Articles

Common Property Externalities: Isolation, Assurance, and Resource Depletion in a Traditional Grazing Context

Carlisle Ford Runge

Institutional alternatives to common property externalities are wider than argued by private exclusive property rights advocates. The "tragedy of the commons" is not a prisoners' dilemma, characterized by the strict dominance of individual strategies. The nonseparable common property externality is an "assurance problem." The assurance problem provides striking perspectives in analytical and policy terms. It redefines the problem of the commons as one of decision making under uncertainty. Institutional rules innovated by the group to reduce uncertainty and coordinate expectations can solve the problem of overexploitation. Rules come in many forms, and private property is only one.

Key words: common property, institutional rules, nonseparabilities, prisoners' dilemma.

Externalities lead to nonoptimal market allocations. The literature is filled with examples of "market failure" arising from the divergence of private from social cost (Bator, Coase, and Meade). The "tragedy of the commons" arising from grazing too many cattle on a given area of land has been widely noted as an important representative case of externality. The private benefit of grazing an additional head of cattle on a common range exceeds the private cost, because part of the cost is incurred by the entire group engaged in grazing. As a result, individuals have an incentive to "free-ride" and resource overexploitation results (G. Hardin).

The example of a common property externality is only one of a large number of structurally similar problems. These include overexploitation of common fishing grounds, extraction of oil and natural gas from a common underground reservoir, deforestation of common lands for fuelwood, depleting underground water sources, and some pollution problems of common air and water resources (Dasgupta and Heal, pp. 73–78).

Economists have struggled to find appropriate analytic and technical tools to model these important problems. One is the theory of games (Von Neuman and Morgenstern, Luce and Raiffa). It has been widely and erroneously assumed that common property externalities arise for reasons associated with the famous "prisoners' dilemma" game. This paper will demonstrate (*a*) that such an assumption is a false interpretation of the problem and (*b*) a correct game-theoretic formulation of common property externalities. This formulation is known as an assurance problem (Sen). Assurance problems have interesting implications for institutional rules designed to halt environmental degradation. The discussion will focus on problems of overgrazing, with particular reference to pastoral grazing in developing countries. The analysis also will be extended to other examples of externalities and to public or collective goods generally.

Overgrazing: Some Theoretical Approaches

In much of the developing world, common property provides a complex system of norms and conventions over individual grazing

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rights, closely resembling the traditional, common property institution of prefeudal Europe. Common property was an old Teutonic institution, which slowly gave way to the forced enclosure movements of the fifteenth and sixteenth centuries, notably in Great Britain. Its existence may be traced to Graeco-Roman times (Vassberg, Blum). Historically, and in its modern version, common property provides regulations of considerable complexity over individual grazing rights. Given its persistence, common property is argued by some scholars to be a relatively stable system (Dahlman).

As an institution, common property is distinguished from free and open access, where there are no rules regulating individual grazing rights (Ciriacy-Wantrup and Bishop). Often, what appears to the outside observer to be open access may really involve tacit cooperation by individual users according to a series of rules. This is common property. As in duopoly, a structure of use-rights to common range may be stable or unstable. It is this problem, not open access, which I will address. Empirically, it is important to distinguish between open access and common property if appropriate policy is to be formulated. The problems of open access arise from unrestricted entry. Problems of common property pertain to use-rights by a group of a given size.

Although common property may be a stable pattern of resource use in traditional societies, population growth, technological change, or rapid climate change can destabilize traditional institutions. Today, especially in areas of the Sahel and southern Africa, the breakdown of common property institutions has led to serious overgrazing (Hitchcock, Picardi and Seifert, Glantz).

Many economic consultants and planners have called for the imposition of private property rights to halt this "tragedy of the commons" (Johnson, Picardi). Following the tradition of enclosure of common grazing lands, efforts have been made to impose private property schemes to "internalize" a common property externality (Foss). Many have failed seriously. Not only have they failed to stop overgrazing, they also have contributed to further inequality in already unequal distributions of wealth. Lands formerly held in common are being transferred to individuals, such as high-ranking government bureaucrats, who can exercise influence in the allocation of use-rights. These individuals often fail to protect range quality (Hitchcock). An analysis of the economic paradigm leading to this failure sheds light on the problem.

The Property Rights Paradigm

Some economists argue that the proper solution for overgrazing a common range is to internalize its costs by making the public aspects of the range private. Instituting a scheme of such rights, if they are properly enforced, will create a market in the private rights to graze. This approach has led Demsetz, among others (Cheung, North and Thomas, Furubotn and Pejovich) to argue that the mere existence of common property rights over a scarce resource will lead to a tragedy of the commons because of the failure to internalize the social costs of grazing the last head of cattle. They argue that the enforcement of private use-rights to the resource will yield internalized costs to each user equal to benefits in total and at the margin.[1]

There are three things wrong with this analysis. First, it does not distinguish between situations of open access (in which the main difficulty is unrestricted entry) and those of common property.[2] This view implies the inevitable overexploitation of common property, an historically false position (Dahlman). Second, it treats the common property externality as if each individual's choices are independent of their expectation of others' choices. Thus, cost functions for each cattle owner are assumed separable in their arguments. Third, and most important, because individuals are assumed to act independently, the property rights paradigm abstracts from the crucial problem of each person's uncertainty about the actions of others.

The first of these problems is empirical. The next two are theoretical and require further elaboration. This may be provided with the

[1] The inherent inefficacy of common ("communal") property regimes in the property rights paradigm is expressed clearly by Demsetz. Demsetz asserts the "great disadvantage" of common property, since "the maximization of the value of communal property rights will take place without regard to many costs, because the owner of a communal right cannot exclude others from enjoying the fruits of his efforts and because negotiation costs are too high for all to agree jointly on optimal behavior" (p. 356).

[2] North and Thomas (p. 234), for example, describe the economic state of traditional pre-agricultural societies as one in which "[T]he natural resources, whether the animals to be hunted or vegetation to be gathered, were initially held as common property. This type of property right implies free access by all to the resource" (p. 234).

familiar prisoners' dilemma game. Its logical similarity to the common property approach in the property rights paradigm highlights the shortcomings of the latter in analyzing externality problems. The prisoners' dilemma, when generalized to more than two actors, is also known as the isolation paradox. The basic result is that collective decisions by independent actors produce inferior outcomes, unless an enforceable rule is imposed from outside the group. To the property rights school, this rule involves private, exclusive use-rights to the resource.

The Isolation Paradox: Independent Choice

The prisoners' dilemma is illustrated in the following gain-loss table.

First Prisoner	Second Prisoner	
	Not Confess	Confess
Not Confess	(1,1)	(10,0)
Confess	(0,10)	(5,5)

"Confess" or "not confess" represent the choices (or strategies) open to each of two prisoners. The ordered pairs indicate the number of years in prison which will result from a particular coincidence of choices. Imagine that the the prisoners are interrogated independently. Both know that if neither confesses, they will receive short sentences and spend a year in prison (1,1); if one confesses and turns state's evidence, he will be released, and the other will receive a heavy term of ten years (1,10), (10,0). If both confess, each gets five years (5,5). Assuming mutually disinterested motivation, the most reasonable course of action, represented by the pair (1,1), is unstable. To protect himself, if not to further his own interests, each has a sufficient reason to confess, whatever the other does. "Rational" decisions by each prisoner individually make both worse off. Even if communication between the individuals results in an agreement to observe choice (1,1), both have an incentive to break it (Sen). Even in repeated plays, the incentive always is to defect (Weintraub). Therefore, the noncooperative pair, (5,5), is a Pareto-inferior equilibrium.

Now imagine a community of N individuals who must graze cattle on a common range of fixed size. Each individual must choose to do one of two things. One is "stinting," or limited grazing on the commons. The second is grazing at a level which, while advantageous to the individual, ultimately results in exploitative overuse of the commons. If each individual formulates his grazing decision independently, the result is an N-person variation on the prisoners' dilemma. The cost of grazing to each individual is a function of the grazing decisions of all N individuals. If all cooperate and stint, then the common range is preserved and cattle remain healthy. Yet independently (even with communication), each individual has an incentive to defect and graze heavily in the near-term, overexploiting the range in the long run. Each individual believes that he will receive a higher profit if he grazes at an exploitative level rather than stints. The incentive structure is such that it does not matter which strategy the others choose. Therefore, grazing at an exploitative level strictly dominates stinting for each individual. Hardin, in his original article on the tragedy of the commons, wrote:

> The rational herdsman concludes that the only sensible course for him to pursue is to add another animal to his herd. And another . . . But this is the conclusion reached by each and every rational herdsman sharing the commons. Therein is the tragedy. Each man is locked into a system that compels him to increase his herd without limit—in a world which is limited. (Hardin and Garrett, p. 20; *Science*, p. 1244)

Curiously, it is individuals' independence that "locks them into" the tragedy. This is the same outcome Demsetz and the property rights school claim as the inevitable result of common property. The main features of this paradox are

(*a*) *Pareto-inferior outcome.* Each individual will choose independently to graze at an exploitative level, leading to a situation in which all are made worse off. All are led toward this noncooperative equilibrium.

(*b*) *Strict dominance of individual strategy.* The result of overgrazing arises independently of the expectations of each individual regarding the actions of others. Because the choices of each are logically independent, there is no problem of uncertainty about the actions of others.

(*c*) *Need for enforcement.* Even if an agreement is struck that specifies all will stint on the range, the strict dominance of individual strategy makes such an agreement unstable. Without compulsory enforcement imposed by an outside authority, any such agreement is unstable because each prefers

that the others stint while he defects and grazes exploitatively (Sen).

Even if individuals attempt to develop cooperative rules to enforce stinting they cannot resolve their problem because nobody has an incentive to keep such agreements. As a result, an enforceable rule must be imposed from outside. Institutional rules are viewed as exogenous to the problem at hand. Private property rights are consistent with this formulation because they can be imposed from outside, as with the parliamentary acts of enclosure. Because this approach starts from the (not always obvious) presupposition that individuals pursue strategies independent of the expected actions of others, the appropriate decision unit must be the private individual user. Also consistent with the strict dominance of individual strategy is the strong assumption that rational individuals will husband and conserve their own private range area at a rate consistent with the time preference of society as a whole.

If this formulation is correct, then only by imposing private property rules from outside can the group optimize its grazing. Any other alternatives are unstable because of the strict dominance of individual strategy.

This approach confounds situations of open access with those of common property, because its noncooperative assumptions leave no place for cooperative rules unless they are imposed and enforced from outside. The second objection is that this game structure treats externalities as if all cattle grazers behave like Robinson Crusoe. This implies "separability" of individual cost functions which, I will show below, is extremely implausible. The third, and crucial, objection is that by assuming the independent formulation of each individual's strategy, this approach does not deal with uncertainty regarding the actions of others. I argue that uncertainty is the major motivating force in overexploitation of common property resources.

External Costs: Separable and Nonseparable Cases

Imagine two representative cattle owners each of whom grazes cattle on a common range.[3] In a competitive situation, each individual cattle owner has a cost function for grazing on the common. They are

$$C_1 = C_1(q_1, q_2), \quad C_2 = C_2(q_1, q_2), \tag{1}$$

where C_1 and C_2 are costs to owners 1 and 2, respectively, q_1 is head of cattle grazed by 1, and q_2 is head of cattle grazed by 2. These owners are linked to each other through their individual cost functions which reflect external diseconomies of grazing. Increases in cattle grazed by 1 impose additional costs on 2, and vice versa. If each individual maximizes profits from cattle holding, they will equate price with marginal cost:

$$p = \frac{\partial C_1}{\partial q_1} = \frac{\partial C_2}{\partial q_2}. \tag{2}$$

The welfare associated with cattle production on the common can be measured by the difference between social benefit and social cost. In a competitive situation, social benefit can be measured for the two owners by their total revenue,

$$\text{total revenue} = p(q_1 + q_2).$$

Social costs can be measured by total costs,

$$\text{total costs} = C_1(q_1, q_2) + C_2(q_1, q_2).$$

To maximize welfare, the joint profit function of the two individuals must be maximized, where π signifies joint profit, and π_1 and π_2 are the profit functions of the cattle owners:

$$\pi = \pi_1 + \pi_2, \quad = p(q_1 + q_2) - C_1(q_1, q_2) - C_2(q_1, q_2). \tag{3}$$

First-order conditions for a maximum are

$$\frac{\partial \pi}{\partial q_1} = p - \frac{\partial C_1}{\partial q_1} - \frac{\partial C_2}{\partial q_1} = 0, \quad \frac{\partial \pi}{\partial q_2} = p - \frac{\partial C_1}{\partial q_2} - \frac{\partial C_2}{\partial q_2} = 0. \tag{4}$$

Second-order conditions for a maximum are

$$\frac{\partial^2 \pi}{\partial q_1^2} < 0, \quad \frac{\partial^2 \pi}{\partial q_2^2} < 0, \text{ and} \quad \frac{\partial^2 \pi}{\partial q_1^2}\frac{\partial^2 \pi}{\partial q_2^2} > \left(\frac{\partial^2 \pi}{\partial q_1 \partial q_2}\right)^2. \tag{5}$$

An externality arises when either

$$\frac{\partial C_2}{\partial q_1} \neq 0 \text{ or } \frac{\partial C_1}{\partial q_2} \neq 0, \tag{6}$$

[3] The exposition of separable and nonseparable externalities follows that of Davis and Whinston, although I have adapted their arguments to the case of profit-maximizing individual cattle grazers.

since (2) and (4) will not then coincide. Profit maximization by each individual will not give the greatest net social benefit possible because of the external effects of one's cattle on another's costs. For completeness, note that these external effects are diseconomies, so that

$$\frac{\partial C_2}{\partial q_1} > 0 \text{ and } \frac{\partial C_1}{\partial q_2} > 0. \tag{7}$$

This much is standard.

A function is said to be separable if and only if

$$f(x_1, x_2) = f_1(x_1) + f_2(x_2). \tag{8}$$

Consider the case in which the cost functions of the individuals are interrelated by external diseconomies but are separable in their arguments:

$$\begin{aligned} C_1(q_1, q_2) &= A_1 q_1^n + B_1 q_2^m, \\ C_2(q_1, q_2) &= A_2 q_2^r + B_2 q_1^s. \end{aligned} \tag{9}$$

Profit maximization is given by

$$p = \frac{\partial C_1}{\partial q_1} = nA_1 q_1^{n-1}, \tag{10}$$

$$= \frac{\partial C_2}{\partial q_2} = rA_2 q_2^{r-1}.$$

The key result is that each individual's marginal cost in the separable case is given entirely in terms of own cattle: q_1 for 1 and q_2 for 2. Davis and Whinston have shown that this result is formally equivalent to the strict dominance of individual strategy. Consistent with the noncooperative nature of the isolation paradox, if each individual formulates his decision independently, then his appropriate decision rule for profit maximization is "price equals marginal cost," as in (10).

A separable cost function leads to the same result as the prisoners' dilemma. Since marginal cost to each individual is defined entirely in terms of own cattle, then whatever the actions of the other individual(s), there is a unique number of own cattle that maximizes each individual's profit. This is no more than a restatement of the strict dominance of individual strategy. In sum, separability implies the dominance of individual strategy (Davis and Whinston).

The effect of separable externalities in grazing is simply to shift the total cost curve of any individual grazer by a constant equal to the magnitude of the external effect. Because marginal conditions are unaffected, the optimal number of cattle for each individual remains the same. A tax or subsidy scheme may then be used to correct the price system according to the classical prescription (Pigou, Meade). Davis and Whinston note that "the typical cases (of externality) with which the classical analysis has been concerned have, in fact, assumed the condition of separability" (p. 245). My purpose in treating separability in such detail is to show that approaches based on the strict dominance of individual strategy, such as the property rights paradigm, also assume separable individual cost functions.

When the assumption of separability is dropped, elements of interdependence and uncertainty are introduced which become difficult to handle with traditional tools and concepts. Because separability is formally equivalent to strict dominance of individual strategy, dropping separability implies interdependence of individual choice. Each individual bases grazing decisions on the expected actions of others.

Nonseparable Externalities

The joint use of a common grazing area is not a separable decision. Choices to graze cattle on a common range are not made by each owner in a vacuum. Rather, they are conditioned on expectations of the likely behavior of others. The common range has tied their welfare and decision making together (Netting, Rhodes and Thompson). In the nonseparable case, the externality enters the cost function of each individual in a multiplicative rather than an additive way, so that

$$f(x_1, x_2) \neq f_1(x_1) + f_2(x_2). \tag{11}$$

For example, consider two cost functions for representative cattle owners of the following form:

$$\begin{aligned} C_1(q_1, q_2) &= A_1 q_1^n + B_1 q_1 q_2^m, \\ C_2(q_1, q_2) &= A_2 q_2^r + B_2 q_2^t q_1^s. \end{aligned} \tag{12}$$

Profit maximization by each individual implies that

$$p = \frac{\partial C_1}{\partial q_1} = nA_1 q_1^{n-1} + B_1 q_2^m,$$

as well as that

$$p = \frac{\partial C_2}{\partial q_2} = rA_2 q_2^{r-1} + tB_2 q_2^{t-1} q_1^s. \tag{13}$$

In contrast to the separable case, marginal cost is affected here not only by the variable under control of the individual, but also by the other's choice variable. Because each person's marginal conditions for profit maximization are affected by the grazing decisions of others, there is no well-defined decision rule for each individual. Externalities will not simply shift total cost by some constant, as in the classical, separable case. Instead, it is likely that the changed marginal cost to each individual caused by the actions of others will alter the slope of the total cost curve along its entire length. This is more plausible. We would not expect that grazing on a common range of fixed size would involve a constant externality independent of the number of cattle put on the range. One cattle owner's decision to graze cattle generally will depend on his expectation of the behavior of others.

In game-theoretic terms, this strategic interdependence implies that the strict dominance of individual strategy no longer holds. Each individual must take into account the actions of others in his decision to graze cattle on the commons. This defines the problem of the commons as decision making under uncertainty. This uncertainty, arising from the interdependence of choice, suggests a logical structure different from the separable case. Nonseparable externalities imply an alternative game structure.

In nonseparable choice problems, there is no unique solution for each individual. Because of the interdependence of choice and the resulting changes in the marginal conditions for profit maximization, the classical tax-subsidy solution breaks down because of the "twists" likely in the total cost curves. The presumed advantage of private property, which is rooted in the strict dominance of individual strategy, can no longer be justified on these grounds. Strict dominance no longer holds. In the nonseparable case, the imposition of private property is an attempt to impose separability on an inherently nonseparable externality. If it is to succeed, it involves creating a set of independent agents out of a community of individuals. While this may be one possible solution, the absence of strict individual dominance does not commend it as the only one. And the transactions costs likely to be incurred will not be trivial. Advocates of independent decision making may promote more costly responses to externalities than necessary by neglecting the interdependencies which exist.

Hence, nonseparabilities suggest that the main problem of common property externalities is uncertainty. This view is held by Dasgupta and Heal, who note that, "contrary to what is often claimed, the problem of 'the common' and the resulting suboptimality of the market equilibrium are *not* formally identical to an N-person version of the prisoners' dilemma game" (p. 59). They also argue that the N-person prisoners' dilemma is erroneous because it is characterized by dominant strategies by each agent. Properly formulated, the commons problem involves the interdependence of agents, such that it is in the interest of each to restrict output (to stint on the range) if that is the only way to get other agents to do likewise. Hence, "the guilty party is not the profit motive per se. Rather, it is the economic and legal environment in which the profit motive is allowed free play" (Dasgupta and Heal, p. 63).

This renewed emphasis on the economic and legal environment places the problem in an institutional context. It also permits reformulation of the problem of the commons. This problem of cooperation, in game-theoretic terms, is known as the "assurance problem."

The Assurance Problem: Interdependent Choice

The assurance problem (Sen) is an amended version of a game called "the Battle of the Sexes," discussed by Luce and Raiffa and Bacharach. This two-person cooperative game has the following payoff matrix, representing the gains and losses of two individuals. The man wishes that they go together to the dog races; the woman wishes that they go to the ballet. But each of them prefers to go together to either of these activities rather than to separate entertainments. This game of pure strategy pairs has two equilibrium points, both going to the ballet or both going to the dogs.

Man	Woman	
	Ballet	Dogs
Ballet	(1,2)	(−1,−1)
Dogs	(−1,−1)	(2,1)

The game is not one of conflict, like the prisoners' dilemma. It is a cooperative game

because there is no dominant strategy for either individual. Hence agreements, once made, contain no incentive to defect; both parties gain from adhering to the rules. The problem is assurance regarding the other person's intended action. The man and woman must correlate their expectations and cooperate through some rule which assures them that wherever they go, they will go together. The payoff matrix may be expressed graphically (fig. 1).

The shaded portion of the graph describes the outcomes which the individuals can achieve without cooperation by choosing their strategy independently, as in the prisoners' dilemma. This shaded portion may be derived more formally so as to illustrate the distinction between the prisoners' dilemma and the assurance problem. By formulating "mixed strategies" of the two and their associated payoffs, it is possible to trace out the "convex hull" shown in figure 1. This convex hull illustrates the gains possible from cooperative rules providing coordinated expectations, or "assurance."

For example, suppose that she goes to the dogs and he picks at random from his two choices, as shown in the payoff matrix above. Then his and her payoffs are given in the graph by the line LJ. Say that she goes to the dogs and he picks with probabilities half and half. His expected payoff is

$$1/2 \times 2 + 1/2 \times (-1) = 1/2.$$

Her payoff is

$$1/2 \times 1 + 1/2 \times (-1) = 0.$$

This gives the payoff pair of (1/2, 0), shown as the point N. Alternatively, suppose that each tosses an unbiased coin and goes to the dogs if it comes up heads. Then each of the four pure strategy pairs shown in the payoff matrix has a probability $(1/2)^2 = 1/4$. His expected utility and hers are the same:

$$1/4(2) + 1/4(-1) + 1/4(-1) + 1/4(1) = 1/4.$$

This gives the payoff pair (1/4, 1/4) at point F. The process can be continued with various probability combinations to trace out the convex hull. The important point is that when the choices of each are made independently, as in the prisoners' dilemma, it can be shown formally that the attainable set is only the shaded region of figure 1. This is the noncooperative attainable set.

However, cooperation enlarges the attainable set to include the entire area bounded by $LKJN$. In the assurance problem, the attainment of cooperative solutions such as point M requires coordinated strategies. These can arise only when the players' choices are interdependent and, recognizing it, the players devise a rule that provides assurance regarding the expected actions of others (Schelling, Bacharach).

The assurance problem provides a formal way of looking at interdependence and uncertainty associated with nonseparable externalities. Coordinated strategies evolve inside the structure of the game. In this sense, they mirror institutional rules which, by providing assurance, extend the set of possible solutions to allocation problems. By providing security of expectation, or assurance, reliable institutions are endogenous responses to the uncertainty of social and economic interaction (Taylor, Schotter, and Schelling).

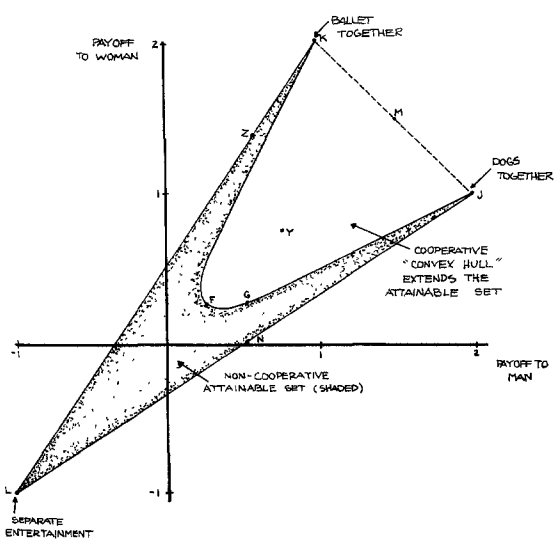

Figure 1. Payoff space: the battle of the sexes assurance problem

Institutional Rules and Common Property Externalities in Grazing

The structure of the assurance game describes the problem of common property externalities in grazing. Its nonseparable character chal-

lenges the notion of strict individual dominance. It is more plausible to treat these externalities as problems of interdependence and uncertainty. Although Pareto-superior solutions may not be achieved, this structure—in contrast to the N-person prisoners' dilemma—does not make such solutions perpetually susceptible to defection and, therefore, inherently unstable.

The structure of the N-person prisoners' dilemma may be transformed into an assurance problem by dropping the assumption that individuals formulate their choices independent of the expected choices of others. When each individual expects everyone else to stint, that individual will stint, too. This has long been noted as an adaptive response in stable pastoral grazing economies (Brokensha, Horowitz, Scudder; Netting; Rhodes and Thompson). On the other hand, if each expects others to graze exploitatively, then each will also have reason to do so. In order to achieve the Pareto-superior outcome of range preservation through stinting, a coordinated strategy must be devised according to some set of rules or institutions.

Approaching overgrazing as an assurance problem provides striking perspectives in both analytical and policy terms. The strict dominance of individual strategy no longer holds. Consistent with the nonseparable common property externality, expectations of others' choices must be entered as a formal part of the determination of one's own choice. No individual can decide the preferred grazing strategy until it is known whether or not others will stint. A Pareto-inferior outcome no longer holds; if everyone is assured that the others will stint, then it is in their individual interest to do likewise. This outcome is not Pareto-inferior, since stinting is preferred by all in such a situation. If some assurance regarding the actions of others is provided, via an institutional rule, it is possible to achieve multiple equilibria in the extended "convex hull" of the attainable set. The lack of a dominant strategy for each individual cattle owner means that there are a variety of alternative solutions possible through cooperative action. Precisely which will be taken depends on individuals' bargaining power, their initial endowment of resources, their culture, climate, and so on. Analytically, the assurance problem's solution is an "equilibrium core" (Scarf, Shapley and Shubik). Unlike the prisoners' dilemma, cooperative solutions offer no incentive to defect. This suggests that institutional rules providing complete assurance are self-reinforcing; the incentive to keep them is that Pareto-superior solutions are attainable via cooperation which are unavailable otherwise. The key element determining the success or failure of institutions is therefore the extent to which they foster coordinated expectations (Ullman-Margalit).

It is hypothesized that the function of institutional rules is to parameterize expectations of the likely behavior of others. More precisely, "assurance" may be expressed in terms of the parameters describing—for each individual—the moments of a subjective probability density function over others' contribution to a public good. The moments of this function identify the expectation of stinting by others, the variance around this expectation, and the pessimism or optimism (skewedness) associated with it. Whether rational, self-interested individuals contribute to range quality by holding cattle off the range depends on the likelihood they attach to the level of voluntary contributions by others (Frohlich and Oppenheimer). The moments, notably the variance, of these density functions describe the level of assurance regarding these actions.

The virtue of institutional rules is that they are a relatively low-cost "shorthand" describing this expected behavior. Suppose that tribal tradition—the result of long-standing agreement—is such that each grazer is expected to stint at an arbitrary level (q^*). The result of this institutional rule is to formalize, for each grazer j, the expected actions of others at level q^*. Each expects the others to graze at level q^*, and, with this assurance, agrees to do the same (Brubaker). The rule extends the set of Pareto-superior allocations available to the tribe by preserving the range. Since communication and transactions needed to achieve cooperative institutional rules are not costless, agreement on the "shorthand" rule for grazing at q^* provides its own incentive to be retained as a tribal tradition.

A number of authors (Taylor; Frohlich and Oppenheimer; Frohlich et al.) have shown that an approach based on this interdependence of choice in the provision of public goods alters the conventional view of enforcement and the "size of the group." In particular, it challenges the well-known results of Olson, Buchanan (1968) and Russell Hardin, in which public goods, such as range quality, are seen as prisoners' dilemmas. These

conclusions, which depend on separability of individual cost functions, imply that expectations regarding the likely choices of others are not important, because for each, the strategy of not cooperating (i.e., exploitative overgrazing) is dominant. The only situation in which voluntary cooperation might be expected is when the group is small. Strictly speaking, even in small groups, the strategy of defection is still dominant without enforcement from outside.

If individuals' choices are interdependent, these results do not hold except under special assumptions about the shape of utility, cost, and production functions of the individuals (Taylor, Frohlich et al.). If expectations about the choices of others are relevant, then coordinated expectations are sufficient to generate voluntary contributions to a public good, independent of group size or outside enforcement (Frohlich and Oppenheimer, Marwell and Ames, Smith, and Bonacich et al.).

The relationship between the assurance problem and group size is that an individual's subjective estimation about the expected actions of others, notably its variance, generally would be expected to increase with the group size along with transactions and communications costs of finding an appropriate coordinating rule. But this is not true in every instance. The benefits derived from finding such a rule also might be expected to increase with the number of contributors, as would the opportunity cost of finding alternative rules.[4] The critical point is that institutions may succeed or fail whether the group is large or small (Taylor, p. 25).

A further point is the need for enforcement from outside the group. In principle, if institutions provide complete assurance, enforcement from outside the group is neither necessary nor sufficient for stable rules which insure nonexploitive grazing. A cooperative institutional rule providing complete assurance implies a total lack of uncertainty regarding the grazing behavior of others. Expectations are perfectly correlated, so that each individual's expectation of others' actions is concentrated around a particular level of grazing such as q^*. This is a limiting case, requiring perfect information and the absence of transactions and communications costs (Elster, pp. 20–23). These assumptions create a "perfect" solution to the assurance problem which is the institutional analogue to "perfect competition." In such situations, individuals have a sufficient incentive to contribute to range quality, without any need for outside enforcement (Frohlich et al., p. 328).

But what prevents someone from ignoring the rule at the expense of the others by "riding free"? The answer is that the benefits possible in the short term may be more than offset by costs arising within the group from breaking the institutional rule. In the absence of strictly dominant individual strategies, recognized interdependence makes the costs of reputation loss high. Pecuniary costs imposed by the group on its own noncooperative members also may occur (Akerlof). "Not to be trusted" in one circumstance may lead to a general loss of reputation, much like losing one's credit rating. These costs, plus reductions in the attainable set if such antisocial behavior "sets a trend" for others, plus the opportunity costs of innovating new rules, may well exceed the expense of stinting on the range. Because defecting or free-riding is not a strictly dominant strategy, enforcement is not a logical necessity.

This does not deny that in cases in which strategies are imperfectly coordinated (for whatever reason), enforcement from outside may help to achieve Pareto-improvements. For example, if cooperative agreements had led to a solution, such as point Y in figure 1, it might then be necessary for some enforcement from outside the group to move beyond point Y in the direction of line KMJ. This enforcement level would be significantly less than that required in a noncooperative environment. By allowing individuals full cooperative play, enforcement costs may be reduced. After exhausting cooperative rule-making potential, it may then be necessary to bind people by recourse to outside rules. But one should not jump, as in the prisoners' dilemma, to the conclusion that all such rules must be imposed and that people are not capable of binding themselves, like Ulysses, for their mutual benefit (Elster). The lesson of the assurance game is to let individuals have full freedom to innovate self-binding rules which best serve their needs before enforcing rules from out-

[4] Buchanan (1968, p. 91) was forced to conclude that "during period of extreme stress, such as was apparently evidenced by the British during World War II, behavior characteristic of small groups may have extended over almost the whole population." Smith concluded from an extensive series of recent experiments in public goods provision that "there appears to be no systematic effect of collective size or experience on the quantity of the public good provided" (p. 592). Similar results have been reported by Marwell and Ames, and Bonacich et al.

side. Rules will be better suited to the needs of the group (whatever its size) and more likely to succeed if based on this premise. These rules may come in many shapes and forms, not all of which are familiar. The institutional opportunity set of solutions to externalities is much wider than we think, and private property is only one.

Finally, enforcement from outside the group is not a sufficient condition for preservation of a public good such as range quality (Frohlich and Oppenheimer). The problem is that there is nothing to prevent the enforcing authority from abusing its position and putting control of land in the hands of a favored few with no interest in preservation or range quality. Any enforcement mechanism operating from outside designed to coerce provision of a public good must invoke a higher authority for its legitimacy. But this legitimacy is also a public good. Land grazing may be privately held and land titles enforced, but the "free-rider" problem will remain without cooperative institutional rules providing assurance within the group.

Conclusion

The assurance game suggests that cooperative institutional rules are endogenous adaptive responses to the problem of uncertainty about the expected actions of others, and that enforcement from outside is a second-order solution if these cooperative strategies are ineffective. The occurence of inferior outcomes, such as overgrazing, does not necessarily arise from the strict dominance of independent individual strategy. Rather, overgrazing results from the inability of interdependent individuals to coordinate their actions. In the pastoral grazing context, population growth, technological change, and climate changes make all such coordinated action more difficult than in more static settings.

Although I have focused on the role of institutional rules and assurance in problems of overgrazing, there are other common property externalities in which assurance problems may be even more important. With underground oil, coal, natural gas, or water, or with problems of air or above-ground water pollution, or with fisheries, it is simply infeasible to impose private property schemes since the common resource pool cannot be divided into discrete pieces. In these cases, the role of cooperative institutional mechanisms providing assurance takes on additional significance.

A key issue in this discussion is the way in which individual choice is modeled. Whether individuals are independent or interdependent is an empirical matter, but it is not without implications. Although everyday experience supports the interdependent view, the notion of "methodological individualism" has sometimes been used to support the argument that man is an independent actor, like Defoe's Robinson Crusoe. This view has deep intellectual roots, stretching back to Hobbes, and even earlier (Gonce). Yet Hayek noted that:

> Far from being opposed to voluntary association, the case of the individualists rests, on the contrary, on the contention that much of what in the opinion of many can be brought about only by conscious direction, can be better achieved by the voluntary and spontaneous collaboration of individuals. The consistent individualist ought therefore to be an enthusiast for voluntary collaboration—wherever and whenever it does not degenerate into coercion of others or lead to the assumption of exclusive powers. (p. 16)

Traditional analysis, treating social choice as the product of aggregated independent individual choices, is given a much richer interpretation through the assurance game. Yet as Mishan noted in his survey of the externalities literature, "economists respond to the real world with a time lag, initially making use of more familiar, if less relevant, bits of apparatus" (p. 1). The familiar assertion of the strict dominance of individual strategy, reflected in the prisoners' dilemma, needs to be replaced with a richer framework.

This is not an argument against private property rights. Such rights may be an entirely appropriate institutional form, especially in societies based on the law of contract. But they are not the only institutional alternative nor the best in all circumstances.

The property rights paradigm, predicated in strictly individual strategies, misdiagnoses the grazing problem. By failing to recognize the endogenous character of property institutions caused by the interdependence of choice, it supports solutions which may be poorly suited to traditions of pastoral grazing societies. By seeking institutional rules imposed and enforced from the outside, it has promoted costly, top-heavy institutional regimes which restrict the potential for cooperative action. One example of such cooperative action is common property. The strict dominance of

individual strategy leaves no place for such solutions.

In the rapidly evolving economies of the developing world, a palpable uncertainty grips efforts to solve problems of growing populations and stagnant agricultural production. Traditional common property institutions may no longer suffice. However, efforts to impose institutions even more alien to the traditional, cooperative rules of a society may be profoundly destabilizing. If private property regimes fail as a solution in these societies, it is because they do not solve the problem of assurance.

Such assurance may require a decentralized approach to institution building based on the institutional norms and conventions of traditional cultures. Cooperative solutions are most likely to succeed where the locus of decision making is a relatively small, cohesive body. This is so, not because of the "size of the group" per se, but because assurance about the actions of others is largely a matter of information conveyed via transactions and communication. Information, organized as a set of rules, reduces uncertainty. In a larger sense it is information, rather than capital, that is the scarcest factor in rapidly changing agricultural societies. The free flow of information, and cooperative institutions which promote it, are most likely to occur at a relatively decentralized level.

Of course, enforced regulation from outside may still be needed. Since enforcement is expensive *vis-à-vis* voluntary cooperation, it should be a second-order solution.

It is ironic that the Hobbesian view of man's fate as a "war of all against all," so deeply imbedded in a strictly individualistic interpretation of economic choice, should lead property rights advocates to conclude that solutions to overgrazing must be imposed from the outside. The isolation paradox should be carefully analyzed by development planners and aid donors who are bent on exporting institutional forms which are a product of our own extraordinary history.

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