Engaging with Impossibilities and Possibilities †

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DOI:10.1093/acprof:oso/9780199239979.003.0029

Abstract and Keywords

Upon thinking deeply about Kenneth Arrow's 'Impossibility Theorem', Amartya Sen advises scholars not to despair, but to engage seriously the impossibility result so that we understand it better and know how to cope with the problems identified. This chapter follows Sen's advice. It engages another impossibility result — that of Garrett Hardin who convinced many economists and policy analysts that it was impossible for those harvesting from a resource to self-organize to sustain that resource over time. The chapter briefly reviews evidence from field and experimental research that challenge the generalizability of Hardin's result. It then presents a theoretical argument for the factors affecting the likelihood that the users of common-pool resource will self-organized to develop new rules restrict how a common-pool resource should be used.

Keywords: common-pool resources, collective action, social dilemmas, tragedy of the commons, Kenneth Arrow, Impossibility Theorem, Garrett Hardin
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 likely net personal returns 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: (p.523) Sen has followed his own advice creatively and seriously and effectively engaged Arrow's “impossibility theorem” over time (see e.g. Sen 1977b, 1986, 1993, 2002). Instead of despair, he has examined both the underlying assumptions of individual rationality (1977a) and the empirical conditions under which 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 with impossibility results, rather than dismissing or accepting them without 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, focusing as they do on immediate material returns to self. His logic was broadly similar to that of the distinguished economist H. Scott Gordon, 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” (1954: 124).

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 and 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: 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).

Policy-makers also tended to accept Hardin’s and Olson’s results and thought their conclusions made it obligatory to take positive action to impose rules on the users of pastures, forests, fisheries, water systems, and other common-pool (p. 524) 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 after the immediate acceptance of the notion that this was the only way to avoid massive deforestation (Feeny 1988; Arnold and Stewart 1991; Shepard 1992; Thomson et al. 1992). In many instances, this, and the related conversion of inshore
fisheries policies, had the effect of overruling locally
developed institutions on the ground and converting these
resources to “open access”, given that there was little
administrative follow-up and that local users were told they
had no rights (Cordell and McKeen 1992; Higgs 1996).
I. Engaging Hardin
Before Hardin published his impossibility results, as my dissertation research I had conducted an in-depth study 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-plus 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 US Geological Survey (USGS) 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 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 1989, 1992; Blomquist and Ostrom 2008). The producers were not forced by an external authority, however, to take these actions.

\(\text{(p.525)}\) 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 Institutional Analysis and Development (IAD) (Kiser and 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 its 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 the level of rules used to make the rules of collective-choice decision-making (Buchanan
and Tullock 1962). These three levels are used in all social groups and political organizations, ranging in spatial terms from the very small to the global (see Aoki 2007b for a similar analysis of the multiple levels of rules). This framework opens up 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 (Netting 1972, 1981; Berkes 1985; McCay and Acheson 1987). It also led to the creation of a National Research Council (NRC) committee to study diverse common-pool resources (NRC 1986). As a member of the NRC committee, I began to recognize the disparity 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 than Hardin's tragedy of the problem faced by resource users.
II. Why Some Users 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 accomplishment of the NRC committee was the emphatic recognition of the long-standing confusion over the names 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. But this term confused a resource system that might or might not have a linked property-rights system with a form of institution called “common property” (Ciriacy-Wantrup and Bishop 1975; Ostrom and Ostrom 1977; Bromley 1992). That is, it 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 the resources, and
2. the amount of resource flows harvested by one user is subtracted from the quantity available to others.

A common-pool resource shares the first characteristic with public goods (the cost of exclusion) and the second characteristic with private goods (subtractability) (Ostrom and Ostrom 1977).

In Hardin's illustrative case of “the tragedy of the commons”, the common-pool resource is “open access”, i.e. owned by no one. But open access is only one of four general possibilities for the use of a common-pool resource. Such a resource can also be managed under any of three kinds of property-rights regimes:

- government ownership, where a formal government ranging in size from a local city all the way up to national government claims ownership of
the resource and the right fully to determine who can or cannot use it 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.

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: 4; see also Bromley 1989, 1991)

In addition to conceptual clarification, the NRC (1986) issued a key reference book that contained many cases vividly illustrating that local users of fisheries, forests and irrigation systems around the world had organized themselves and (p. 527) overcome the presumed tragedy of the commons. This led to the creation of the CPR database at Indiana University, where attributes of the resource systems and of their users were systematically coded from in-depth case studies that contained sufficient 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 on the importance of game-theoretical analyses as complements to more complex empirical studies (Sen 2002: 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 by Gordon 1954) versus allocating effort to an activity that yielded
constant returns (e.g. working as a day laborer for a set wage) (Gardner and 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 increase greatly their individual and joint outcomes, particularly when the opportunity to communicate was repeated over ten or more trials (Ostrom and Walker 1991). To be sure, 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. But allowing subjects to engage in costly punishment and to devise their own rules, monitored by themselves, also greatly increased the joint payoffs, coming 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 effort 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 brought to light the fact 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 communication, 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: ch. 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 argue 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.
III. 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 successfully when government ownership
will perform well or whether privatization will improve
outcomes. After more than three decades of research on
whether or not resource users will organize themselves and
manage a common-pool resource, it is now possible to provide
a theoretical explanation of the factors affecting the likelihood
that the users of a common-pool resource will commit
themselves to changing the rules from open access to a new
set of rules that restricts who can use resource flows, and
perhaps also 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: ch. 6 and Ostrom 1992 for
earlier sketches of this theory). Each user $i$ ($i \in U$) has to
calculate the net benefits of harvesting when
continuing to use no rules (p.529) or existing rules that are
not working well ($R_o$) to the benefits he or she expects to
achieve with a proposed new set of rules ($R_n$). Each user $i$ can
do this by asking whether his or her evaluation of future
benefits ($B_i$) given the following equation is positive or
negative:

$$B_i = R_n - R_o$$

if $B_i$ is negative for all users, no one has an incentive to change
and one can predict that the resource will remain 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

\[ B_i < (C_1 + C_2 + C_3) \]

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

In field settings, not everyone is 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 (1999: 354-5), 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 for 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 Arrow's conditions.

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 the accepted rules that have evolved over time in either social games or political games related to the villages where resource users live. It maybe 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 arrangement, such as unanimity, majority or 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 every individual who is a member of \( U \),

\[ B_i \leq (C_1 + C_2 + C_3) \]

no new rules will be adopted. And if at least one coalition \( K \subset U \) is such that

\[ B_k > (C_1 + C_2 + C_3) \]

(p.530) 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 \( B \) as greater than \( C \), 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 one 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 near-unanimity. If there are substantial differences in the perceived benefits and costs of users, it is possible that $K$ 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 the expected benefits from a change in operational rules are not greater than the 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 $K$, the distribution of costs and benefits is more likely to benefit $K$ and may impose costs on the other users.
IV. 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 (Ostrom 1990, 1992; McKean 1992, 2000; Schlager and Ostrom 1992; Tang 1992; Ostrom et al. 1994; (p.531) Wade 1994; Baland and Platteau 1996; Schweik et al. 1997). There is a considerable consensus, drawing on Ostrom (1992: 298–9) and Baland and Platteau (1996: 286–9), 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 have not deteriorated to the point 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 micro-environments.

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–R4 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 each other to keep promises and relate to each other 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.

V. 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 the relative abundance of the resource units may occur rapidly and users may not adapt quickly enough to the new circumstances (Libecap and Wiggins 1985).

The presence of frequently available, reliable indicators about the conditions of a resource (R2) affects the capacity of users to adapt relatively quickly to changes that can 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 and Carpenter 2007). If the resource flow is unpredictable, 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 micro-settings, 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...
and 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 multi-species or multi-product 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 one is destroyed, assuming there will always be other resources available to them.

Users who trust one another to keep agreements and use reciprocity in their relationships with one another (U4) face lower expected costs 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) by initially adopting small changes 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 for achieving various forms of regulation. Further, users are more likely to agree upon rules whose operation they understand from prior experience than rules introduced by external actors and 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 period of time. 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 do not imply that most users of common-pool resources will undertake self-governed regulation (as recognized in Berkes 2007 and Meinzen-Dick 2007). There are many settings where the theoretical expectation should be the opposite: the resource will be overused unless efforts are made to change one or more of the variables affecting perceived costs or benefits. Given the number of such variables, 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 policy-makers have a lot to learn about how these variables operate interactively in field settings (Ostrom 2007).

Many aspects of the macro-institutional structure surrounding a particular setting affect the perceived costs and benefits. Thus, external authorities can do a lot to enhance or reduce 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 manifestations 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 there are few roads which 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 (p.534) or a discriminatory labor market. Users’ discount rates in relation to a particular resource (U3) 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 and Ostrom 1992). Reliable indicators of the condition of a resource (R2) may result from activities of the users themselves—such as regularly shearing the wool from sheep (see Gilles and Jamtgaard 1981)—or because of efforts to gather reliable information by users or by external authorities (Blomquist 1992; Blomquist and Ostrom 2008). Predictability of resource units (R3) may result from a clear regularity in the natural environment or because storage evens out the flow of resource units over both good and bad years (Schlager et al. 1994). Users 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 great, users lacking many of the attributes conducive to the development of self-governing institutions may nonetheless be able to overcome their liabilities and develop effective agreements. The crucial factor is not whether all of the attributes are favorable but the relative size of the expected costs and benefits 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 costs and benefits of users. It is difficult, however, particularly for outsiders, to estimate their impact on expected costs and benefits, given the difficulty of measuring these variables precisely and weighing them on a cumulative scale.

VI. Puzzles
Despite the consensus concerning the variables most likely to enhance self-organization, many unresolved issues remain about the self-governance of common-pool resources. Two major empirical and theoretical questions concern the effect of size and heterogeneity.
VI.1 Size

The effect of the number of participants on the likelihood of creating and sustaining a self-governing enterprise is unclear. Many theorists argue that the size of a 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 the overview of this literature in Baland and 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: 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 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 and any of the three performance variables he studied (Lam 1998: 115).

One of the problems with a focus on group size 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 can 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).

VI.2 Heterogeneity
One reason 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 and Platteau 1996). Each may operate differently.

If groups 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, the interpretation of rules, trust, and reciprocity differ or are similar. In other words, do they share a common understanding of their situation (U2)? 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 interests similar 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 members of K and thus have a bigger impact on decisions about institutional changes.

Differences in the endowments of appropriators can be associated with both extreme levels of conflict and very smooth and low-cost transitions to a sustainable, self-governed system. Heterogeneity of wealth or power may or may not be associated with differences in interests. When those who have more assets share similar interests with those who have fewer, 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 whose assets differ significantly will tend to agree to and follow such rules (see Design Principles in Ostrom 1990: 90).

Even in a group that differs on many variables, if at least a minimal winning subset of $K$ harvesting an endangered but valuable resource is dependent on it (U1), shares a common understanding of its situation (U2), has a low discount rate (U3), trusts one another (U4), and has autonomy to make its own rules (U5), it is more likely that it will estimate the expected benefits of governing the resource to be 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 affect the cost—benefit calculus of those involved in negotiating and sustaining agreements.\(^5\) Their impact on costs of producing and distributing information is particularly important.

(p.537) VII. Conclusion
Engaging with impossibility results is much to be preferred to oversimplified rejection or despair. We have all learned much from Amartya Sen as he has engaged with a number of impossibility issues for all of us. It is not possible to repay Sen for all he has taught us, but I hope that sharing the experience of engaging with impossibilities is an appropriate form of homage to one of the great scholars of this age.

Bibliography references:


—— (1990), Governing the Commons (New York: Cambridge University Press).


Notes:

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 which consensual and compatible decisions can emerge. (Sen 1999: 365)

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 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 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, as long as they were willing to contribute a portion of the costs, they were able to obtain accurate information compiled by third-party experts.

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 (such as calling the fire department by making one phone call) through to unanimity.

(5) When analyzing the effect of multiple variables, simple mathematical models become very difficult to use, but agent-based models become a powerful tool (see Janssen and Ostrom 2006a, b, c).