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THE INNOVATION OF RULES AND THE STRUCTURE
OF INCENTIVES IN OPEN ACCESS RESOURCES

by

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* An invited paper presented at a session of the Allied Social Sciences Association Meetings, jointly sponsored by the American Agricultural Economics Association (AAEA), Dallas, Texas, Dec. 28-30, 1984. My thanks to Ted Graham-Tomasi for helpful comments and suggestions.

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The Innovation of Rules and the Structure of Incentives in Open Access Resources*

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Open access to resources implies the absence of restrictions affecting extraction or use. Such restrictions may range from common property regimes to privately held plots or quantities and include many possible combinations and intermediate arrangements. Whatever the ultimate arrangement, moving from unrestricted open access to a stable structure of well-defined use rights requires agreement by a minimum coalition that is prepared to observe restrictive rules. These rules can affect the rate of resource use, the distribution of returns, or other management practices. They may arise from within a resource using group or be coercively imposed from outside.[1/]

In many cases, an outside authority does not exist, and some form of self-policing is necessary. In international fisheries, for example, open access has led to overfishing and rules restricting access must be innovated precisely because a coercive overriding authority is infeasible. Even where the capacity for coercion exists, an underlying consensus concerning the efficacy of the restrictions is important. The innovation of rules in these cases shares many features with oligopoly pricing or constitutional government, in which agents must exercise some form of "self-command."

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This paper considers the innovation of such rules as a strategically interdependent n-person game. From the point of view of a particular agent in a resource-consuming population, innovating these restrictions involves three decisions: (a) deciding on a rule that will restrict future actions; (b) deciding whether to enter into the initial coalition observing this rule; (c) deciding whether to continue to be bound by the rule and remain part of the coalition in succeeding periods. I shall be primarily concerned with decision (b). Although this decision can be a function of enforcement by a coercive authority outside the group, to assume a priori that such an enforcement authority exists obscures the important inverse relationship between the level of voluntary cooperation and the need for coercion. It also begs the question of whether rules innovated where outside coercion is impossible or infeasible can be partially or even fully self-enforcing.

Rather, I assume that a particular restrictive rule -- such as limited entry to a fishery -- has been proposed together with a set of penalities and other coercive arrangements, ex ante. Each agent's problem is whether voluntarily to cooperate (C) with or to defect (D) from the group following this rule [2/]. The need for additional coercion (or an alternative rule) will be revealed by the level of cooperation and defection, ex post. The higher the level of voluntary cooperation, the lower the need for additional coercion and the lower the social costs of enforcing the resource regime.

Repeating the problem over time makes this a dynamic issue, in which the parameters affecting the choice are likely to change. [3/] Here I am concerned with only one in a sequence of decisions to adhere to a given rule. Although the entire sequence results in a particular pattern of resource use over time, in which expectations of future use rates are clearly important, systematic analysis of alternative restrictions requires knowledge of when cooperation dominates defection for a sufficiently large group (given expectations) at each point in time. This paper employs a simple framework which can be used to illustrate this issue, lending insight into how much coercion may be necessary in alternative resource regimes.

The decision to cooperate with others in observing a rule, or to defect, is a binary choice with externalities. It is binary because the choice is between cooperation and defection, and it has external effects if it alters the consumption of the resource by other agents. (In trivial cases the resource is so abundant that no negative external consumption effect occurs.) For simplicity I assume that agents derive payoffs from cooperation or defection based only on the number of other agents who also choose either C or D. Among $n + 1$ individuals, there are 2^n possible configurations of choice, depending on how many choose C or D. Again for simplicity, I assume no differences in intensity of resource use across agents, although this assumption is not necessary. The decisions of all agents result in a particular physical product of the resource (e.g., "total catch") from which each agent derives positive utility. Using graphical techniques proposed by Schelling (1973), I consider this binary choice first in terms of a uniform multiperson prisoner's dilemma (MPD), then extend the analysis to include multiple equilibria and the absence of dominant strategies, which I have argued elsewhere may better approximate actual resource decisions (Runge, 1981, 1984a). This approach provides a theoretical basis for empirical testing of complex incentive structures in various resource regimes. I conclude with several empirical implications and hypotheses generated by the analysis.

The Multiperson Prisoners' Dilemma (MPD)

The MPD is characterized by n agents each with the same binary choice and the same payoffs. Each agent has a dominant choice, whatever others do, which is dominant for all n agents. Each also has a dominant preference for the others' choice, so that preferences for others' actions are unaffected by the choice he makes himself. These preferences go in opposite directions: each prefers that all others cooperate while he himself defects so defection strictly dominates cooperation, and the defection strategy leads to a unique, Pareto-inferior Nash equilibrium. However, there is some number k > 1 such that if k individuals cooperate and the rest defect, those who cooperate are still better off than if they had all defected. The uniformity of agents makes k independent of the particular agents who cooperate or defect, eliminating the possibility (at this level of analysis) of "leadership." The number k represents the minimum coalition that can make positive gains by cooperating with the rule even though others do not. Where k = n, the only rule which is viable is one in which there are no free riders (a coalition of the whole). Where k < n, some free riders (n - k) can be tolerated, and the k cooperators can still profit (even if the n - k free riders profit more than the cooperators do).

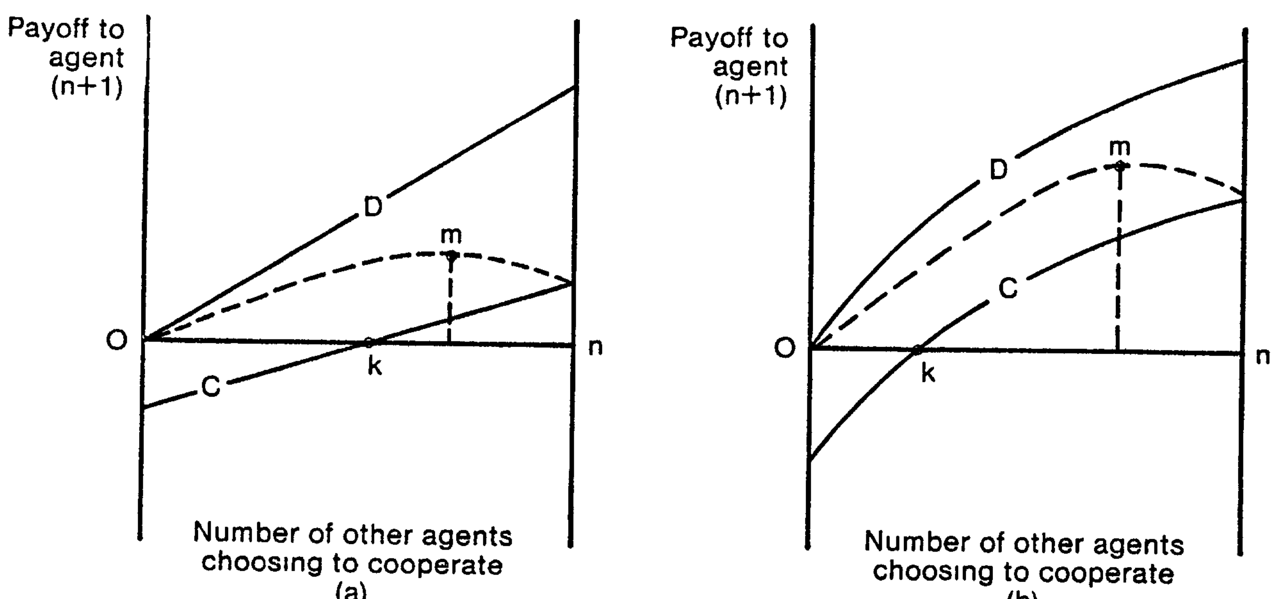

Figure 1

Consider Figure 1(a), in which two linear payoff curves are drawn for a population of n + 1, reflecting the benefits of cooperation and defection in an interdependent decision framework to the (n+1)th agent, where n equals the number of "other" resource users in an MPD game. The upper curve corresponds to the dominant choice of defection D. Its left end is labeled 0, the open access equilibrium, in which no agents cooperate due to the absence of restrictive rules. The D curve rises monotonically to the right. Below it is the dominated cooperation strategy C, which also begins at the open access equilibrium 0, rises monotonically and crosses the axis at point k where positive gains to cooperation begin. The number choosing to cooperate with the proposed rule in Figure 1 is denoted by the distance along the horizontal axis. The vertical axis shows the payoff to cooperation by individual (n+1) when a certain number of others choose to cooperate and the remainder defect. At $k = n/2$ in Figure 1(a), for example, positive gains are made by cooperators whenever at least half of the other agents cooperate. Because D lies everywhere above C, it is a strictly dominant strategy. Monotonicity of both curves in the same direction implies that cooperation leads to uniformly positive externalities, and defection to uniformly negative externalities. The C curve is higher on the right than the D curve on the left, reflecting the Pareto-inefficiency of the dominant defection strategy. The dotted lines show total (or average) values corresponding to the number of agents choosing the two strategies, and point m represents the maximum collective payoff (Pareto's "maximum d'utilité collective") for the group. The slope of these schedules may be interpreted as the marginal payoff to defection and cooperation inside the structure of the game.

In Figure 1(a), D rises more rapidly than C, indicating that the more agents who join the cooperative coalition, the greater is the advantage of defecting. The collective maximum at point m is achieved with some agents choosing D and some C. Moreover, point m falls to the right of k on the horizontal axis. This implies that collective gains are greatest when there are more than k cooperators, and that these gains reach a maximum at point m, and diminish thereafter. In 1(b), the slopes of the C and D functions reflect an alternative incentive structure, in which the proposed rule achieves most of its benefits after about half of the population participates, and benefits diminish thereafter. The collective maximum occurs at about two-thirds participation, with room for gains to cooperators from point k to point m along the horizontal axis. Cases 1(a) and 1(b) represent two of an infinite number of possible variations on the MPD example, a distinguishing feature of which is that defection strictly dominates, making some form of coercion necessary to solve the problem of collective action (Sen, 1967). Restrictive rules and the level of coercion accompanying them alter the payoffs, and thus the level and shape, of the C and D schedules.

Alternative incentive structures can be represented in the same framework, in which the C and D curves may (a) cross or not; (b) rise in the same or opposite direction; (c) be vertically arranged so that D is above C or below it; (d) have the same or different slopes and curvatures. All of these variations represent different incentive structures leading to particular decisions to join in a coalition following a rule of resource use.

Multiple Equilibria

Consider the more complex (and arguably more realistic) case in which neither C nor D represents a strictly dominant strategy. This situation is not captured by the MPD, in which defection dominates throughout. In constrast, Figure 2(a) shows a situation in which a linear D curve dominates a linear C curve until point y, after which C dominates D. The absence of a strictly dominant strategy raises

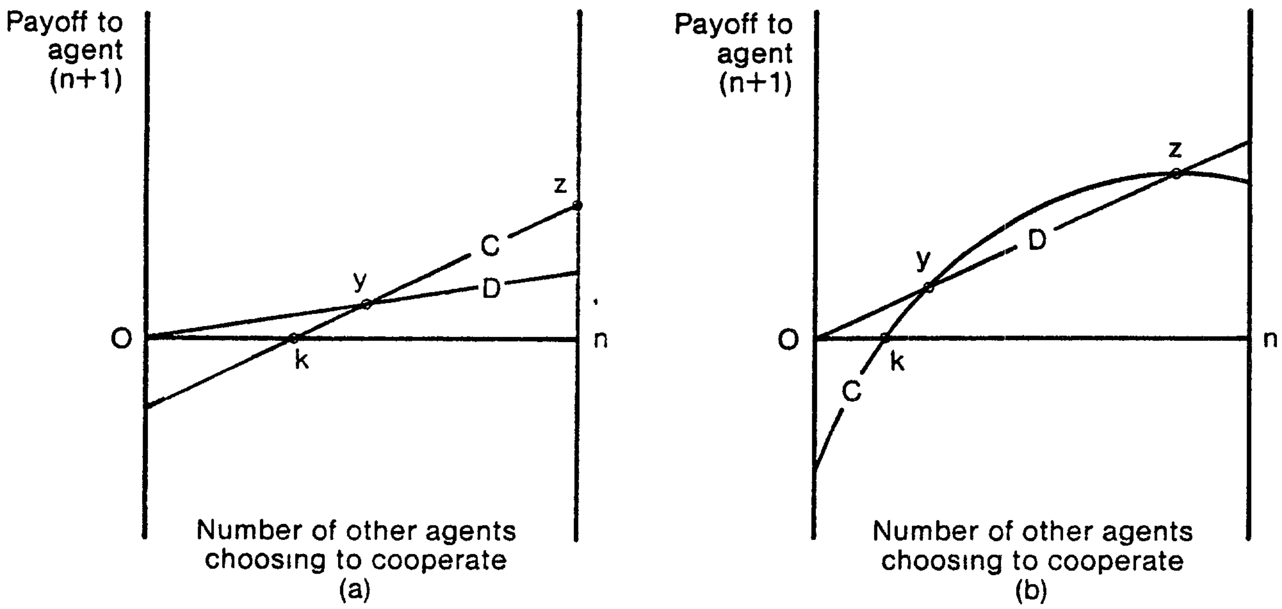

Figure 2

the problem of coordinating the expectations of a "critical mass" of agents around a particular rule change. In Figure 2(a), there are two equilibria: one at 0 and one at z. The problem of coordination is to achieve the Pareto-superior equilibrium at z. In cases such as these, the coalition must move beyond k to the switch point y; otherwise, defection will dominate and lead to the Pareto-inferior equilibrium at 0. Unlike the MPD, in which defection dominates at all levels of participation, implying the need for outside enforcement, this situation rests on the contingent strategies of agents. If enough people choose C in the first place, then z will emerge as the equilibrium. However, if a Pareto-inferior open access equilibrium has become established, no agent will decide to join a coalition subscribing to a restrictive rule unless he expects a sufficient number of others to do so. Achieving a Pareto-superior solution will require an organized change in behavior over and above the establishment of a viable coalition at point k.[4/]

In the MPD case, coercion is necessary to achieve cooperation with a given rule. Once this coercion is undertaken, the game changes, becoming more like those pictured in Figure 2 as coercion lowers the payoff to defection in relation to cooperation. If the situation resembles Figure 2 ex ante, however, less coercion may be necessary to organize a change in behavior. This particular structure of incentives ex ante may make coordination based on education and information dissemination sufficient to achieve a cooperative equilibirum. As Hayek (1948) argued, in many cases spontaneous recognition of the need for organized collective action occurs on the part of the affected group simply because the payoff to such organization is substantial.

In Figure 2(b), we introduce curvature in the C schedule, which now intersects the D schedule twice. The value to a given agent of defecting is high at low levels of cooperation by others so that defection dominates cooperation until point y. At point y, people expect a sufficient number of others to cooperate to be induced to cooperate themselves, and this allows cooperation to dominate up to z. At z, so many agents are cooperating that it again becomes advantageous to defect. There are again two equilibria, a Pareto-superior one at z and an inferior one at 0.

This structure of incentives, I conjecture, is applicable to a variety of restricted open access situations. To take the case of the fishery, suppose that a limited entry rule is proposed. Everybody suffers from the open access situation 0, but it is not worth cooperating with a restrictive rule unless a sufficient number (y) of other agents are expected to do so too. Over some range (from k upward) one's participation in the coalition observing the rule leads to enough improvement in the total catch to make observing it beneficial, although free riders continue to benefit even more. At point y, observing the catch limit is clearly superior to free riding since a "critical mass" of others also observe it. Eventually, however, so many agents observe the limit that there appears to be no need for a given agent to do so, and free riding is again a dominant strategy. Clearly, if this situation characterizes the payoffs ex ante, less coercion will be necessary ex post compared with the MPD case.

Empirical Implications

Whether the structure of incentives in restricted open access situations is as conjectured above is an empirical question. Field research is currently underway in which direct survey methods elicit the perceived threshold of beneficial cooperation k and the level at which different agents believe it acceptable to defect (see Bromley and Chapagain, 1984). Other recent research conducted in an experimental setting also examines the need for a "critical mass" of cooperators (Oliver, Marwell and Teixeira, forthcoming, 1985). The issue of dominance has also been tested, based on questions about the expected impact on individual choice of others' strategies to cooperate or defect (Roth and Schoumaker, 1983). Explicit applications of Schelling's framework have been conducted successfully using experimental techniques (Schwartz-Shea and Simmons, 1983), although no direct application to natural resources policy has been developed.

As an agenda for research on rules restricting open access resources, I would propose further testing of three key hypotheses emerging from the analysis above.

H1: Situations exist such that defection from given restrictive rules of use is not a strictly dominant strategy for all agents.

H2: The range over which voluntary cooperation dominates defection is a function of expected payoffs (rents) gained from a given resource when a "critical mass" adheres to a rule restricting use.

H3: Particular restrictions may have a comparative advantage in promoting voluntary cooperation, reducing the need for coercion in the form of outside enforcement.

A growing body of evidence already questions the strict dominance of free rider behavior in a variety of experimental and actual situations (see Isaac, Walker and Thomas, 1984), suggesting that the MPD may be an inappropriate model of incentives for restrictions on open access. Little is known, however, about when and how voluntary cooperation with restrictive rules can be promoted or organized. Perhaps the most important need is to isolate empirically the variables, in additional to outright coercion, that would shift the C schedule up or D schedule down for particular resources, lowering the threshold at which voluntary cooperation dominates defection. Isolating resource regimes which are characterized by high levels of voluntary cooperation would provide important insights into policies for resource conservation and use, allowing more costly enforcement mechanisms to be applied only after the innovation of voluntary restrictions had been given full play.

Footnotes

1/ For two excellent recent discussion of these issues in the context of fisheries, see Young (1983), and Johnson and Libecap (1982).

2/ It should be noted that any structure of restrictive rules, including private property, is subject to cooperation or defection.

3/ These changes make the situation more complex than a simple "iterated" game (e.g., Hardin, 1982), the limitations of which were noted by Shubik (1970) in his early exposition. Parameter changes in the game over time may lead to what Easly and Spulber (1981) and others have referred to as "rolling plans," in which agents must reassess the current state of the resource regime in each period. Among other things, cooperation in a given period may be a function of rule changes as well as changes in the environment (Runge, 1984b).

4/ Schelling (1973, p. 407), echoing Keynes description of the liquidity trap, notes that "People can get trapped at an inefficient equilibrium, everyone waiting for the others to switch, nobody willing to be the first unless he has confidence that enough others will switch to make it worthwhile."

References

Bromley, D.W. and D.P. Chapagain, "The Village Against the Center: Resource Depletion in South Asia," American Journal of Agricultural Economics 66:5 (December, 1984).

Easley, David and Daniel F. Spulber, "Stochastic Equilibrium and Optimality with Rolling Plans," International Economic Review 22:1 (February, 1981):79-103.

Hardin, Russell, Collective Action, Baltimore: Johns Hopkins University Press, 1982.

Hayek, F.A., Individualism and Economic Order, Chicago: University of Chicago Press, 1948.

Isaac, R.M., J.M. Walker and S.H. Thomas, "Divergent Evidence on Free Riding: An Experimental Examination of Possible Explanations," Public Choice 43 (1984):113-49.

Johnson, R.N. and G.D. Libecap, "Contracting Problems and Regulation: The Case of the Fishery," American Economic Review 72:5 (December, 1982): 1005-1022.

Oliver, Pamela, Gerald Marwell and Ray Teixeira, "Independence, Group Heterogeneity, and the Production of Collective Action: A Theory of the Critical Mass, I," American Journal of Sociology, forthcoming, 1985.

Roth, A.E. and F. Shoumaker, "Expectations and Reputations in Bargaining: An Experimental Study," American Economic Review 73(1983):362-72.

Runge, C.F., "Common Property Externalities: Isolation, Assurance and Resource Depletion in a Traditional Grazing Context," American Journal of Agricultural Economics 63:4 (November, 1981):595-606.

Runge, C.F., "Institutions and the Free Rider: The Assurance Problem in Collective Action," Journal of Politics 46(February, 1984a):154-81.

Runge, C.F., "Strategic Interdependence in Models of Property Rights," American Journal of Agricultural Economics 66:5 (December, 1984b).

Schelling, Thomas C., "Hockey Helmets, Concealed Weapons and Daylight Savings: A Study of Binary Choices with Externalities," Journal of Conflict Resolution 17:3 (September, 1973):381-428.

Schwartz-Shea, P. and Randy T. Simmons, "Social Dilemmas with an Exit Option," Paper presented at the Public Choice Society meetings, San Antonio, Texas, 1982.

Sen, A.K., "Isolation, Assurance, and the Social Rate of Discount," Quarterly Journal of Economics 81(1967):112-24.

Shubik, Martin, "Game Theory, Behavior and the Paradox of the Prisoners' Dilemma: Three Solutions," Journal of Conflict Resolution 14(1970):181-93.

Young, Oran, "Fishing by Permit: Restricted Common Property in Practice," Ocean Development and International Law Journal 13:2 (1982):121-70.