2009; Kaczan et al. 2017; Rodriguez et al. 2019, 2021). Moreover, studies show that building trust (e.g., by starting with schemes that are less stringent so that cooperation is easier to achieve) as well as having strong internal governance and leadership, a say in the incentive design, and open communication channels can improve the performance of group incentives (Reichhuber et al. 2009; Travers et al. 2011; Narloch et al. 2012; Kaczan et al. 2017; Andersson et al. 2018; Rodriguez et al. 2019, 2021). In contexts where group members might have an incentive to contribute even in the absence of an externally imposed incentive mechanism (e.g.,

[24]Exceptions include Reichhuber et al. (2009), Suter & Vossler (2014), and Alpízar et al. (2004), all of whom test incentive schemes originally developed in the context of nonpoint pollution. Kaczan et al. (2017) also include a group fine in their scheme, but the group also shares the total group contributions.

[25]While many experimental studies test incentive schemes that, in theory, can induce first-best outcomes, some field experiments do not. Because of this, the analysis focuses on the effectiveness of the scheme in improving environmental behavior rather than its efficiency. See, e.g., Narloch et al. (2012), Midler et al. (2015), Kaczan et al. (2017), and Moros et al. (2019).

due to within-group externalities or altruism), studies have also found mixed evidence regarding whether external imposition of group-based policies affects intrinsic motivations and hence either crowds-in or crowds-out baseline contributions (Narloch et al. 2012, Midler et al. 2015, Rode et al. 2015, Kaczan et al. 2017, Ezzine-de-Blas et al. 2019, Kaczan et al. 2019, Moros et al. 2019).

6.2. Observational Studies

There is an extensive literature on circumstances under which groups are able to solve common property problems or manage collective rights that have been allocated to a group such as a fishing cooperative or village (e.g., Ostrom 1990, Ostrom et al. 1994, Townsend et al. 2008, Gutiérrez et al. 2011, McCay et al. 2014, Holland 2018). Much of this literature draws on case studies (rather than statistical analysis), and draws on the design principles for effective collective action developed by Ostrom (1990). It shows that comanagement based on exclusive community rights (that can be established and, if necessary, enforced externally) can lead to effective collective action. Moreover, consistent with some of the experimental literature discussed above, strong social capital, leadership and community engagement, and traditions or histories of cooperation and trust are also important contributors to success (Gutiérrez et al. 2011, Holland et al. 2013, McCay et al. 2014).

Although case studies provide important insight into factors that contribute to effective collective management, most do not include statistical analysis of the impact of externally imposed group incentive schemes. There have been a limited number of studies that seek to identify these impacts explicitly and, to the extent possible, determine their magnitude. These primarily study contexts where the group incentive scheme explicitly or implicitly involves fixed rewards or penalties (rather than proportional taxes and/or subsidies). In the context of fisheries, these studies examine the impact of moving to a management system based on collective quotas, where the collective penalty takes the form of closure of the fishery if the group exceeds the quota. For example, consistent with the results of the case studies, Abbott et al. (2015) show that allocating quota to cooperatives (rather than setting a fleet-wide limit) in a North Pacific trawl fishery creates greater incentives for vessel owners to manage harvest and bycatch effectively. Several studies have examined the impact of collective rights on the efficiency of production, defined in terms of either technical efficiency (Felthoven 2002, Estrada et al. 2017, Huang et al. 2018) or efficiency gains from effort reallocations within the group (Deacon et al. 2008, 2013).

Observational studies of the impact of real-world collective incentive schemes have also been conducted in the context of PES programs, where payment is conditional on the collective performance of some group (for a recent survey, see Hayes et al. 2019). In many cases, the paying agency contracts with a community or village that collectively manages land, and the resulting compensation (either monetary or in-kind) is made to the community rather than to individuals within it (and the community then decides how to use the compensation or distribute it to group members).[26] Contexts that have been studied include payments for reduced deforestation (to promote hydrological services, biodiversity, and/or carbon sequestration) in Mexico (e.g., Alix-Garcia et al. 2012, Costedoat et al. 2015), shared grazing land in Ecuador (Hayes et al. 2015), conservation-related initiatives and land uses in Japan (Ito et al. 2018) and the Andes (Narloch et al. 2017), and wildlife conservation in Sweden (Zabel et al. 2014). Again, the results generally confirm the theory, suggesting that group incentives can effectively incentivize proenvironmental behavior, particularly in contexts where local governance is strong. Moreover, the results suggest that the

[26]Several studies have used choice experiments to elicit preferences over payment options, including payments to individuals versus payments to the group. See, e.g., Kuhfuss et al. (2016), Kerr et al. (2012), Kaczan et al. (2013), and Costedoat et al. (2016).

relationship between collective PES programs and local governance may be reciprocal; i.e., good local governance can increase the likelihood that a group incentive will be effective while at the same time the use of group incentives can create incentives for the development of good local governance (Hayes et al. 2019).

Finally, a limited number of observational studies have examined the impact of collective rewards or punishments in the context of industry-wide voluntary approaches, where a collective gain from group performance might result from a corresponding reputational gain for all firms within the industry while a collective penalty might be an industry-wide regulatory threat. This is a context in which within-group coordination or collaboration is less likely, except, for example, when there is a strong industry trade group that can monitor and sanction its members. Thus, it is not surprising that there is evidence of free-riding in this context (see discussion in Segerson 2017). However, there is also evidence that group incentives can be effective in this context, presumably because the benefits of an industry-wide reputational gain or the avoidance of industry-wide regulation are sufficiently large for some firms that they are willing to ensure compliance with a broad target despite the free-riding of other firms (e.g., Lenox 2006, Brouhle et al. 2009).

7. CONCLUDING COMMENTS

Group incentives are frequently used in a variety of contexts. For example, they have been shown to increase productivity and firm profits when used for employee compensation in the workplace. Analogous incentive schemes can and in some cases have been used to address a range of environmental and resource problems, including agricultural pollution, PES, fisheries management, and voluntary programs to reduce air and water pollution. These schemes base individual penalties and/or rewards (e.g., taxes or subsidies/payments) on the performance of an entire group of individuals (e.g., farmers, landowners, firms) who contribute to the environmental or resource degradation problem. In doing so, they create a collective action problem for members of the group, whereby group performance effectively becomes a public good for the group. The key challenge is then to design the associated penalties and/or rewards to avoid potential free-riding that can arise in collective action settings and instead enhance the group's performance.

The general economics literature on team incentives and public goods, as well as the literature specifically on environmental and natural resource management, provides insights into how group incentives can be designed and their likely effectiveness and efficiency. This literature suggests that either proportional schemes (under which rewards/penalties vary proportionately with performance) or fixed payment schemes (under which fixed rewards/penalties are realized only when performance crosses a threshold) can in theory provide incentives for efficient behavior (cooperation) to emerge as a Nash equilibrium. However, the empirical literature shows that, although these schemes can be effective and even efficient, in practice the outcomes under group incentives will depend on a combination of the policy design and the nature of the internal group interactions (reflecting the levels of, for example, trust, social capital, and leadership). Within-group interactions are likely to be particularly important when policies involve thresholds that can generate multiple equilibria so that coordination is needed to reach the cooperative equilibrium. More generally, as noted by Hayes et al. (2019) in the context of collective PES programs, the relationship between the effectiveness of group incentives and local governance is likely to be reciprocal, with each reinforcing the other.

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