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COMMON-POOL RESOURCES AND INSTITUTIONS: TOWARD A REVISED THEORY

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Common-pool resources are systems that generate finite quantities of resource units so that one person's use subtracts from the quantity of resource units available to others (E. Ostrom, Gardner, and Walker 1994). Irrigation systems are among the most important type of common-pool resource (E. Ostrom, 1992). Most common-pool resources are sufficiently large that multiple actors can simultaneously use the resource system and efforts to exclude potential beneficiaries are costly. When the resource units (e.g., water) are highly valued and many actors benefit from appropriating (harvesting) them for consumption, exchange, or as a factor in a production process, the appropriations made by one individual are likely to create negative externalities for others.

The "tragedy of the commons" will occur, therefore, in open-access commons where those involved and/or external authorities do not establish an effective governance regime. Governance regimes regulate one or more of the following:

- who is allowed to appropriate resource units;
- the timing, quantity, location, and technology of appropriation;
- who is obligated to contribute resources to provide or maintain the resource system itself;
- how appropriation and obligation activities are to be monitored and enforced;
- how conflicts over appropriation and obligation activities are to be resolved; and
- how the rules affecting the above will be changed over time with changes in the performance of the resource system and the strategies of participants.

A self-governed common-pool resource is one where actors, who are major appropriators from the resource, are involved over time in making and adapting rules within collective-choice arenas regarding the inclusion or exclusion of participants, appropriation strategies, obligations of participants, monitoring and sanctioning, and conflict resolution. Some extremely remote common-pool resources

are governed entirely by appropriators and are not governed at all by external authorities. In most modern political-economies, however, it is rare to find any resource systems—including the treasuries of private for-profit corporations—that are governed *entirely* by participants without rules made by local, regional, national, and international authorities also affecting key decisions (V. Ostrom 1991, 1997). Thus, in a self-governed system, participants make many, but not necessarily all, rules that affect the sustainability of the resource system and its use.

The Conventional Theory of Common-Pool Resources

Since the important early studies of open-access fisheries by Gordon (1954) and Scott (1955), most theoretical studies by political-economists have analyzed simple common-pool resource systems using relatively similar assumptions (Feeny, Hanna, and McEvoy 1996). In such systems, it is assumed that the resource generates a highly predictable, finite supply of one type of resource unit (one species, for example) in each relevant time period. Appropriators are assumed to be homogenous in terms of their assets, skills, discount rates, and cultural views. They are also assumed to be short-term, profit-maximizing actors who possess complete information. In this theory, *anyone* can enter the resource and appropriate resource units. Appropriators gain property rights only to what they harvest, which they then sell in an open competitive market. The open access condition is a given. The appropriators make no effort to change it. Appropriators act independently and do not communicate or coordinate their activities in any way.

> In this setting, as the incisive analysis of Gordon and Scott demonstrates, each fisherman will take into account only his own marginal costs and revenues and ignores the fact that increases in his catch affect the returns to fishing effort for other fishermen as well as the health of future fish stocks. . . . [E]conomic rent is dissipated; economic overfishing, which may also lead to ecological overfishing, is the result (Feeny, Hanna, and McEvoy 1996: 189).

Many textbooks in resource economics and law and economics present this conventional theory of a simple common-pool resource as the only theory needed for understanding common-pool resources more generally (see Dasgupta and Heal 1979; for a different approach, see Baland and Platteau 1996).

With the growing use of game theory, appropriation from common-pool resources is frequently represented as a one-shot or finitely repeated, Prisoner's Dilemma game (Dawes 1973; Dasgupta and Heal 1979). These models formalize the problem differently, but do not change any of the basic theoretical assumptions about the finite and predictable supply of resource units, complete information, homogeneity of users, their maximization of expected profits, and their lack of interaction with one another or capacity to change their institutions.

A sufficient number of empirical examples have existed where the absence of property rights and the independence of actors captures the essence of the problem facing appropriators that the broad empirical applicability of the theory was not challenged until the mid-1980s. The desertification of the Sahelian area, the massive deforestation in tropical countries, and the collapse of the California sardine fishery and other ocean fisheries confirmed the worst predictions to be derived from this theory for many scholars. Garrett Hardin's (1968) dramatic article in *Science* convinced many noneconomists that this theory captures the essence of the problem facing most common-pool resources in the world. Since appropriators are viewed as being trapped in these dilemmas, repeated recommendations were made that external authorities must impose a different set of institutions on such settings. Some recommend private property as the most efficient form of ownership (Demsetz 1967; Posner 1977; Simmons, Smith, and Georgia 1996). Others recommend government ownership and control (Ophuls 1973). Implicitly, theorists assume that regulators will act in the public interest and understand how ecological systems work and how to change institutions so as to induce socially optimal behavior (Feeny, Hanna, and McEvoy 1996: 195).

Until recently, the possibility that the appropriators themselves would find ways to organize themselves has not seriously been considered in much of the economics literature. Organizing so as to create rules that specify rights and duties of participants creates a public good for those involved. Anyone who is included in the community of users benefits from this public good, whether they contribute or not. Thus, getting "out of the trap" is itself a second-level dilemma. Further, investing in

monitoring and sanctioning activities so as to increase the likelihood that participants follow the agreements they have made, also generates a public good. Thus, these investments represent a third-level dilemma. Since much of the initial problem exists because the individuals are stuck in a setting where they generate negative externalities on one another, it is not consistent with the conventional theory that they solve a second- and third-level dilemma in order to address the first-level dilemma under analysis.

Until the work of the National Academy of Sciences' Panel on Common Property (National Research Council 1986), however, the basic theory discussed above was applied to all common-pool resources regardless of the capacity of appropriators to communicate and coordinate their activities. The growing evidence from many studies of common-pool resources in the field called for a serious re-thinking of the theoretical foundations for the analysis of common-pool resources (see Berkes 1986, 1989; Berkes et al. 1989; Bromley et al. 1992; McCay and Acheson 1987). The consequence of these empirical studies is not to challenge the empirical validity of the conventional theory where it is relevant but rather its generalizability.

A Common-Pool Resource in the Laboratory

The structure of Gordon's time-independent model (1954) has been used as the foundation to create a series of baseline laboratory experiments where the number of appropriators is fixed at eight (Walker, Gardner, and Ostrom 1990). In this experiment, all subjects are similarly endowed with either 10 or 25 tokens in each period of a finitely repeated game. Any or all of these tokens can be invested in a joint activity with the mathematical structure of a quadratic production function (the common-pool resource) or in an alternative activity that generates a fixed return per token (similar to investing time in wage labor). Subjects are privately paid at the end of the experiment based on the total returns obtained during the experiment and earn between $15 to $25 per experiment lasting from 1 to 1.5 hours. In this stark institutional setting, appropriators are not allowed to communicate. Given the

payoff parameters, a group investment of 36 tokens yields the optimal level of investment. The noncooperative Nash equilibrium for a finitely repeated game is for each subject to invest 8 tokens in the common-pool resource (regardless of the number of tokens provided as an endowment). Thus, the predicted outcome is for a total group investment of 64 tokens. The outcome reached at the predicted Nash equilibrium is 39% of the joint optimum that could be earned. Complete rent dissipation is not the predicted outcome, since the number of appropriators is fixed by the experimental design.

In these baseline experiments, subjects make investment allocations to the common-pool resource that are well above optimum. Significant rent dissipation occurs as predicted. The Nash equilibrium is the best predictor of aggregate outcomes for low-endowment experiments. In the high-endowment setting, aggregate behavior is far from Nash in early rounds but approaches Nash in later rounds. In this series of experiments as well as others (see E. Ostrom, Gardner, and Walker 1997), virtually *no* evidence supports the prediction of appropriators using individual Nash equilibrium.strategies. Investments in the common-pool resource across rounds are characterized by an unpredicted pulsing pattern in which investments increase leading to a reduction in yield, at which time subjects tend to reduce their investments in the common-pool resource and their yields increase. This pattern reoccurs across decision rounds within an experiment. The variation across rounds tends to diminish as the experiment continues. A further result that is not predicted by the theory is that the amount of tokens invested by subjects is affected by token endowments. Yields as a percentage of optimum are much lower in the high-endowment (25-token) experiments than in the low-endowment (10-token) experiments.

Overall, the prediction of excessive appropriation from a common-pool resource by appropriators who are constrained not to communicate but unconstrained by prior appropriation rules is supported by evidence from experimental studies. These conditions are roughly analogous to unorganized, large groups of actors appropriating from an international commons. Many common-pool resources,

however, are contained within a single country where a smaller number of actors may be able to communicate, coordinate strategies, and even find means to enforce these strategies themselves.

Self-Governance of Common-Pool Resources in the Field

In the field, many common-pool resources are characterized by substantially higher levels of complexity than the base theory of homogeneous appropriators taking one type of resource unit from a resource system that generates a predictable flow of units. As mentioned above, the rich case-study literature illustrates a wide diversity of settings in which appropriators dependant upon common-pool resources have organized themselves to achieve much higher outcomes than is predicted by the theory described above (Cordell 1989; Wade 1994; Ruddle and Johannes 1985; Sengupta 1991).

Small- to medium-sized irrigation systems come closer than many biological resources to approximating these conditions and are, thus, an appropriate setting in which to examine these patterns of relationships quantitatively. One resource unit—water—is the focus of efforts to organize and coordinate activities. Recent research on small- to medium-sized irrigation systems in Nepal has found a very substantial difference in performance between those systems owned and governed by the farmers themselves as contrasted to those systems owned and operated (but in some cases, not governed) by a national governmental agency.

While most farmers own land in Nepal, most own very small parcels of less than 1 hectare. They are relatively homogeneous with similar preferences in regard to obtaining water for rice production during the monsoon and winter seasons and various crops during the spring. Farmers in Nepal have long had the authority to create their own water associations, construct and maintain their own systems, and monitor and enforce conformance to their rules (see Benjamin et al. 1994; Lam, Lee, and Ostrom, 1997). The irrigation systems constructed and maintained by farmers tend to rely on low-tech construction techniques including building nonpermanent headworks from mud, trees, and stones.

International aid agencies have provided considerable funding to government agencies in an effort to upgrade the engineering standards.

In a detailed analysis of data from 150 farmer-governed and national government irrigation systems in Nepal, W. F. Lam (1994, forthcoming) develops three performance measures: (1) the physical condition of irrigation systems, (2) the quantity of water available to farmers at different seasons of the year, and (3) the agricultural productivity of the systems. Using multiple regression analysis techniques so as to control for environmental differences among systems, Lam finds several variables strongly related to these dependent variables. One is the form of governance of the system. Holding other variables constant, irrigation systems governed by the farmers themselves perform significantly better on all three performance measures. This variable has the largest explanatory power of any variable in Lam's analysis, including the physical size of the system, terrain characteristics, and the number of farmers.

Thus, farmers with long-term ownership claims, who can communicate, develop their own agreements, establish the positions of monitors, and sanction those who do not conform to their own rules, are more likely to grow more rice, distribute water more equitably, and keep their systems in better repair than is done on government systems. While there is variance in the performance of these Nepali systems, and also among the 47 farmer-governed systems in the Philippines described by de los Reyes (1980), few perform as poorly as government systems holding other relevant variables constant. Since many of the government systems rely on high-tech engineering, the capability of farmers to increase agricultural production on their "primitive systems" while they also provide the labor to maintain and operate the system, is particularly noteworthy.

On the Origin of Self-Governed Common-Pool Resources

Evidence from the field research thus challenges the generalizability of the conventional theory. While it is generally successful in predicting outcomes in settings where appropriators are alienated

from one another or cannot communicate effectively, it does not provide an explanation for settings where appropriators are able to create and sustain agreements to avoid serious problems of overappropriation. Nor does it predict well when government ownership will perform appropriately or how privatization will improve outcomes. A fully articulated, reformulated theory encompassing the conventional theory as a special case does not yet exist. On the other hand, scholars familiar with the results of field research substantially agree on a set of variables that enhance the likelihood of appropriators organizing themselves to avoid the social losses associated with open-access, common-pool resources (McKean 1992, 1996; Wade 1994; Schlager 1990; Tang 1992; E. Ostrom 1990, 1992a, 1992b; Baland and Platteau 1996; E. Ostrom, Gardner, and Walker 1994). Drawing heavily on Ostrom (1992b: 298-99) and Baland and Platteau (1996: 286-89), considerable consensus exists that the following attributes of resources and of appropriators 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 Appropriators:

A1. Salience: Appropriators are dependant on the resource system for a major portion of their livelihood.

A2. 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.

A3. Discount rate: Appropriators use a sufficiently low discount rate in relation to future benefits to be achieved from the resource.

A4. Distribution of interests: Appropriators with higher economic and political assets are similarly affected by a lack of coordinated patterns of appropriation and use.

A5. Norms of trust, reciprocity, and punishment: Appropriators trust one another to keep promises and relate to one another with reciprocity.

A6. Autonomy: Appropriators are able to determine access and harvesting rules without external authorities countermanding them.

A7. Prior organizational experience: Appropriators have learned at least minimal skills of organization through participation in other local associations or learning about ways that neighboring groups have organized.

Many of these variables are in turn affected by the type of larger regime in which users are embedded. Larger regimes can facilitate local self-organization by providing accurate information about natural resource systems, providing arenas in which participants can engage in discovery and conflict-resolution processes, and providing mechanisms to back up local monitoring and sanctioning efforts. The probability of participants adapting more effective rules in macroregimes that facilitate their efforts over time is higher than in regimes that ignore resource problems entirely or, at the other extreme, presume that all decisions about governance and management need to be made by central authorities.

The key to further theoretical integration is to understand how these attributes interact in complex ways to affect the basic benefit-cost calculations of a set of appropriators (A) using a resource (E. Ostrom 1990: ch. 6). Each appropriator i ($i \in A$) has to compare the expected net benefits of harvesting continuing to use the old rules (BO) to the benefits he or she expects to achieve with a new set of rules (BN). Each appropriator i must ask whether his or her incentive to change (D_i) is positive or negative.

$$D_i = BN_i - BO_i .$$

If D_i is negative for all appropriators, no one has an incentive to change. If D_i is positive for some appropriators, they then need 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 appropriation strategies; and C3—the long-term costs of monitoring and maintaining a self-governed system over time

(given the norms of the community in which they live). If the sum of these expected costs for each appropriator exceeds the incentive to change, no appropriator will invest the time and resources needed to create new institutions. Thus, if

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

for all $i \in A$, no change occurs.

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 related to appropriation, affects whether an institutional change favored by some and opposed by others will occur. For any collective-choice rule, such as unanimity, majority, ruling elite, or one-person rule, there is a minimum coalition of appropriators, $K \subset A$, that must agree prior to the adoption of new rules. If for any individual k, a member of K,

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

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

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

for all members of K, it is feasible for a new set of rules to be adopted. If there are several such coalitions, the question of which coalition will form, and thus which rules will result, is a theoretical issue beyond the scope of this entry. 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 rule used to change institutional arrangements 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 appropriators, it is possible that K appropriators will impose a new set of rules on the A-K other appropriators that strongly favors those in the winning coalition and imposes losses or

lower benefits on those in the losing coalition (Thompson, Mannix, and Bazerman 1988). If expected benefits from a change in institutional arrangements are not greater than expected costs for many appropriators, 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 A - K other appropriators lower the long-term costs of monitoring and sanctioning for a governing coalition. Where external authorities enforce the rules agreed upon by K appropriators, the distribution of costs and benefits are more likely to benefit K and may impose costs on the A - K other appropriators (see Walker et al. 1997).

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 appropriators 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 appropriators observe substantial scarcity. The danger here, however, is that exogenous shocks leading to a change in relative abundance of the resource units occur rapidly and appropriators 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 appropriators to adapt relatively soon to changes that could adversely affect their long-term benefit stream (Moxnes 1996). A resource flow that is highly predictable (R3) is much easier to understand and manage than one that is erratic. In the latter case, it is always difficult for appropriators (or, for that matter, for scientists and government officials) to judge whether changes in the resource stock or flow are due to overharvesting or to random exogenous variables (see Feeny, Hanna, and McEvoy 1996 for a discussion of these issues related to the collapse of the California sardine industry). Unpredictability of resource units in microsettings, such as private pastures, may lead appropriators 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 appropriators themselves (listed above) also affect their expected benefits and costs. If appropriators do not obtain a major part of their income from a resource (A1), the high costs of organizing and maintaining a self-governing system may not be worth their effort. If appropriators do not share a common understanding of how complex resource systems operate (A2), they will find it extremely difficult to agree on future joint strategies. Given the complexity of many common-pool resources—especially multispecies or multiproduct resources— understanding how these systems work may be counterintuitive even for those who make daily contacts with the resource. In resources that are highly variable (R3), it may be particularly difficult to understand and to sort out those outcomes stemming from exogenous factors and those resulting from the actions of appropriators. Of course, this is also a problem facing officials as well as appropriators. Appropriators with many other options, who thus discount the importance of future income from a particular resource (A3), may prefer to "mine" one resource without spending resources to regulate it. They simply move on to other resources once this one is destroyed, assuming there will always be other resources available to them.

Appropriators who possess more substantial economic and political assets may have similar interests to those with fewer assets (A4) 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. Mancur Olson (1965) long ago recognized the possibility of a privileged group whereby some were sufficiently affected to bear a disproportionate share of the costs of organizing to provide public goods (such as the organization of a collectivity). On the other hand, if those with more assets also have low discount rates (A3) related to a particular resource and lower salience (A1), they may simply be unwilling to expend inputs or

actually imped organizational efforts that might lead to their having to cut back on their productive activities.

Appropriators who trust one another (A6) 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. Appropriators who lack trust at the beginning of a process of organizing may be able to build this form of social capital (Coleman 1988; E. Ostrom 1992a) if they initially adopt small changes that most appropriators follow before trying to make major institutional changes. Autonomy (A7) 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 appropriators to achieve regulation. (See Libecap 1995 for a discussion of the efforts to use the courts to challenge the validity of *de facto* governance of inshore fisheries in the U.S.; see also Alexander 1982.) With the legal autonomy to make their own rules, appropriators face substantially lower costs in defending their own rules against other authorities. Prior experience with other forms of local organization (A7) greatly enhances the repertoire of rules and strategies known by local participants as potentially useful to achieve various forms of regulation. Further, appropriators 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, appropriators 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.

The growing theoretical consensus does *not* lead to a conclusion that most appropriators using common-pool resources will undertake self-governed regulation. Many settings exist where the theoretical expectation should be the opposite: Appropriators 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 appropriators' agreeing upon and following rules that generate higher social returns. But both social scientists and policymakers have a lot to learn about how these variables operate interactively in field settings and even how to measure them so as to increase the empirical warrantability of the growing theoretical consensus. 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 the likelihood and performance of self-governing institutions. Their actions can also seriously impede these developments as well. Further, when the activities of one set of appropriators, A, have "spillover effects" on others beyond A, 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. Appropriators may be highly dependant on a resource (A1), 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. Appropriator's discount rates (A3) 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 and Ostrom 1992). Reliable indicators of the condition of a resource (R2) may result from activities that the appropriators themselves do—such as regularly shearing the wool from sheep (see Gilles and Jamtgaard 1981) or because of efforts to gather reliable information by appropriators or by external authorities (Blomquist 1992). 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. They may have autonomy to make their own rules (A6) 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—as is the case with Japanese inshore fisheries.

When the benefits of organizing are commonly understood by participants to be very high, appropriators 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 participants. While all of these variables affect the expected benefits and costs of appropriators, it is difficult—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. Further empirical analysis of these theoretical propositions is, thus, dependant on the conduct of careful comparative over-time studies of a sufficiently large number of field settings using a common set of measurement protocols (see E. Ostrom and Wertime 1994).

On the Design Principles of Robust. Self-Governed Common-Pool Resource Institutions

Of course, the performance of self-governed common-pool resource systems varies across systems and time. Some self-governed common-pool resource systems have survived and flourished for centuries, while others falter and fail. As discussed above, some never get organized in the first place. In addition to the consensus concerning the theoretical variables conducive to self-organization, considerable agreement also exists about the characteristics of those self-governing systems that are robust in the sense that they survive for very long periods of time utilizing the same basic rules for adapting to new situations over time (Shepsle 1989).

The particular rules used in the long-surviving, self-governing systems varied substantially from one another. Consequently, it is not possible to arrive at empirical generalizations about the particular types of rules used to define who is a member of a self-governing community, what rights they have to access a common-pool resource and appropriate resource units, and what particular obligations they

face. It is possible, however, to derive a series of design principles that characterize the configuration of rules that are used. By design principles, I mean an "element or condition that helps to account for the success of these institutions in sustaining the [common-pool resource] and gaining the compliance of generation after generation of appropriators to the rules in use" (E. Ostrom 1990: 90). Robust, long-term institutions are characterized by most of the design principles listed in Table 1. The farmer-owned irrigation systems in Nepal analyzed by Benjamin et al. (1994) and Lam (1994, forthcoming), for example, are characterized by most of these design principles. Fragile institutions tend to be characterized by only some of these design principles. Failed institutions are characterized by very few of these principles (see, for example, Schweik, Adhikari, and Pandit, 1997; Morrow and Hull 1996; Blomqvist 1996).

[Table 1 about here]

These principles work to enhance the shared understanding of participants of the structure of the resource and its appropriators and of the benefits and costs involved in following a set of agreed-upon rules. Design Principle 1—having rules that clearly define who has rights to use a resource and the boundaries of that resource—ensures that appropriators can clearly identify anyone who does not have rights and take action against them.

Design Principle 2 involves two parts. The first is a congruence between the rules that assign benefits and the rules that assign costs. The crucial thing here is that these rules be considered fair and legitimate by the participants themselves (see McKean 1992). In many settings, fair rules are those that keep a relative proportionate relationship between the assignment of benefits and of costs. In irrigation systems, for example, rules that allocate water to different farmers according to the amount of land they own as well as allocating duties for costs of operation and maintenance using the same formula, are usually considered by farmers to be fair (as well as effective from an agricultural perspective). The second part of this design principle is that both types of rules be well-matched to local conditions such as soils, slope, number of diversions, crops being grown, etc.

Design Principle 3 is concerned with the collective-choice arrangements used to modify the operational rules of regular operation of the resource. If most appropriators are not involved in modifying these rules over time, the information about the benefits and costs as perceived by different participants is not fully taken into account in these efforts to adapt to new conditions and information over time. Appropriators who begin to perceive the costs of their system being higher than their benefits and who are prevented from making serious proposals for change, may simply begin to cheat whenever they have the opportunity. Once cheating on rules becomes more frequent for some appropriators, others will follow suit. In this case, enforcement costs become very high or the system fails.

No matter how high the level of agreement to an initial agreement is, there are always conditions that tempt some individuals to cheat (even when they perceive the overall benefits of the system to be higher than the costs). If one person is able to cheat while others conform to the rules, the cheater is usually able to gain substantially to the disadvantage of others. Thus, without monitoring of rule conformance—Design Principle 4—few systems are able to survive very long at all. The sanctions that are used, however, do not need to be extremely high in the first instance. The important thing about a sanction for an appropriator who has succumbed to temptation is that their action is noticed and that a punishment is meted out. This tells all appropriators that cheating on rules is noticed and punished without making all rule infractions into major criminal events. If the sanctions are graduated (Design Principle 5), however, an appropriator who breaks rules repeatedly and who is noticed doing so, eventually faces a penalty that makes rule breaking an unattractive option. While rules are always assumed to be clear and unambiguous in theoretical work, this is rarely the case in field settings. It is easy to have a disagreement about how to interpret a rule that limits appropriation activities or requires input resources. If these disagreements are not resolved in a low-cost and orderly manner, then appropriators may lose their willingness to conform to rules because of the ways that "others" interpret them in their own favor (Design Principle 6).

Design Principles 7 and 8 are related to autonomy. When the rights of a group to devise their own institutions are recognized by national, regional, and local governments, the legitimacy of the rules crafted by appropriators will be less frequently challenged in courts, administrative and legislative settings. Further, in larger resources with many participants, nested enterprises that range in size from small to large enable participants to solve diverse problems involving different scale economies. By utilizing base institutions that are quite small, face-to-face communication can be utilized for solving many of the day-to-day problems in smaller groups. By nesting each level of organization in a larger level, externalities from one group to others can be addressed in larger organizational settings that have a legitimate role to play in relationship to the smaller entities.

Theoretical Puzzles

In addition to the consensus concerning the variables most likely to enhance self-organization and the design principles characterizing successful, long-term governance arrangements, many unresolved theoretical issues still exist about the self-governance of common-pool resources. Two major 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. Drawing on the early work of Mancur Olson (1965), many theorists argue that size of group is negatively related to solving collective-action problems in general (see also Buchanan and Tullock 1962). 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 and Platteau 1996). Scholars who have studied many user-governed irrigation and forestry institutions in the field have concluded that success will more likely happen in smaller groups (see, for example, Barker et al. 1984; Cernea 1989).

On the other hand, several studies of multiple sites have not found that size was positively related. While most of the 37 farmer-governed irrigation systems studied by Tang (1992) 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 (1992: 68). 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 also 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 (1994: 182). Further, in a systematic study of forest institutions, Agrawal (1996) has not found smaller forest user groups as able to undertake the level of monitoring needed to protect forest resources as moderately sized groups.

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 (Chamberlin 1974; R. Hardin 1982). 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, Walker, and Williams 1993). Marwell and Oliver (1993: 45) conclude that when a "good has pure jointness of supply, group size has a *positive* effect on the probability that it will be provided." On the other hand, if one is analyzing the conflict levels over a subtractable good and the transaction costs of arriving at acceptable allocation formulas, group size may well exacerbate the problems of self-governing systems. Since there are tradeoffs among various impacts of size on other variables, a better working hypothesis is that group size has a curvilinear relationship to performance.

Heterogeneity

Many scholars conclude that only very small groups can organize themselves effectively because they presume that size is related to the homogeneity of a group and that homogeneity is needed to

initiate and sustain self-governance. 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 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 (A2) 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 appropriators differ, achieving a self-governing solution to common-pool resource problems is particularly challenging. This problem characterizes some fisheries where local subsistence fishermen have strong interests in the sustenance of an inshore fishery, while industrial fishing firms have many other options and may be more interested in the profitability of fishing in a particular location than its sustained yield. The conflict between absentee livestock owners versus local pastoralists has also proved difficult to solve in many parts of the world.

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. Johnson and Libecap (1982) reason that the difference in the skills and knowledge of different kinds of fishers frequently prevents them from arriving at agreements about how to allocate quantitative harvesting quotas (see also Scott 1993). In this case, heterogeneity of endowments and of interests coincide. Heterogeneity of wealth or power may or may not be associated with a difference in interests. As discussed above, when those who have more assets share similar interests with those who have less

assets (A4), 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. Appropriators 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 (Design Principle 2A), appropriators who differ significantly in terms of assets will tend to agree to and follow such rules.

Even in a group that differs on many variables, if at least a minimally winning subset of K appropriators from an endangered but valuable resource are dependant on it (A1), share a common understanding of their situations (A2), have a low discount rate (A3), include some with more assets among their members (A4), trust one another (A5), and have autonomy to make their own rules (A6), 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. The debate about their effect is focusing on the wrong variables. 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. Their impact on costs of producing and distributing information (Scott 1993) is particularly important.

Conclusion

The conventional theory of common-pool resources, which presumed that external authorities were needed to impose new rules on those appropriators trapped into producing excessive externalities on themselves and others, has now been shown to be a special theory of a more general theoretical structure. For appropriators to contemplate changing the institutions they face, they have to conclude that the expected benefits from an institutional change will exceed the immediate and long-term

expected costs. When appropriators cannot communicate and have no way of gaining trust through their own efforts or with the help of the macroinstitutional system within which they are embedded, the prediction of the earlier theory is likely to be empirically supported. Ocean fisheries, the stratosphere, and other global commons come closest to the appropriate empirical referents. If appropriators can engage in face-to-face bargaining and have autonomy to change their rules, they may well attempt to organize themselves. Whether they organize depends on attributes of the resource system and the appropriators themselves that affect the benefits to be achieved and the costs of achieving them. Whether their self-governed enterprise succeeds over the long-term depends on whether the institutions they design are consistent with design principles underlying robust, long-living, self-governed systems. The theory of common-pool resources has progressed substantially during the past half century. There are, however, many challenging puzzles to be solved.

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Design Principles Illustrated by Long-Enduring Common-Pool Resource Institutions

1. Clearly Defined Boundaries

Individuals or households with rights to withdraw resource units from the common-pool resource and the boundaries of the common-pool resource itself are clearly defined.

2. Congruence

A. The distribution of benefits from appropriation rules is roughly proportionate to the costs imposed by provision rules.

B. Appropriation rules restricting time, place, technology, and/or quantity of resource units are related to local conditions.

3. Collective-Choice Arrangements

Most individuals affected by operational rules can participate in modifying operational rules.

4. Monitoring

Monitors, who actively audit common-pool resource conditions and appropriator behavior, are accountable to the appropriators and/or are the appropriators themselves.

5. Graduated Sanctions

Appropriators who violate operational rules are likely to receive graduated sanctions (depending on the seriousness and context of the offense) from other appropriators, from officials accountable to these appropriators, or from both.

6. Conflict-Resolution Mechanisms

Appropriators and their officials have rapid access to low-cost, local arenas to resolve conflict among appropriators or between appropriators and officials.

7. Minimal Recognition of Rights to Organize

The rights of appropriators to devise their own institutions are not challenged by external governmental authorities.

For common-pool resources that are part of larger systems:

8. Nested Enterprises

Appropriation, provision, monitoring, enforcement, conflict resolution, and governance activities are organized in multiple layers of nested enterprises.

Adapted from: E. Ostrom (1990: 90).