W07-15 9/27/07
Forthcoming 2009 in *Arguments for a Better World: Essays in Honor of Amartya Sen,* ed. Kaushik Basu and Ravi Kanbur, 522–41. New York: Oxford University Press.

ENGAGING IMPOSSIBILITIES AND POSSIBILITIES

by

Elinor Ostrom

In the lecture that Amartya Sen delivered on the occasion of receiving the Alfred Nobel Memorial Prize in Economic Sciences (Sen 1999), he devoted considerable attention to Kenneth Arrow's (1951, 1963) "impossibility theorem." Arrow had elegantly demonstrated that short of a dictatorship, social choice procedures could not always generate unambiguous and consistent outcomes for a group of rational individuals who had their own preference rankings over collective outcomes that simultaneously met a set of reasonable conditions. Arrow used the definition of rationality accepted by most economists in the mid-twentieth century. He assumed that individuals making a social choice had well-defined, complete, and transitive preferences regarding the net personal returns likely given the set of alternatives under consideration.

Sen argued against the grim predictions that social choice theory had been destroyed. Instead, he posited that Arrow's theorem should generate engagement rather than resignation. The theoretical results deserve serious study, Sen argued, given their sweeping reach, even though he agreed that democratic decisions do not always generate good results and that they can at times lead to incongruities.

> To the extent that this is a feature of the real world, its existence and reach are matters for objective recognition. Inconsistencies arise more readily in some situations than in others, and it is possible to identify the situational differences and to characterize the processes through consensual and compatible decisions can emerge. (Sen 1999, p.365)

Sen has followed his own advice creatively and seriously and effectively engaged Arrow's "Impossibility Theorem" over time (e.g. see Sen 1977b, 1986, 1993, 2002). Instead of despair, he has examined both the

underlying assumptions of individual rationality (1977a) and the empirical conditions where diverse voting rules make a major difference in outcomes.[1]

In this chapter, I wish to honor Amartya Sen by illustrating how his advice to engage impossibility results, rather than dismissing or accepting them without any question, has been an important inspiration related to another widely acclaimed impossibility result—that of Garrett Hardin (1968) in his influential article in *Science* on "The Tragedy of the Commons." While Hardin was an ecologist rather than an economist, his assumptions regarding individual preferences and behavior are closely aligned with those of many economists—focused on immediate material returns to self. His logic was broadly similar to that of the distinguished economist, H. Scott Gordon (1954, p.124), who had earlier argued that: "The fish in the sea are valueless to the fisherman, because there is no assurance that they will be there for him tomorrow if they are left behind today."

Hardin envisioned a pasture open to all, in which each herder received an individual benefit from adding animals to graze on the pasture and suffered only delayed costs (with his fellow herders) from overgrazing. He assumed that there were no property rights to the land or no specified rights related to grazing on the land.[2] Hardin concluded:

> Therein is the tragedy. Each man is locked into a system that compels him to increase his herd without limit—in a world that is limited. Ruin is the destination toward which all men rush, each pursuing his own best interest in a society that believes in the freedom of the commons. (Hardin 1968, p.1244)

Hardin's conclusion was immediately accepted by many scientists from multiple disciplines. His article is still required reading in most environmental science programs and frequently assigned multiple times during an undergraduate program. It was the article most frequently cited as having the greatest career impact in a recent survey of biologists undertaken by Barrett and Mabry (2002). For many economists, Hardin's theory was accepted as an extreme example of the theory developed by Mancur Olson (1965) on the logic of collective *in*action (if I may be pardoned for a play on words.)

Policymakers also tended to accept Hardin's and Olson's results and thought their conclusions made it obligatory to take positive actions to impose rules on the users of pastures, forests, fisheries, water systems, and other common-pool resources (CPRs) in their domain. Government officials did not examine whether the users of these resources had developed rules of their own over time, because it was simply assumed that resource users were trapped and helpless. National governments around the world declared that government ownership was the *only* way to save resources from destruction. Forests in India, Thailand, and many countries in Africa were nationalized during the 1970s and 1980s in an immediate acceptance that this was the *only* way to avoid massive deforestation (Arnold & Stewart 1991; Feeny 1988; Thomson et al. 1992; Shepard 1992). In many instances, these and related conversion of inshore fisheries policies had the effect of overruling locally developed institutions that were on the ground and converting these resources to "open access" given the lack of administrative follow-up and that local users were told they had no rights (Higgs 1996; Cordell & McKean 1992).

Engaging Hardin

Before Hardin had published his impossibility results, I had conducted an in-depth study as my dissertation research of how groundwater producers had grappled with serious problems resulting from their own overuse of groundwater underlying the Los Angeles metropolitan area in the 1960s (Ostrom 1965). The 500+ producers were located in parts of a dozen general-purpose local governments but none of these governmental jurisdictions had boundaries that were similar to those of the underlying groundwater basins. The producers were fortunate, however, to be in a state that encouraged diverse forms of self-governance, to have access to expert technical information from the U.S. Geological Survey and the California State Department of Natural Resources, and to be able to utilize the California courts in a series of cases utilizing equity jurisprudence.[3]

Watching these efforts, I gained considerable respect for the capability of *public* entrepreneurs in creating new institutional arrangements to cope relatively effectively with severe overdrafts and the threat of losing the high value of a groundwater basin to the threat of salt-water intrusion from the Pacific

Ocean. The producers did utilize public facilities in the form of equity jurisprudence in the California courts and the capacity to establish special districts within the California legal framework (Blomquist & Ostrom 2007; Blomquist 1989, 1992). The producers were not forced by an external authority, however, to take these actions.

During the 1970s and 1980s, colleagues at the Workshop in Political Theory and Policy Analysis at Indiana University developed a framework for studying institutions called the Institutional Analysis and Development (IAD) framework (Kiser & Ostrom 1982; Oakerson 1992; Ostrom 2005). A key element of that framework distinguished among three levels of rules. Operational rules are the rules that individuals or groups use in daily life and affect real-world phenomena directly. They include the speed limits set on roads of various classes, the hours that a private firm is open for business, the rules that define who can use a resource and the conditions of their use. Collective-choice rules are those that are used in making operational-choice rules. Elections, most decisions made in a legislature, and many court rulings exist at a collective-choice level. Constitutional-choice rules are then the level of rules to determine the rules used in making collective-choice decisions (Buchanan & Tullock 1962). These three levels are used in all social groups and political organizations ranging from the very small to global in spatial scales (see Aoki 2007b for a similar analysis of the multiple levels of rules). This framework opens the possibility that resource users could change their own rules.

By the early 1980s, the widespread acceptance of the gloomy predictions of both Olson (1965) and Hardin (1968) had led the governments of multiple developing countries to nationalize common-pool resources. Overuse tended to *increase* after nationalization, however. Scholars began to gather evidence that demonstrated how some local users had actually overcome the problems they faced (McCay & Acheson 1987). It also led to the creation of a National Research Council committee to study diverse common-pool resources (NRC 1986). As a member of the NRC committee, I began to recognize the *disjunction* between the impossibility result and the repeated evidence that many (but certainly not all) resource users had found ways to change their own institutions. Since then, I have been actively engaged in coming to grips with the impossibility results of Garrett Hardin and the gloomy predictions of Mancur

Olson. Let me provide a quick review of this engagement and present a theory of self-organization that is more representative of the problem that resource users face than Hardin's tragedy.

Why Some Overcome Common-Pool Resource Dilemmas and Others Do Not

When dealing with a presumption of an *impossibility* of resource users solving their own problems of overuse, finding a very large number of cases where resource users succeed is an important accomplishment. That is exactly what the NRC committee did. A major conceptual accomplishments of the NRC committee was the emphatic recognition of the confusion that had existed for some time over the name used for resources and for potential institutional arrangements or property regimes. The term "common property resource" was abbreviated as CPR and widely used across the social sciences for resources such as forests, lakes, pastures, fisheries, and irrigation systems. The term confused a resource system that might or might not have a linked property-rights system with a form of institution called "common property" (Bromley 1992; Ciriacy-Wantrup & Bishop 1975; V. Ostrom & E. Ostrom 1977). This confused a resource—a common-pool resource—with a property system—a common-property regime. The initials, CPR, were used for both concepts.

Slowly, over time, general agreement has been reached that common-pool resources have two characteristics: (1) it is very costly to exclude potential beneficiaries from accessing and harvesting from a resource and (2) the amount of resource flows harvested by one user is subtracted from the quantity available to others. Thus, it shares the first characteristic with public goods (the cost of exclusion) and the second characteristic with private goods (subtractability) (V. Ostrom & E. Ostrom 1977). A common-pool resource can be managed under any of a broad type of property-rights regimes ranging from:

> government ownership, where a formal government ranging in size from a local city all the way to national government claimed ownership of the resource and the right to fully determine who could or could not use and under what circumstances;
>
> private ownership, where a single individual or private firm has full claims to determine use patterns; and

community or common-property ownership, where a group of individuals shares rights to ownership.

A fourth possibility is "no ownership" or "open access," which is what Hardin assumed in his illustrative case. Open access is only one out of four general possibilities that can relate to a common-pool resource. As Bromley has so clearly stated:

> There is no such thing as a common property *resource*; there are only resources controlled and managed as common property, or as state property, or as private property. Or—and this is where confusion persists in the literature—there are resources over which *no property rights* have been recognized. We call these latter "open-access resources" (*res nullius*, which is Latin for "no one's property. (Bromley 1992, p.4; see also Bromley 1989, 1991)

In addition to conceptual clarification, the NRC (1986) issued a key reference book that contained many cases that vividly illustrated that local users of fisheries, forests, and irrigation systems around the world had self-organized and overcome the presumed tragedy of the commons. This also led to the creation of the CPR database at Indiana University where attributes of the resource systems and of the users were systematically coded from in-depth case studies that contained sufficiently complete information related to a core set of variables. Thirty inshore fisheries and 47 irrigation systems managed by farmers or by government agencies were carefully coded and statistical analysis undertaken to assess how some of the attributes of resources and of users discussed later in this chapter affect the patterns of organization and performance of these systems (see Schlager 1994; Tang 1994).

We also followed Sen's advice regarding the importance of game-theoretical analyses to complement more complex empirical studies (Sen 2002, p.207). We first developed an initial game-theoretical analysis of N players facing a choice between harvesting from an open-access, common-pool resource (with a quadratic production function as proposed earlier (1954) by Scott Gordon) versus allocating effort to an activity that yielded constant returns (such as would be involved in working as a day laborer for a set wage) (Gardner & Ostrom 1991).

Using game theory to formalize the problem enabled us to start an extensive experimental research program by rigorously operationalizing the parameters of the model in an experimental laboratory. When subjects were anonymously placed in a common-pool resource experiment, and not allowed to communicate in any manner, they did substantially overharvest as predicted by Hardin (Walker et al. 1990). Simply allowing subjects to engage in face-to-face communication, however, enabled them to greatly increase their individual and joint outcomes, particularly when the opportunity to communicate was repeated over ten or more trials (Ostrom & Walker 1991). This form of communication without a third-party enforcer of agreements is considered "cheap talk" in game theory and is posited not to make any difference, let alone the very substantial difference achieved. Allowing subjects to engage in costly punishment and to devise their own rules that would be monitored by themselves also greatly increased the joint payoffs to come close to the optimal level achievable in the formal model (Ostrom et al. 1992).

The laboratory experiments did not establish that subjects lacked rationality or were inexperienced (our statistical analysis was based on experiments conducted with subjects who had already experienced our experimental setting) as some critiques of experimental methods have indicated in their efforts to retain a narrow model of individual choice in all social settings. Rather, as Sen has argued in his famous article on "Rational Fools" (1977a), the experiments illuminated that the subjects used a different form of reasoning than that presumed in many formal economic theories of human behavior. When subjects had an opportunity for repeated communications, they used this opportunity first to discuss the problem they faced and to ask what joint strategy would get the most money for the group from the experimenters (Ostrom et al. 1994, chap. 7). Then, they discussed what was the best way of dividing that optimal payoff among members of the group.

Adam Simon and David Schwab (2006) have conducted an in-depth analysis of the verbatim transcripts from these experiments to assess whether participants attempted to increase group identity during the communication rounds. They argued that when individuals see themselves as a member of a potential group, they can use solidarity language to increase the likelihood of other participants seeking

group benefits rather than their own short-term benefits. The original transcripts were coded independently by three coders who categorized phrases into multiple categories. In their analysis, Simon and Schwab correlated the number of solidarity words used and the number of defections (individual investment made above the level the group had agreed upon) observed for each period of an experiment. They found that defections were inversely correlated to the number of solidarity words used. Thus, subjects used communication as a way of increasing the sense that they were a group jointly affected by the results they obtained.

Toward a Theory of Self-Organization

Evidence from field and experimental research challenges the generalizability of Hardin's tragedy of the commons theory. While his theory is successful in predicting outcomes in settings where resource users are alienated from one another or cannot communicate effectively for reasons including the size of the group or their total separation, it does not provide an explanation for settings where resource users are able to engage in collective choice to create their own agreements. Nor does it predict well when government ownership will perform well or whether privatization will improve outcomes. After more than three decades of research related to the possibility that some resource users will self-organize and manage a common-pool resource, while others will not, it is now possible to provide a theoretical argument for the factors affecting the likelihood that the users of a common-pool resource will commit themselves to changing rules from open access to a new set of rules that restricts who can use resource flows and potentially other rules affecting the sustainability of the resource.[4]

Let us assume a set of resource users (U) contemplating a proposed change in the rules related to their use of a common-pool resource (R) (see Ostrom 1990, chap. 6, 1992 for earlier sketches of this theory). Each user i ($i \in U$) has to compare the expected net benefits of harvesting continuing to use no rules or existing rules that are not working well (Ro) to the benefits he or she expects to achieve with a new set of rules (Rn) that has been proposed. Each user i must ask whether his or her evaluation of future benefits (B_i) under a new set of rules is positive or negative.

$$B_i = Rn_i - Ro_i .$$

If B_i is negative for all users, no one has an incentive to change and one can predict the resource will remain as open-access. If B_i is positive for some users, each of these users needs to estimate three types of costs:

C1—the up-front costs of time and effort spent devising and agreeing upon new rules;

C2—the short-term costs of adopting new harvesting strategies; and

C3—the long-term costs of monitoring and maintaining a self-governed system.

If the sum of these expected costs for all users exceeds the incentive to change, no user will invest the time and resources needed to create new institutions. Thus, if

$$B_i < (C1_i + C2_i + C3_i)$$

for all $i \in U$, no change will occur.

In field settings, everyone is not likely to expect the same costs and benefits from a proposed change. Some may perceive positive benefits after all costs have been taken into account, while others perceive net losses. Consequently, the collective-choice rules used to change the day-to-day operational rules in a group of resource users affect whether an institutional change favored by some and opposed by others will be adopted. Given Arrow's theorem, Sen argues that no guarantee exists that any such decisions taken in the field will be Pareto optimal and meet the full set of conditions that Arrow posited as a good collective-choice rule. As Sen points out, one must recognize that not all collective decisions made in the field are democratic or, even if they are democratic, meet all of the conditions specified by Arrow.

Aoki (2001, 2007a) cogently describes the social games that are likely to exist in any community and how social games and economic games may be linked. In many field studies, resource users draw on either the accepted rules that have evolved over time in social games or in political games related to the villages where resource users live. It may be that these rules are used as collective-choice rules to decide on future operational rules related to a common-pool resource.

For any collective-choice rule, such as unanimity, majority, a small ruling elite, there is a minimum coalition of users, $K \subset U$, that must agree prior to the adoption of new rules. If for all individuals who are a member of U,

$$B_k \leq (C1_k + C2_k + C3_k) ,$$

no new rules will be adopted. And if for at least one coalition $K \subset U$, it is such that

$$B_k > (C1_k + C2_k + C3_k) ,$$

for all members of K, it is feasible for a new set of rules to be adopted. If no minimum winning coalition (given the collective-choice rule in use) evaluates $B > C$, no new operational rules will be adopted.

If a local chief or other notable has dictatorial powers at the collective-choice level, then only this single person has to estimate that the costs of changing a rule are less than the benefits of a new rule. In this case, of course, there may not be widespread benefits for other members of the group. If the group relies on a larger collective-choice rule and if there are several such coalitions, the question of which coalition will form, and thus which rules will result, is a further theoretical issue that I do not address in this chapter (see Shepsle 1989 and others on coalition building in collective-choice settings). This analysis is applicable to a situation where a group starts with an open access set of rules and contemplates adopting its first set of rules limiting access. It is also relevant to the continuing consideration of changing operational rules over time.

The collective-choice rule used to change operational rules in field settings varies from reliance on the decisions made by one or a few leaders, to a formal reliance on majority or super-majority vote, to reliance on consensus or close to unanimity. If there are substantial differences in the perceived benefits and costs of users, it is possible that K users will impose a new set of rules on the other users that strongly favors those in the winning coalition and imposes losses or lower benefits on those in the losing coalition (Thompson et al. 1988). If expected benefits from a change in operational rules are not greater than expected costs for many users, however, the costs of enforcing a change in institutions will be much higher than when most participants expect to benefit from a change in rules over time. Where the enforcement costs are fully borne by the members of K, operational rules that benefit the other users

lower the long-term costs of monitoring and sanctioning for a governing coalition. Where external authorities enforce the rules agreed upon by K users, the distribution of costs and benefits is more likely to benefit K and may impose costs on the other users.

Variables Affecting the Calculation of Benefits and Costs of Changing Operational Rules

Scholars familiar with the results of field research tend to agree on a set of variables that enhance the likelihood of resource users organizing themselves to avoid the social losses associated with open-access, common-pool resources (McKean 1992, 2000; Wade 1994; Schlager & Ostrom 1992; Schweik et al. 1997; Tang 1992; Ostrom 1990, 1992; Baland & Platteau 1996; Ostrom et al. 1994). Drawing on Ostrom (1992, p.298–99) and Baland and Platteau (1996, p.286–89), considerable consensus exists that the following attributes of resources and of users are conducive to an increased likelihood that self-governing associations will form.

Attributes of the Resource:

R1. Feasible improvement: Resource conditions are not at a point of deterioration such that it is useless to organize or so underutilized that little advantage results from organizing.

R2. Indicators: Reliable and valid indicators of the condition of the resource system are frequently available at a relatively low cost.

R3. Predictability: The flow of resource units is relatively predictable.

R4. Spatial extent: The resource system is sufficiently small, given the transportation and communication technology in use, that appropriators can develop accurate knowledge of external boundaries and internal microenvironments.

Attributes of the Resource Users:

U1. Salience: Appropriators are dependent on the resource system for a major portion of their livelihood.

U2. Common understanding: Appropriators have a shared image of how the resource system operates (attributes R1, 2, 3, and 4 above) and how their actions affect each other and the resource system.

U3. Low discount rate: Appropriators use a sufficiently low discount rate in relation to future benefits to be achieved from the resource.

U4. Trust and reciprocity: Appropriators trust one another to keep promises and relate to one another with reciprocity.

U5. Autonomy: Appropriators are able to determine access and harvesting rules without external authorities countermanding them.

U6. Prior organizational experience and local leadership: Appropriators have learned at least minimal skills of organization and leadership through participation in other local associations or learning about ways that neighboring groups have organized.

Integrating Findings from Field Studies with Theory

The attributes of a resource (listed above) affect both the benefits and costs of institutional change. If resource units are relatively abundant (R1), there are few reasons for users to invest costly time and effort in organizing. If the resource is already substantially destroyed, the high costs of organizing may not generate substantial benefits. Thus, self-organization is likely to occur only after users observe substantial scarcity (Wade 1994). The danger here, however, is that exogenous shocks leading to a change in relative abundance of the resource units may occur rapidly and users may not adapt quickly enough to the new circumstances (Libecap & Wiggins 1985).

The presence of frequently available, reliable indicators about the conditions of a resource (R2) affects the capacity of users to adapt relatively soon to changes that could adversely affect their long-term benefit stream (Moxnes 1998). A resource flow that is highly predictable (R3) is much easier to understand and manage than one that is erratic. This is true for both the users themselves and for public officials who may have acquired management responsibilities for a resource of a particular type in a

region (Brock & Carpenter 2007). In the latter case, it is always difficult for users (or, for scientists and government officials) to judge whether changes in the resource stock or flow are due to overharvesting or to random exogenous variables. Unpredictability of resource units in microsettings, such as private pastures, may lead users to create a larger common-property unit to increase the predictability of resource availability somewhere in the larger unit (Netting 1972; Wilson & Thompson 1993). The spatial extent of a resource (R4) affects the costs of defining reasonable boundaries and then of monitoring them over time.

The attributes of the users themselves also affect their expected benefits and costs. If users do not obtain a major part of their income from a resource (U1), the high costs of organizing and maintaining a self-governing system may not be worth their effort. If users do not share a common understanding of how complex resource systems operate (U2), they will find it extremely difficult to agree on future joint strategies. As Libecap and Wiggins (1985) argue, asymmetric private information about heterogeneous assets may adversely affect the willingness of participants to agree to a reduction in their use patterns before considerable damage is done to a resource. Given the complexity of many common-pool resources—especially multispecies or multiproduct resources—understanding how these systems work may be challenging even for those who make daily contacts with the resource. In resources that are highly variable (U3), it may be particularly difficult to understand and to sort out those outcomes stemming from exogenous factors and those resulting from the actions of users. And as Brander and Taylor (1998) have argued, when the resource base itself grows very slowly, population growth may exceed the carrying capacity before participants have achieved a common understanding of the problem they face. Of course, this is also a problem facing officials as well as users. Users with many other viable and attractive options, who thus discount the importance of future income from a particular resource (U3), may prefer to "mine" one resource without spending resources to regulate it (Berkes et al. 2006). They simply move on to other resources becoming "roving bandits" once this one is destroyed, assuming there will always be other resources available to them.

Users who trust one another (U4) to keep agreements and use reciprocity in their relationships with one another face lower expected costs involved in monitoring and sanctioning one another over time. Users who lack trust at the beginning of a process of organizing may be able to build this form of social capital (Coleman 1988) if they initially adopt small changes that most users follow before trying to make major institutional changes. Autonomy (U5) tends to lower the costs of organizing. A group that has little autonomy may find that those who disagree with locally developed rules seek contacts with higher-level officials to undo the efforts of users to achieve their own new rules.

With the legal autonomy to make their own rules, users face substantially lower costs in defending their own rules against other authorities. Prior experience with other forms of local organization (U6) greatly enhances the repertoire of rules and strategies known by local participants as potentially useful to achieve various forms of regulation. Further, users are more likely to agree upon rules whose operation they understand from prior experience, than upon rules that are introduced by external actors and are new to their experience. Given the complexity of many field settings, users face a difficult task in evaluating how diverse variables affect expected benefits and costs over a long time horizon. In many cases, it is just as difficult, if not more so, for scientists to make a valid and reliable estimate of total benefits and costs and their distribution (Wilson et al. 2007).

The theory presented above and the empirical evidence does *not* lead to a conclusion that most users using common-pool resources will undertake self-governed regulation (Berkes 2007; Meinzen-Dick 2007). Many settings exist where the theoretical expectation should be the opposite: Users will overuse the resource unless efforts are made to change one or more of the variables affecting perceived costs or benefits. Given the number of variables that affect these costs and benefits, many points of external intervention can enhance or reduce the probability of users' agreeing upon and following rules that generate higher social returns (Nagendra 2007). Both social scientists and policymakers have a lot to learn about how these variables operate interactively in field settings (Ostrom 2007).

Many aspects of the macroinstitutional structure surrounding a particular setting affect the perceived costs and benefits. Thus, external authorities can do a lot to enhance or impede the likelihood

and performance of self-governing institutions. Further, when the activities of one set of users, U_j, have "spillover effects" on others beyond U_j, external authorities can either facilitate processes that allow multiple groups to solve conflicts arising from negative spillovers or take a more active role in governing particular resources themselves.

Researchers and public officials need to recognize the multiple manifestation of these theoretical variables in the field. Users may be highly dependent on a resource (U1), for example, because they are in a remote location and few roads exist to enable them to leave. Alternatively, they may be located in a central location, but other opportunities are not open to them due to lack of training or a discriminatory labor market. Users' discount rates (U3) in relation to a particular resource may be low because they have lived for a long time in a particular location and expect that they and their grandchildren will remain in that location, or because they possess a secure and well-defined bundle of property rights to this resource (see Schlager & Ostrom 1992). Reliable indicators of the condition of a resource (R2) may result from activities that the users themselves do—such as regularly shearing the wool from sheep (see Gilles & Jamtgaard 1981) or because of efforts to gather reliable information by users or by external authorities (Blomquist 1992; Blomquist & Ostrom 2007). Predictability of resource units (R3) may result from a clear regularity in the natural environment of the resource or because storage has been constructed in order to even out the flow of resource units over both good and bad years (Schlager et al. 1994). They may have autonomy to make their own rules (U5) because a national government is weak and unable to exert authority over resources that it formally owns, or because national law formally legitimates self-governance.

When the benefits of organizing are commonly understood by participants to be very high, users lacking many of the attributes conducive to the development of self-governing institutions may be able to overcome their liabilities and still develop effective agreements. The crucial factor is *not* whether all attributes are favorable but the relative size of the expected benefits and costs they generate as perceived by the participants who comprise a winning coalition given the collective-choice rules in use. All of these variables affect the expected benefits and costs of users. It is difficult, however, particularly for outsiders,

to estimate their impact on expected benefits and costs given the difficulty of making precise measures of these variables and weighing them on a cumulative scale.

Puzzles

In addition to the consensus concerning the variables most likely to enhance self-organization, many unresolved issues still exist about the self-governance of common-pool resources. Two major empirical and theoretical questions relate to the effect of size and heterogeneity.

Size

The effect of the number of participants facing problems of creating and sustaining a self-governing enterprise is unclear. Many theorists argue that size of group is negatively related to solving collective-action problems in general because of its impact on the costs of agreement in the first place (C1) and of monitoring (C3) in the second. Many results from game-theoretical analysis of repeated games conclude that cooperative strategies are more likely to emerge and be sustained in smaller rather than larger groups (see synthesis of this literature in Baland & Platteau 1996). Scholars who have studied many self-organized irrigation and forestry institutions in the field have concluded that success will more likely happen in smaller groups (see e.g. Barker et al. 1984; Cernea 1989). Other empirical studies have generated mixed results. While most of the 37 farmer-governed irrigation systems studied by Tang (1992, p.68) were relatively small, ranging in size from 7 to 300 appropriators, he did not find any statistical relationship within that size range between the number of appropriators or the amount of land being irrigated and performance variables. In Lam's (1998, p.115) multiple regression analysis of the performance of a much larger set of irrigation systems in Nepal ranging in size up to 475 irrigators, he did not find any significant relationship between either the number of appropriators or the amount of land included in the service area with any of the three performance variables he studied.

One of the problems with a focus on size of group as a key determining factor is that many other variables change as group size increases. If the costs of providing a public good related to the use of a common-pool resource, say a sanctioning system, remain relatively constant as group size increases, then increasing the number of participants brings additional resources that could be drawn upon to provide the benefit enjoyed by all (see Isaac et al. 1994). On the other hand, if one is analyzing the transaction costs

of arriving at acceptable allocation formulas, group size may well exacerbate the problems of self-governing systems. Given trade-offs among various impacts of size on other variables, a better working hypothesis is that group size has a curvilinear relationship to performance (Agrawal 2000).

Heterogeneity

One reason that some scholars conclude that only very small groups can organize themselves effectively is because they presume that size is related to the homogeneity of a group. Heterogeneity is also a highly contested variable. For one thing, groups can differ along a diversity of dimensions including their cultural backgrounds, interests, and endowments (see Baland & Platteau 1996). Each may operate differently.

If groups coming from diverse cultural backgrounds share access to a common resource, the key question affecting the likelihood of self-organized solutions is whether the views of the multiple groups concerning the structure of the resource, authority, interpretation of rules, trust, and reciprocity differ or are similar. In other words, do they share a common understanding (U2) of their situation? New settlers to a region may simply learn and accept the rules of the established group, and their cultural differences on other fronts do not affect their participation in governing a resource. On the other hand, new settlers are frequently highly disruptive to the sustenance of a self-governing enterprise when they generate higher levels of conflict over the interpretation and application of rules and increase enforcement costs substantially.

When the interests of users differ, achieving a self-governing solution to common-pool resource problems is particularly challenging. Users who possess more substantial economic and political assets may have similar interests to those with fewer assets or they may differ substantially on multiple attributes. When the more powerful have similar interests, they may greatly enhance the probability of successful organization if they invest their resources in organizing a group and devising rules to govern that group. Those with substantial economic and political assets are more likely to be a member of K and thus have a bigger impact on decisions about institutional changes.

Differential endowments of appropriators can be associated with both extreme levels of conflict as well as very smooth and low-cost transitions into a sustainable, self-governed system. Heterogeneity of wealth or power may or may not be associated with a difference in interests. When those who have more assets share similar interests with those who have less assets, groups may be privileged by having the more powerful take on the higher initial costs of organizing while crafting rules that benefit a large proportion of the appropriators. Users may design institutions that cope effectively with heterogeneities. Thus, when they adopt rules that allocate benefits using the same formulae used to allocate duties and responsibilities, users who differ significantly in terms of assets will tend to agree to and follow such rules (see Design Principles in Ostrom 1990).

Even in a group that differs on many variables, if at least a minimally winning subset of K appropriators harvesting an endangered but valuable resource are dependent on it (U1), share a common understanding of their situations (U2), have a low discount rate (U3), trust one another (U4), and have autonomy to make their own rules (U5), it is more likely that they will estimate the expected benefits of governing their resource greater than the expected costs. Whether the rules agreed upon distribute benefits and costs fairly depends both on the collective-choice rule used and the type of heterogeneity existing in the community. Neither size nor heterogeneity are variables with a uniform effect on the likelihood of organizing and sustaining self-governing enterprises. Instead of focusing on size or the various kinds of heterogeneity by themselves, it is important to ask how these variables affect other variables as they impact on the benefit-cost calculus of those involved in negotiating and sustaining agreements.[5] Their impact on costs of producing and distributing information is particularly important.

Conclusion

Engaging impossibility results is much to be preferred in contrast to oversimplified rejection or despair. We have all learned much from Amartya Sen as he has engaged a number of impossibility issues for all of us. It is not possible to repay Sen for all that he has taught us, but I hope that sharing the

experience of engaging impossibilities is an appropriate form of homage to one of the great scholars of this age.

Notes

[1] See, for example, Sen (1981, 1984) where he shows that no famine has ever occurred in an independent country except when the country is run by a dictator, an alienated set of rules, or by a single party.

[2] Hardin (1998) did clarify thirty years later that he had meant an "open-access commons," but many readers do not see any significant difference between open-access regimes and a common-pool resource with a common-property regime.

[3] The producers had contributed a required portion of the costs to the studies undertaken by the USGS as well as to the cost of the Equity Jurisprudence proceedings in the courts. Thus, they were able to obtain accurate information compiled by third-party experts as long as they were willing to contribute a portion of the costs.

[4] Earlier, Buchanan and Tullock (1962) developed a theory of constitutional choice regarding the calculus that a group would use to select rules for making collective choices ranging from an "any one" rule through to unanimity.

[5] When analyzing the effect of multiple variables, doing simple mathematical models becomes very difficult but utilizing agent-based models becomes a powerful tool (see Janssen & Ostrom 2006a, b, c).

References

Agrawal, A., 2000. Small is beautiful, but is larger better? forest-management institutions in the Kumaon Himalaya, India. In C. Gibson, M. McKean, and E. Ostrom, eds. *People and forests: communities, institutions, and governance.* Cambridge, MA: MIT Press, p. 57-86.

Aoki, M., 2001. *Toward a comparative institutional analysis.* Cambridge, MA: MIT Press.

Aoki, M., 2007a. Linking economic and social-exchange games: from the community norm to CSR. Keynote speech delivered at the Conference on Social Capital, Corporate Social Responsibility, and Sustainable Economic Development, University of Torino, Italy, July.

Aoki, M., 2007b. Three-level approach to the rules of societal games: generic, substantive, and operational. Working Paper. Stanford, CA: Stanford University.

Arnold, J.E.M. & Stewart, W.C., 1991. *Common property resource management in India.* Tropical Forestry Papers no. 24. Oxford: Oxford Forestry Institute.

Arrow, K., 1951. *Social choice and individual values*. New York: Wiley.

Arrow, K., 1963. *Social choice and individual values.* 2nd ed. New York: Wiley.

Baland, J.-M. & Platteau, J.-P., 1996. *Halting degradation of natural resources: is there a role for rural communities?* Oxford: Clarendon Press.

Barker, R., Coward, Jr., E.W., Levine, G., & Small, L.E., 1984. *Irrigation development in Asia: past trends and future directions*. Ithaca, NY: Cornell University Press.

Barrett, G.W. & Mabry, K.E., 2002. Twentieth-century classic books and benchmark publications in biology. *Bioscience,* 52(3), p. 282-86.

Berkes, F., 2007. Community-based conservation in a globalized world. *PNAS* 104(39), p. 15188–93.

Berkes, F., Hughes, T.P., Steneck, R.S., Wilson, J.A., Bellwood, D.R. et al., 2006. Globalization, roving bandits, and marine resources. *Science*, 311(5767), p. 1557-58.

Blomquist, W., 1989. *The performance of groundwater management: volume 8, the Mojave River Basin.* Bloomington: Indiana University, Workshop in Political Theory and Policy Analysis.

Blomquist, W., 1992. *Dividing the waters: governing groundwater in southern California.* Oakland, CA: ICS Press.

Blomquist, W. & Ostrom, E., 2007. Deliberation, learning, and institutional change: the use of judicial forums in institutionally diverse settings. Working Paper. Bloomington: Indiana University, Workshop in Political Theory and Policy Analysis.

Brander, J.A. & Taylor, M.S., 1998. The simple economics of Easter Island: a Recardo-Malthus model of renewable resource use. *American Economic Review,* 88(1), p. 119-38.

Brock, W. A. & Carpenter, S.R., 2007. Panaceas and diversification of environmental policy. *PNAS,* 104(39), p. 15206-11.

Bromley, D., 1989. *Economic interests and institutions: the conceptual foundations of public policy.* Oxford: Basil Blackwell.

Bromley, D., 1991. *Environment and economy: property rights and public policy.* Oxford: Basil Blackwell.

Bromley, D., 1992. The commons, property, and common-property regimes. In D. Bromley et al. eds. *Making the commons work: theory, practice, and policy.* San Francisco, CA: ICS Press, p. 3-16.

Buchanan, J.M. & Tullock, G., 1962. *The calculus of consent: the logical foundations of constitutional democracy.* Ann Arbor: University of Michigan Press.

Cernea, M.M., 1989. *User groups as producers in participatory afforestation strategies*. World Bank Discussion Papers no. 70. Washington, D.C.: The World Bank.

Ciriacy-Wantrup, S.V. & Bishop, R.C., 1975. 'Common property' as a concept in natural resource policy. *Natural Resources Journal,* 15(4), p. 713-27.

Coleman, J.S., 1988. Social capital in the creation of human capital. *American Journal of Sociology,* 94(supplement), p. S95-S120.

Cordell, J.C. & McKean, M., 1992. Sea tenure in Bahia, Brazil. In D. Bromley et al. eds. *Making the commons work: theory, practice, and policy.* San Francisco, CA: ICS Press, p. 183-205.

Feeny, D., 1988. Agricultural expansion and forest depletion in Thailand. In J.F. Richard and R.P. Tucker, eds. *World deforestation in the twentieth century*. Durham, NC: Duke University Press, p. 112-43.

Gardner, R. & Ostrom, E., 1991. Rules and games. *Public Choice,* 70(2), p. 121-49.

Gilles, J.L. & Jamtgaard, K., 1981. Overgrazing in pastoral areas: the commons reconsidered. *Sociologia Ruralis,* 21, p. 129-41.

Gordon, H.S., 1954. The economic theory of a common property resource: the fishery. *Journal of Political Economy,* 62, p. 124-42.

Hardin, G., 1968. The tragedy of the commons. *Science,* 162, p. 1243-48.

Hardin, G., 1998. Extension of 'the tragedy of the commons'. *Science,* 280(5364), p. 682-83.

Higgs, R., 1996. Legally induced technical regress in the Washington salmon fishery. In L.J. Alston, T. Eggertsson, and D.C. North, eds. *Empirical studies in institutional change*. New York: Cambridge University Press, p. 247-79.

Isaac, R.M., Walker, J., & Williams, A., 1994. Group size and the voluntary provision of public goods: experimental evidence utilizing large groups. *Journal of Public Economics,* 54(1), p. 1-36.

Janssen, M. & Ostrom, E., 2006a. Adoption of a new regulation for the governance of common-pool resources by a heterogeneous population. In J.-M. Baland, P. Bardhan, and S. Bowles, eds. *Inequality, cooperation, and environmental sustainability*. Princeton, NJ: Princeton University Press, p. 60-96.

Janssen, M. & Ostrom, E., 2006b. Empirically based, agent-based models. *Ecology and Society,* 11(2), p. 37.

Janssen, M. & Ostrom, E., 2006c. Governing social-ecological systems. In L. Tesfatsion and K.L. Judd, eds. *Handbook of computational economics: agent-based computational economics,* vol. 2. Amsterdam: Elsevier, p. 1465-1509.

Kiser, L. & Ostrom, E., 1982. The three worlds of action: a metatheoretical synthesis of institutional approaches. In E. Ostrom, ed. *Strategies of political inquiry*. Beverly Hills, CA: Sage, 179-222.

Lam, W.F., 1998. *Governing irrigation systems in Nepal: institutions, infrastructure, and collective action.* Oakland, CA: ICS Press.

Libecap, G. & Wiggins, S.N., 1985. The influence of private contractual failure on regulation: the case of oil field unitization. *Journal of Political Economy,* 93, p. 690-714.

McCay, B.J. & Acheson, J.M., 1987. *The question of the commons: the culture and ecology of communal resources.* Tucson: University of Arizona Press.

McKean, M., 1992. Management of traditional common lands (*Iriaichi*) in Japan. In D. Bromley et al., eds. *Making the commons work: theory, practice, and policy.* San Francisco, CA: ICS Press, p. 63-98.

McKean, M., 2000. Common property: what is it, what is it good for, and what makes it work? In C. Gibson, M. McKean, and E. Ostrom, eds. *People and forests: communities, institutions, and governance*. Cambridge, MA: MIT Press, p. 27-55.

Meinzen-Dick, R., 2007. Beyond panaceas in water institutions. *PNAS,* 104(39), p. 15200-05.

Moxnes, E., 1998. Not only the tragedy of the commons: misperceptions of bioeconomics. *Management Science,* 44(9), p. 1234-48.

Nagendra, H., 2007. Drivers of reforestation in human-dominated forests. *PNAS,* 104(39), p. 15218-23.

Netting, R. McC., 1972. Of men and meadows: strategies of Alpine land use. *Anthropological Quarterly,* 45, p. 132-44.

NRC (National Research Council), 1986. *Proceedings of the conference on common property resource management*. Washington, D.C.: National Academy Press.

Oakerson, R.J., 1992. Analyzing the commons: a framework. In D. Bromley et al., eds. *Making the commons work: theory, practice, and policy.* San Francisco, CA: ICS Press, 41-59.

Olson, M., 1965. *The logic of collective action: public goods and the theory of groups.* Cambridge, MA: Harvard University Press.

Ostrom, E., 1965. Public entrepreneurship: a case study in ground water basin management. Ph.D., University of California, Los Angeles.

Ostrom, E., 1990. *Governing the Commons.* Cambridge: Cambridge University Press.

Ostrom, E., 1992. The rudiments of a theory of the origins, survival, and performance of common-property institutions. In D. Bromley et al., eds. *Making the commons work: theory, practice, and policy*. San Francisco, CA: ICS Press, 293-318.

Ostrom, E., 2005. *Understanding institutional diversity.* Princeton, NJ: Princeton University Press.

Ostrom, E., 2007. A diagnostic approach for going beyond panaceas. *PNAS*, 104(39), p. 15181-87.

Ostrom, E., Gardner, R., & Walker, J., 1994. *Rules, games, and common-pool resources*. Ann Arbor: University of Michigan Press.

Ostrom, E. & Walker, J., 1991. Communication in a commons: cooperation without external enforcement. In T.R. Palfrey, ed. *Laboratory research in political economy*. Ann Arbor: University of Michigan Press, 287-322.

Ostrom, E., Walker, J., & Gardner, R., 1992. Covenants with and without a sword: self-governance is possible. *American Political Science Review*, 86(2), p. 404-17.

Ostrom, V. & Ostrom, E., 1977. Public goods and public choices. In E. S. Savas, ed. *Alternatives for delivering public services: toward improved performance*. Boulder, CO: Westview Press, p. 7-49.

Schlager, E., 1994. Fishers' institutional responses to common-pool resource dilemmas. In E. Ostrom, R. Gardner, and J. Walker, eds. *Rules, games, and common-pool resources*. Ann Arbor: University of Michigan Press, p. 247-67.

Schlager, E., Blomquist, W., & Tang, S.Y., 1994. Mobile flows, storage, and self-organized institutions for governing common-pool resources. *Land Economics*, 70(3), p. 294-317.

Schlager, E. & Ostrom, E., 1992. Property-rights regimes and natural resources: a conceptual analysis. *Land Economics*, 68(3), p. 249-62.

Schweik, C.M., Adhikari, K., & Pandit, K.N., 1997. Land-cover change and forest institutions: a comparison of two sub-basins in the southern Siwalik hills of Nepal. *Mountain Research and Development*, 17(2), p. 99-116.

Sen, A., 1977a. Rational fools: a critique of the behavioral foundations of economic theory. *Philosophy and Public Affairs,* 6(4), p. 317-44.

Sen, A., 1977b. Social choice theory: a re-examination. *Econometrica,* 45(1), p. 53-89.

Sen, A., 1981. *Poverty and famines: an essay on entitlement and deprivation.* Oxford: Oxford University Press.

Sen, A., 1984. *Resources, values, and development*. Oxford: Blackwell.

Sen, A., 1986. Social choice theory. In K.J. Arrow and M. Intriligator, eds. *Handbook of mathematical economics,* vol. 3. Amsterdam: North Holland.

Sen, A., 1993. Internal consistency of choice. *Econometrica,* 61, p. 495-521.

Sen, A., 1999. The possibility of social choice. *American Economic Review,* 89(3), p. 349-78.

Sen, A., 2002. *Rationality and freedom.* Cambridge, MA: Harvard University Press.

Shepard, G., 1992. *Managing Africa's tropical dry forests.* London: Overseas Development Institute.

Shepsle, K.A., 1989. Studying institutions: some lessons from the rational choice approach. *Journal of Theoretical Politics,* 1, p. 131-49.

Simon, A. & Schwab, D., 2006. Say the magic word: effective communication in social dilemmas. Working Paper. Bloomington: Indiana University, Workshop in Political Theory and Policy Analysis.

Tang, S.Y., 1992. *Institutions and collective action: self-governance in irrigation.* San Francisco, CA: ICS Press.

Tang, S.Y., 1994. Institutions and performance in irrigation systems. In E. Ostrom, R. Gardner, and J. Walker, eds. *Rules, games, and common-pool resources*. Ann Arbor: University of Michigan Press, p. 225-47.

Thompson, L.L., Mannix, E.A., & Bazerman, M.H., 1988. Group negotiation: effects of decision rule, agenda and aspiration. *Journal of Personality and Social Psychology,* 54(1), p. 86-95.

Thomson, J., Feeny, D., & Oakerson, R.J., 1992. Institutional dynamics: the evolution and dissolution of common-property resource management. In D. Bromley et al., eds. *Making the commons work: theory, practice, and policy*. San Francisco, CA: ICS Press, p. 129-60.

Wade, R., 1994. *Village republics: economic conditions for collective action in south India*. San Francisco, CA: ICS Press.

Walker, J., Gardner, R., & Ostrom, E., 1990. Rent dissipation in a limited-access common-pool resource: experimental evidence. *Journal of Environmental Economics and Management,* 19, p. 203-11.

Wilson, J., Yan, L., & Wilson, C., 2007. The precursors of governance in the Maine lobster fishery. *PNAS,* 104(39), p. 15212-17.

Wilson, P.N. & Thompson, G.D., 1993. Common property and uncertainty: compensating coalitions by Mexico's pastoral *Ejidatorios*. *Economic Development and Cultural Change,* 41(2), p. 299-318.