A MODEL FOR THE ANALYSIS OF COMMON PROPERTY PROBLEMS

Ronald J. Oakerson
Marshall University

May 17, 1984

Prepared for the Common Property Steering Committee, Board on Science and Technology for International Development (BOSTID), National Research Council. Thanks to Mike Dow, David Feeny, Louise Fortmann, Jere Gilles, Margaret McKean, Pauline Peters, Ford Runge, and James Thomson for their comments on an earlier version.

A MODEL FOR THE ANALYSIS OF COMMON PROPERTY PROBLEMS

The subject of this paper could be stated as a riddle: how are forests, fishing grounds, pastures, parks, ground water supplies, and public highways all alike? Answer: each one is often--even typically-- a "common," a resource or facility shared by a community of producers or consumers. The list of common property resources and facilities could be greatly extended; and it is a highly diverse list. A common can have a fixed location or it can occur as a "fugitive" resource (fish and wildlife). Some commons are renewable (grasslands), others not (oil pools). Some are both open-access and indivisible and therefore must be organized as common property, if organized at all (large fishing grounds or large forests); others are treated as a common by choice (small pastures). All nevertheless face one problem alike: how to coordinate individual users in order to attain an optimal rate of production or consumption for the whole community.

A "common" is, more precisely, an economic resource or facility subject to individual use but not to individual possession. It can be distinguished from both (1) collective consumption goods (also called "pure" public goods) and (2) private goods. The first are collectively consumed, as in the case of a street lamp, in the sense that the rate of consumption is independent of the number of consumers

and the particular use made of the good. The second is subject to the exclusive use and possession of individuals. With respect to a common, the total rate of consumption varies with both the number of users and the type of use and, at the same time, use is joint in the sense that several individuals share the same resource or facility. Problems of coordination generally become apparent when there is some significant change in the pattern and/or level of use, often associated with increasing scarcity. If the community of users is unable to work through existing arrangements to respond appropriately to changes, destructive competition or conflict among users may follow. Resource depletion (or degradation of facilities) results--an eventuality characterized by Hardin (1968) as the "tragedy of the commons." In specific cases, the consequences may be soil erosion, over-grazing, diminishing fish harvests, disappearing species, non-renewing woodlots, or impassible roads.

The purpose of this paper is to present a model that can be used to analyze common property problems whatever the specific resource or facility. Such a model must be specific enough to offer guidance in the field, yet general enough to permit application to widely variable situations. The trick is to develop concepts which identify <u>key attributes</u> shared broadly by common property problems and which can be treated as <u>variables</u> that take on different values from one circumstance to another. Relationships among these variables

should be specified in a way that allows one to diagnose what is wrong and why in particular situations. On this basis, potential solutions can be advanced.

A scholar or practitioner familiar with a particular problem situation will have access to a large body of information concerning it: technical, historical, cultural, economic, and political. The model presented here invites the analyst to sort this information into four mutually exclusive subsets: (1) the technical and/or physical nature of the specific resource or facility; (2) the decision-making arrangements (organization and rules) that presently govern relationships among users (and others relevant); (3) the patterns of interaction among decision-makers; and (4) outcomes or consequences (V. Ostrom 1974, p. 55; Oakerson 1981, p. 81). Each subset is a separate component of the model. The plan of discussion, to follow, is to introduce each of the four components, examine the relationships in the model among its components, and finally to suggest ways of applying the model iteratively to understand the impact of institutional change and adaptation.

Components of the Model

(1) Technical/Physical Attributes

All common property problems are rooted in some set of constraints either given in nature or inherent in available technology. The technical/physical constraints can be analyzed usefully in terms of three concepts drawn from

economics literature: (a) jointness of consumption or supply, (b) exclusion, and (c) indivisibility. Each concept can be expressed as a variable, as indicated below.

(a) Jointness. This concept was originally used to define a "pure public good" (Samuelson 1954). It means that no single beneficiary of some good subtracts from the ability of others to derive benefits. Jointness ordinarily refers to simultaneous use, but can be modified to include serial use. The opposite of jointness defines the case in which a single individual fully consumes (and destroys) a good. As a variable, jointness refers to degrees of subtractability (V. Ostrom and E. Ostrom 1978) in the use of common property. All common property falls, by definition, into the broad range of partial subtractability. Each individual user is potentially capable of subtracting from the welfare of other users; but within limits all users can derive benefits jointly. The analyst should specify, as precisely as possible, the limiting conditions within which jointness can be maintained. The relevant conditions include, for example, grazing limits in a common pasture, trapping limits in a lobstery, and weight limits on a highway. These limits, established in nature or technology, provide essential information for devising rules to maximize the joint beneficial use of the commons. "Jointness can then characterize common property as it does a pure public good with this difference: one person's

lawful use does not subtract from the lawful use of others (Oakerson 1978). Given an appropriate set of rules, based on limiting conditions, the same economies of sharing that Samuelson demonstrated with respect to a pure public good may also be available to the users of common property.

It is important, however, that limiting conditions be specified without respect to any rules in place. The relevant limits at this point in the analysis are those derived from nature or technology, not those derived from rules.

(b) Exclusion. The "exclusion principle," also used by economists to differentiate private from public goods (Musgrave 1959), refers ordinarily to the ability of sellers to exclude potential buyers from goods and services unless they pay the stipulated price. The concept can be broadened somewhat to include the question of access to any good, including a common. The opposite of exclusion is complete openness--unlimited access. Common property is not necessarily characterized by open-access (Runge 1981). Access may be fully controlled on an individual basis or partially controlled and applied only to those outside the immediate community. As a variable, the degree of exclusion attainable depends upon both the physical nature of a resource (or design of a facility) and available technology. Historically, open range was difficult to fence; but the development of barbed wire greatly relaxed this limitation.

Again, at this point in the analysis, one is interested not in an exclusion or non-exclusion policy, but rather in "excludability," the limiting conditions that apply to the possibility of exclusion--conditions established by nature and/or technology. Although common property problems do not depend upon the existence of difficulty with exclusion, these problems are clearly exacerbated by non-exclusion.

(c) Indivisibility. Is the common divisible? Could the property held in common be feasibly divided among private property holders? What would be the costs of doing so? If the common is not divisible, what are the boundary conditions that apply to its regulation? On what scale would regulation have to occur in order to be effective?

Underlying boundary conditions derive from nature or technology and should not be confused with legal boundaries, i.e., boundaries imposed by rule. Consider the example of a ground water basin. The common pool of water has a definite set of physical boundaries. The legal boundaries of a jurisdictional unit formed to deal with the ground water problem may or may not correspond to the physical boundaries of the resource. Other common property resources may have less determinate physical boundaries; but it still may be possible to assign boundaries based upon physical or technical attributes of the common. The Western range in the United States, for example, might superficially be viewed as a single common; but variations in weather and

soil conditions prompt the "division" of the range into much smaller units for management purposes.

The analysis must contain some sense of underlying boundary conditions, even if somewhat ambiguous. If the choice of boundaries for the purpose of analysis is too small, then relevant aspects of the problem will be left outside; if too large, then multiple problems may be confounded. If the precise boundary is somewhat arbitrary, the question is whether it lies within an acceptable range.

Together, the three concepts--jointness, exclusion, and indivisiblity--provide a way of summarizing the physical and technical nature of a common. In general, common property is characterized by partial jointness and the probability of some difficulty with exclusion within a limited set of boundaries. The precise conditions of course vary from one situation to another.

(2) Decision Making Arrangements

The second component of the model consists of rules--those rules which structure the making of individual and collective choices with respect to the particular "common" defined by the first component. These arrangements may also be thought of as "organizational" or "institutional," as the reader prefers. The designation used here is intended to convey a very broad set of arrangements, not confined to any single "organization" or "institution." Parts of

several institutions are generally implicated in the management or mis-management of a common.

In general, decision-making arrangements have to do with those authority relations that determine who decide(s) what in relation to whom. In the discussion below, decision-making arrangements are sorted into three subsets: first, rules that establish conditions of collective choice within the group most immediately involved with the common; second, "operational" rules that regulate use; and third, external arrangements, those decision structures outside the immediate group which impinge on how the common is used.

(a) Conditions of Collective Choice. Rules which establish the ability of some group to act collectively, i.e., to make decisions common to the group, are especially relevant to the management of common property. Obstacles to collective choice are at the same time opportunities for individualistic choice--decisions that individuals can make on their own without the consent of others. When a group is unable to act collectively, individual members are left free to act separately. Four different relationships can be considered as affecting the conditions of collective choice: (1) the capacity of individuals to act solely on the basis of personal discretion in matters of concern to others, perhaps preempting action by others or initiating an action which creates costs of opposition for others; (2) the availability of potential sources of remedy to individuals

adversely affected by others; (3) the capacity of an affected population to relax the rule of willing consent and make a collective decision binding on all parties; and (4) the presence of potential veto positions in any process of collective decision making--opportunities for one or more decision makers to say "no."

Typically, common property arrangements give use rights to individuals. Hardin's "tragedy of the commons" occurs in a context of unrestricted individual rights to use the common. Individuals may also, however, be vested with rights which protect them from injury caused by others. Remedies may be available through "third-party" arrangements, such as courts. Beyond the domain of individual decision making, a community of users may be able to act collectively to establish limits on individual use. Some decision-makers may enjoy a veto capability in this process, perhaps by virtue of official position.

(b) Operational Rules. The content of collective choice are those "operational rules" which regulate use of the common. Three types can be distinguished, each related to one of the three technical/physical features found in the first component of the model. (1) Partitioning rules are those which serve to limit user behavior in the interest of jointness. Behavior is partitioned into subtractive and non-subtractive sets. If more than one type of use is made of a common, partitioning rules should take into account the relationships among those various uses. Some types of

use may be compatible; others, sharply conflicting. At times a common is physically partitioned for individual use without dividing it into separate parcels of property, partially segregating different users or incompatible uses (e.g., a parking lot). (2) Entry and exit rules (E. Ostrom n.d.) are concerned with exclusion and seek to regulate access to a common. This set of rules includes qualifications for participation in a community of users (entry) and whether membership in an organization of users is compulsory (exit). (3) Any organizational arrangement for governing a common must stipulate a set of jurisdictional boundaries. These boundary rules, however, may be more or less congruent with the underlying boundary conditions determined by the technical/physical nature of the common.

(c) External Arrangements. Decision-making arrangements external to the community of users will also be relevant in most cases. The relevance, however, varies widely. Some external arrangements may be mainly constitutional in connection to the common, establishing the capability of the community of users to act collectively. (E.g., California enabling legislation allowing the formation of ground water basin management districts.) At the other extreme, a community of users may be entirely dependent on external decision makers for the legislation and enforcement of operational rules. In this case, external arrangements are frequently bureaucratic, characterized by some combination

of central rule-making and field officer discretion. Third-party arrangements may also be available externally to consider disputes between users. Courts of law fall into this category, but so do other arrangements including a bureaucratic hearing officer and a traditional local chief in areas with a tribal history. Finally, market arrangements external to the common may be relevant in establishing economic parameters within which management of the common can be undertaken. The unavailability of a market in land, for example, would have a great impact on the users of common property in land for grazing or agriculture.

(3) Patterns of Interaction

Given the technical/physical features of a common and the decision-making arrangements available to govern it, the next question concerns behavior: what patterns of interaction characterize the behavior of users and other decision makers in relation to the common? It is assumed that the important elements of individual behavior are interdependent (Runge 1981). What matters is how individuals choose to behave in relation to one another. Patterns of interaction derive from mutual choice of strategies, i.e., each individual's choice of strategy (how to relate to others) depends upon individual expectations of others' behavior.

Subjective choices are generally viewed in terms of a comparison of costs and benefits. These economic concepts, however, are very abstract. Behaviorally, a cost can be treated as any perceived obstacle to the choice of some alternative (Buchanan 1969). Conversely, a benefit is any perceived inducement to choose one alternative over another. Individual choices thus derive from a mental image of obstacles and inducements in one's environment. Patterns of interaction cannot be understood except in terms of these elements of choice.

The basic pattern of interaction upon which successful joint use of a common depends is reciprocity. In a pattern of reciprocity, individuals contribute (through mutual action or mutual forbearance) to the welfare of one another, but without the interposition of an immediate quid pro quo. Instead, reciprocity depends upon mutual expectations of positive performance (Oakerson 1983). Note that a pattern of reciprocity differs from exchange (Boulding 1972). Exchange is a fully contingent relationship with each transaction; but reciprocity is contingent only through time, as individuals learn what to expect from one another. What is ordinarily called "collective action" can be understood as the reciprocal interaction of individuals.

The abandonment of reciprocity is reflected in the development of freerider strategies. Freeriding is the opposite of reciprocity: one fails to contribute with the expectation that others will contribute. The prospect

of "riding free" on the contributions of others can be a considerable inducement; but an even more powerful obstacle to the choice of cooperative strategies may be the expectation that others will choose freerider strategies. The avoidance of a structure of inducements and obstacles to choice that lead persons to abandon a pattern of reciprocity is the primary task of decision-making arrangements.

Although cooperation and non-cooperation among users are the primary strategies of interest, there are also important secondary strategies (which in turn affect the choice of primary strategies). Within the community of users the degree to which individuals attempt to monitor one another's behavior and to hold one another accountable to common standards of behavior is a relevant variable. If decision making arrangements include provision for the enforcement of rules and application of sanctions, then the choice of enforcement strategies by officials may be critical. Other decision makers from bureaucrats to judges may also be relevant. In general, any assignment of a decision-making capability simply sets parameters within which individuals choose strategies.

If reciprocity among users is fully abandoned, what follows is some pattern of mutually destructive competition and/or conflict. Users may seek to drive one another out in order to preclude mutually subtractive use. Or, users may engage in a competitive race to exploit the common without regard to an optimal rate of use. Relevant patterns

of interaction may include concealment, deceit, intimidation, threats, and violence.

(4) Outcomes

Patterns of interaction produce outcomes. In order to supply information for this fourth component of the model, the analyst is required to (1) stipulate the use of evaluative criteria and (2) search for consequences that affect relevant persons in accordance with these criteria. The study of consequences is necessarily value-laden. One cannot even distinguish relevant consequences without first having in mind evaluative criteria. The most commonly used criteria are efficiency and equity. The analyst, however, must somehow convert these abstractions into operational measures of social value that can be used to appraise specific outcomes.

(a) Efficiency. Considerations of efficiency in the use of a common generally relate to the overall rate of use. Technical/physical attributes dictate some optimal rate. Excessive use leads to resource depletion or facility degradation. Inefficiency is also present if the resource or facility is under-utilized. Closure of a common can create inefficiency as much as openness. To exclude potential users when it would be feasible to develop a rule structure to sustain joint use with greater openness is inefficient. A plan of regulation should be evaluated in terms of the value of uses foregone in addition to the value of uses retained.

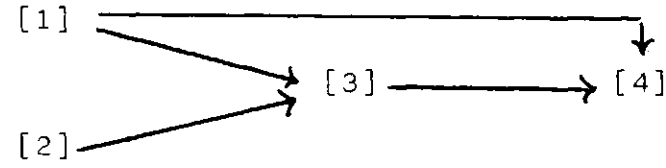
To conclude there is inefficiency in the use of common property, one should be able to use the test of Pareto optimality: if at least one person can be made better off, and no one worse off, by a modification in the use of the common, present outcomes are inefficient. Conversely, the proposed change is efficient. The emphasis here is upon identifying Pareto efficient changes, i.e., improvements in efficiency, rather than upon the identification of a Pareto optimum condition from which no further improvement is possible. Information requirements are reduced by seeking amelioration rather than optimization *per se*.

(b) Equity. Considerations of equity are, somewhat surprisingly, closely related to efficiency concerns. The basic question of equity is this: do individuals get a reasonable and fair return on their contribution to a collective undertaking to regulate a common? Inefficiency and inequity are apt to be mixed together in common property problems. Indeed the presence of inequities may lead to the collapse of collective efforts, resulting in inefficiency. Equity problems are exacerbated by asymmetries among users, creating opportunities for some to benefit at others' expense. This, in turn, can lead to costly conflict where all parties lose. Such situations still may admit of Pareto efficient change. In any event, Pareto efficient changes satisfy a minimal standard of fairness: do not harm.

Other questions which arise from considerations of equity include the possibility of arbitrary exclusion from the common or selective enforcement of rules. Abuse of authority and/or corruption may contribute to a pattern of inequity.

Relationships in the Model

The first two components of the model can be thought of broadly as independent or exogenous variables in the short term. The third and fourth components are endogenous, the third intervening. The basic relationships are depicted in the figure below:



[1] Technical/Physical Attributes
[2] Decision-Making Arrangements
[3] Patterns of Interaction
[4] Outcomes or Consequences

Individuals choose strategies in [3]. These choices reflect the combined set of constraints and opportunities found in [1] and [2]. The mutual choice of strategies comprises some pattern of social interaction. From interactions, consequences follow, subject to evaluation.

The technical/physical characteristics of a common [1] affect outcomes [4] both through the mutual choice of strategies by relevant decision makers and independently of human choice. The constraints found in [1] are "hard" constraints. If ignored in the process of choice, constraints in [1] still affect outcomes in [4]. Decision-making arrangements in [2], on the other hand, have no effect on outcomes [4] independent of human choice and interaction [3]. Institutional constraints are "soft" constraints, made operative only through human knowledge, choice, and action. Rules found in [2] exist entirely in the realm of language, whether written or unwritten. Decision-making arrangements therefore need to be comprehended as commonly understood and applied by the relevant community of decision makers.

A good example of the way in which the physical nature of a resource affects individual strategies and social interaction is found in the case of Maine inshore lobster fisheries (Wilson 1977). Unlike schooling fish, lobsters are sedentary creatures which inhabit small inshore areas. This permits daily access to the fishing area and promotes ease of monitoring within the community of fishermen. Lobster traps are marked by each fisherman in distinctive colors. Small communities of fishermen are able in these circumstances to define and monitor exclusive fishing areas. Fishermen from outside the community suffer gear losses; but within the community mutual forbearance allows fishing gear to remain. This pattern of interaction allows the

community to control access to the common. Decision-making arrangements within the community are entirely voluntary. Those outside the community have no effective recourse to gain access. The relatively small set of boundaries which define each inshore area and the excludability of individual fishermen derive from the physical nature of the resource. Jointness is feasible, so long as fishermen are willing to act with mutual forbearance toward one another.

Coal-haul roads in E. Kentucky (Oakerson 1981) afford an example of how the distribution of decision-making capabilities [2] can affect the mutual choice of strategies [3]. Rural highway development, provision, and maintenance is largely a state government responsibility in Kentucky; but the application of criminal sanctions against violators of state prescribed legal weight limits is in the hands of locally elected judges. Through the office of county judge, local communities are able to maintain a freerider strategy in behalf of the coal industry. State efforts to respond with a strategy of withholding maintenance form coal field highways did not prove to be politically feasible because ordinary users were affected jointly with coal haulers. State highway officials nevertheless can and do reduce the maintenance effort on selected coal-haul routes. The outcome is a highway system subject to severe over-use and under-maintenance.

Each component of the model separately summarizes some portion of a problem. When an outcome [4] is evaluated negatively, one should then work backward through the model to determine relationships. How do adverse consequences [4] flow from the prevailing patterns of interaction [3]? What strategies are inherent in those patterns? What structure of obstacles and inducements contribute to those choices? How does the structure of obstacles and inducements derive from elements of decision-making arrangements [2] and the technical/physical attributes [1] of the common?

Consequences disclose the effect [4] of some difficulty. The difficulty is manifest behaviorally in patterns of interaction [3]. The source of the difficulty, however, lies in some lack of symmetry or congruence between [1] and [2]--a mismatch between the technical/physical nature of a common and the decision making arrangements used to govern its use. The lack of a good "fit" between these two components of the model sets up a perverse structure of obstacles and inducements leading individuals into counterproductive patterns of interaction [3].

Incongruence between [1] and [2] is first apparent in the relationship between operational rules and corresponding technical/physical attributes of a common. Partitioning rules should closely match underlying conditions of jointness; entry and exit rules must be related to conditions of exclusion (excludability); and boundary rules ought to

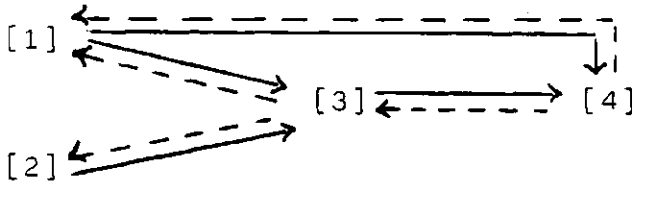
reflect those boundary conditions inherent in the nature of a common. If efforts to adapt operational rules to technical/physical attributes have failed, and there is a general understanding in the relevant community of the relationships between attributes of the common and specific operational rules, one can conclude there is some problem with the organizational conditions of collective choice. Further, if efforts to adjust the conditions of collective choice in the community have failed, the difficulty may lie with external arrangements. At some point an analyst may choose to arbitrarily close off the analysis, accepting some larger set of decision making arrangements as given, and inquire into means of improvement within that which is simply accepted as the established order.

Having made a diagnosis of problematic conditions by working backward through the model, one can turn to questions of <u>design</u>: how to rearrange decision making by adjusting rules to better fit the nature of a common. Design requires that one work <u>prospectively</u> <u>forward</u> through the model. What do key features of the technical/physical component [1] require of operational rules and conditions of collective choice? What adjustments might be made in external decision making arrangements? How would these changes in [2] affect the structure of obstacles and inducements to choice which face relevant decision makers? What choice of strategies, and resultant patterns of interaction [3], would the analyst predict? How would predicted patterns of interaction affect

users of the common and others [4]? Rule changes produce different outcomes only to the extent that individual choices of strategy are modified.

A Dynamic Model

Often there are opportunities to study specific problem situations over a considerable period of time and thereby to observe various efforts to resolve a difficulty. Each change in decision making arrangements can be associated with changes in patterns of interaction and outcomes. Over time changes can also occur in the technical/physical nature of a common. In the short-run analysis, undertaken for a diagnostic purpose, both the nature of the common [1] and decision making arrangements [2] are assumed to be unchanging. A long-run analysis, however, must allow for change in both sets of variables. The model is modified by adding a set of long-term relationships, shown by the broken lines in the figure below:



---

[1] Technical/Physical Attributes
[2] Decision Making Arrangements
[3] Patterns of Interaction
[4] Outcomes or Consequences

One way to introduce a longer time horizon into the analysis is to apply the simpler (solid-line) model iteratively. As changes occur in [1] and [2], changes in [3] and [4] are observed. This approach treats institutional change as exogenous to the model; the aim is simply to understand how changes in decision making arrangements affect patterns of interaction and outcomes. Viewing change as exogenous, however, contributes nothing to an understanding of how change comes about.

The more complex model (with broken-lines) introduces a set of relationships relevant to understanding institutional change. Outcomes can affect patterns of interaction insofar as a process of learning occurs, causing individuals to modify their strategies. Instead of continuing to produce outcomes on the basis of decision making arrangements as given, individuals may seek to modify those arrangements in order to produce better outcomes. Similarly, individuals may invest in technological innovation which has the effect of changing the technical/physical attributes of the common. The latter may also be subject to change over time as an indirect result of strategies pursued in securing outcomes; this is easily seen if prevailing patterns of interaction result eventually in the destruction of a resource.

The effort to understand institutional change raises new issues. What opportunities are present for learning the consequences of one's action? How do existing decision making arrangements constrain the ability of individuals

to make relevant incremental adjustments in those same decision making arrangements? This question touches upon the ability of a community to make effective constitutional choices in order to modify perverse patterns of interaction. Moreover, what incentives are present to to invest in technological change?

Conclusion

The purpose of the model presented in this paper is to aid in the collection and assimilation of case-by-case analysis. The ability to observe regularities across many different cases depends upon the use of a common framework for analysis. Some method is needed to array information into meaningful sets in order to examine relevant relationships in a particular case. Use of a common method by a community of scholars enhances the comparability of separate case studies. As scholars use and apply a model, and exchange ideas, the model too becomes the subject of change--elaboration or modification--in view of experience. The model developed here is therefore offered simply as a point of departure in a joint effort of scholarship and research.

Bibliography

Boulding, Kenneth E. (1972). The Household as Achilles' Heel. Journal of Consumer Affairs 6: 111-119.

Buchanan, James M. (1969). Cost and Choice. Chicago: Markham.

Hardin, Garrett. (1968). The Tragedy of the Commons. Science 162 (December): 1243-48.

Musgrave, Richard A. (1959). The Theory of Public Finance: A Study in Public Economy. New York: McGraw-Hill.

Oakerson, Ronald J. (1981). Erosion of Public Goods: The Case of Coal-Haul Roads in Eastern Kentucky. Research in Public Policy Analysis and Management, vol. 2, ed. by John P. Crecine. Greenwich, Conn.: JAI Press, 73-102.

_____ (1983). Reciprocity: The Political Nexus. Under review.

Olson, Mancur. (1965). The Logic of Collective Action. Cambridge, Mass.: Harvard University Press.

Ostrom, Elinor. (n.d.). Strategy and the Structure of Decision Making Mechanisms. Unpublished paper.

Ostrom, Vincent. (1974). The Intellectual Crisis in American Public Administration. Rev. Ed. University, Alabama: University of Alabama Press.

_____ and Elinor Ostrom. (1978). Public Goods and Public Choices. In Alternatives for Delivering Public Services. E.S. Savas, ed. Boulder, Colo.: Westview, 7-49.

Runge, C. Ford. (1981). Common Property Externalities: Isolation, Assurance, and Resource Depletion in a Traditional Grazing Context. American Journal of Agricultural Economics 63, no. 4 (November): 595-606.

Samuelson, Paul A. (1954). The Pure Theory of Public Expenditure. Review of Economics and Statistics 36 (November): 387-389.

Wilson, James A. (1977). A Test of the Tragedy of the Commons. In Managing the Commons, Garrett Hardin and John Baden, eds., San Francisco: W.H. Freeman, 96-111.