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GAME-THEORETIC ANALYSIS OF DECISION MAKING IN FARMER COOPERATIVES

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A GAME-THEORETIC ANALYSIS OF DECISION MAKING IN FARMER COOPERATIVES[1]

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Most formal models of the economic behavior of farmer cooperatives picture that behavior as deriving from the optimization of a single objective function by a single agent (as in the Helmberger-Hoos model), by a group of agents with identical goals (as in the Phillips model) or from simple, nonstrategic majority-rule voting of the membership (as in the Zusman model). Models incorporating voting assume that the distribution of members' preferences is single-peaked and no logrolling (interdependent voting) between issues takes place; therefore, no voting paradoxes arise, and the cooperative's objective is determined by the preferences of the median member. With few exceptions, formal models fail to address the issue of group choice in cooperatives whose members have at least partially divergent goals and engage in strategic behavior.

Cooperatives face many decisions, however, in which members' preferences cannot be assumed to be homogeneous. Examples include the pricing of different services to members, including the possibility of differential pricing based on members' patronage; the choice of what products and services to offer members; location of facilities; and the allocation of overhead costs and pool receipts. Furthermore, the preferences of management and the board of directors on many of these issues may differ from those of the rank-and-file membership. Although both the cooperative management literature and many cooperative theorists have informally discussed cooperative decision making in the context of heterogeneous preferences, there is a need to develop models that address this issue explicitly and in so doing suggest alternative ways for cooperatives to deal with group choice. The purpose of this paper is to discuss how game theory can be used to analyze many of the issues involving group choice in farmer cooperatives. The aim of the paper is not to develop a comprehensive theory of the behavior of farmer cooperatives in the marketplace but to focus on the relatively neglected issues related to group choice, which have become increasingly important as farmer cooperatives have grown and diversified in recent years. As in any theoretical paper, the purpose is not to "prove" certain relationships (that can only be done through empirical work) but to suggest hypotheses regarding them that can guide future policy and research.

Game theory addresses the issue of group choice when the preferences of the members of a group are at least partially conflicting. A major area investigated by game theory is that of nonzero-sum games, that is, games in which the interests of the members of a group, while usually not entirely coincident, are not diametrically opposed. As will become evident below, most decisions in farmer cooperatives are nonzero-sum.[2]

Two general types of group behavior are analyzable using the theory of nonzero-sum games. The first occurs when, because of high communication costs, unenforceability of contracts, lack of trust, or other reasons, members of the group eschew joint strategies and act independently; this behavior involves a noncooperative game. The second arises when members of the group can communicate and make binding commitments with one another; these situations are analyzable using the theory of cooperative games. In cooperative games there are gains from joint action by a potential coalition of players, but the players must bargain among themselves about how the net benefits of the joint action are to be shared. Failure to agree on an allocation of net benefits among players prevents the coalition from forming (Roth). Many decisions in farmer cooperatives, such as how to allocate joint costs and pool receipts among producers of different products, can be modeled using cooperative games. Others, such as how to ensure member loyalty in a "competitive-yardstick" cooperative, more closely resemble noncooperative games because in these situations co-op participants face individual incentives to act independently even though the group as a whole would benefit from collective action.

The paper is organized into four sections. Section I discusses the application of the theory of cooperative games to the modeling of certain types of decisions in farmer cooperatives, such as how to price services to a heterogeneous membership. Section II investigates how other situations facing farmer cooperatives, such as how to maintain member loyalty and member discipline over management, can be analyzed using concepts from the theory of noncooperative games, particularly the prisoner's dilemma. The analysis in sections I and II is based on several restrictive assumptions inherent in game theory, and Section III analyzes how relaxing those assumptions modifies the results derived earlier. A final section briefly summarizes the major conclusions of the paper.

I. Cooperative Behavior as a Cooperative Game

Although the preferences of different participants in a farmer cooperative are seldom strictly opposed, neither are they identical. Co-op participants, therefore, face two interrelated questions: (1) Can the participants identify and agree upon a set of objectives yielding benefits of joint action? And (2) can an allocation of the benefits and costs of this action be found that maintains the incentives of each group to participate in the activity? "The mere existence of potential gains does not necessarily mean that they can be realized. There is the problem of building an organization with sufficient cohesion to withstand the disintegrating forces arising out of conflicting interests" (Helmberger and Hoos, 1965, p. 184).

The theory of cooperative games addresses the issue of group choice when the preferences of the members of a group are at least partially conflicting. Viewing the allocation of benefits and costs in a cooperative as a cooperative game focuses attention on the following questions: (1) How do the policies of a cooperative regarding the allocation of benefits and costs among the membership affect the payoffs (both pecuniary and nonpecuniary) to various potential coalitions within the cooperative? And

(2) how do these payoffs affect the willingness of various coalitions to remain active in the cooperative as opposed to taking their business elsewhere?

A. Types of Bargaining Issues

In farmer cooperatives, many potential bargaining situations such as those portrayed in the theory of cooperative games arise. Bargaining issues between the three main actors in farmer cooperatives (farmer-members, management, and the board of directors) generally fall into one of five categories: (a) selection of products and services to be handled by the cooperative, including the choice of product quality; (b) allocation of revenues and pricing of services; (c) joint cost allocation; (d) financing of the cooperative; and (e) constitutional issues, which influence the distribution of power and decision-making authority within the cooperative.[3] For example, the pricing of goods and services to members can be conceived of as a bargaining game between two groups of members: those whom the cooperative can serve at relatively low per-unit costs or who have attractive market alternatives outside of the cooperative (for example, large farmers) and those whom it is more costly to serve or who have few attractive noncooperative alternatives (for example, small farmers). The low-cost patrons argue for differential pricing of goods and services based on the cost of service or on "meeting the competition", while the higher-cost patrons argue for uniform pricing.

Similarily, the issue of what proportion of the cooperative's net earnings should be retained rather than rebated to members can be viewed as a bargaining game involving management and possibly the board, on the one hand, and farmer-members on the other. Management, and perhaps the board, interested in promoting growth of the cooperative, may lobby for a high level of retained earnings to finance that growth, while farmer-members, particularly those nearing retirement and having only a limited ability to redeem their equity in the cooperative, may argue that net earnings should be rebated to the members as cash.[4] Murray (1983a, 1983b, 1983c) examined this bargaining issue in detail in the context of British cooperatives, although not from a game-theoretic perspective.

Constitutional issues can be viewed as bargaining games that occur among various co-op participants at the time of the writing of the cooperative's bylaws. In deciding how to vote on constitutional issues the various participants have to project how their net returns from the cooperative will be affected by the coooperative's adoption of different organizational structures.[5]

B. Representing the Gains from Joint Action: The Characteristic Function

A basic assumption underlying the analysis in this paper is that farmers engage in collective action via cooperatives because there are efficiencies in certain joint, as opposed to individual, actions. These efficiencies are represented in game-theoretic terms by a superadditive characteristic function. A characteristic function shows the minimum level of payoffs that any potential coalition of players can guarantee itself. Superadditivity of the characteristic function means that a single coalition of all the players ("the grand coalition") can always guarantee itself a higher level of payoff than can two or more disjoint subcoalitions which in total involve all the players. Mathematically, superadditivity of the characteristic function is expressed as follows:

For any two disjoint sets K and L in the set N ($K, L \subseteq N$, $K \cap L = \emptyset$), the characteristic function V is superadditive if

$$(1) \qquad V(K) + V(L) \subset V(K \cup L),$$

that is, if the sum of the characteristic functions of K and L is a proper subset of the characteristic function of their union. This means that K and L can always gain at least as much in total by working together as they can by working separately. This does not, however, mean that K and L will work together. For joint action to occur, not only must the total payoff to K and L be greater than the sum of the payoffs that would result from their individual actions, but both K's and L's individual shares of the joint "pie" must be greater than the payoffs each could achieve by acting independently.

In applying game theory to farmer cooperatives one can often equate superadditivity of the characteristic function with subadditivity of the cost function. In the context of farmer cooperatives, subadditivity of a cost function means that it is cheaper to provide some service to the members of a cooperative as whole than to provide it to them individually or in subgroups. Subadditivity of a cost function is expressed mathematically as follows:

For any $K, L \subseteq N$, $K \cap L = \emptyset$, the cost function is subadditive if

(2) $$C(q^k) + C(q^l) \geq C(q^k + q^l)$$

where

$C(q)$ is the cost of producing quantity q of the service;

q^k is the quantity of the service demanded by K; and

q^l is the quantity of the service demanded by L.

For reasons that will become apparent below it is important to distinguish between a subadditive cost function and economies of scale. Economies of scale exist when the cost function is homogeneous of degree less than one, that is, when average cost declines monotonically throughout the range of production. The existence of economies of scale (declining average cost) is neither a necessary nor a sufficient condition for a cost function to be subadditive. In particular, a subadditive cost function can exhibit increasing average cost over a certain range of output. It is subadditivity of the cost function rather than economies of scale that makes joint provision of a service to a group more economical than providing the service to individual subunits of the group.[6]

C. An Example of a Cooperative Game: Cost Allocation among a Heterogeneous Membership

An example will illustrate how the theory of cooperative games can illuminate some of the trade-offs facing participants making decisions in farmer cooperatives. This example examines cost allocation (pricing of services) in a farmer cooperative serving a heterogeneous membership and draws on a general analytic approach outlined by Faulhaber. The example assumes that farmers are profit maximizers and hence evaluate payoffs purely in monetary terms. Part III of the paper relaxes this assumption.

The Example

Consider a cooperative that provides a service to a heterogeneous set of members $N = \{1, 2, \ldots, n\}$. For example, the members may differ in the crops they grow, their sizes of operations, or their time preference for money. Assume:

(a) There are economies in the joint provision of the service to the membership, i.e., the cost function for producing the service is subadditive: for any disjoint subsets S and T in the set N ($S, T \subseteq N$, $S \cap T = \emptyset$):

$C(q^{s+t}) \leq C(q^s) + C(q^t)$, where $C(q^i)$ is the cost of providing the quantity of services q^i to group i. For example, $C(q^S)$ is the total cost S would incur providing q^S of the service to itself; $C(q^{s+t})$ is the total cost at which S and T could jointly provide $(q^s + q^t)$ of the service.[7]

(b) Farmers in group i have only the option of purchasing q^i from the cooperative or exiting the cooperative to obtain q^i in another way, either from an IOF or by forming another cooperative by themselves or with other disaffected members. (Allowing each group to vary its patronage with the cooperative would expand the number of strategies open to each player but would not change the basic results of the game-theoretic analysis.)

(c) For S, $T \subseteq N$, $S \cap T = \emptyset$, the cross-elasticity of demand between q^s and q^t is zero.

The cost function for providing the service to each possible coalition in N, combined with the prices at which the service can be obtained outside the cooperative, can be used to define a characteristic function, $v(q^S)$, which shows the minimum payoff (i.e., the minimum cost of obtaining q^S) that each group S contained in N can guarantee itself, either by acting alone or by forming coalitions with other groups within or outside the cooperative.[8]

The board and management of the cooperative must decide how to allocate the cost of producing the services among the membership. Subadditivity of the cost function implies joint costs, and hence any allocation will be in some sense arbitrary (Clark). This does not mean, however, that management can allocate costs in any way it chooses; it must take into account the effect of its allocations on members' incentives to remain in the organization. If the cost allocated to group S, $A(q^S)$, is greater than $v(q^S)$, the minimum cost that S can guarantee itself, then S has an incentive to leave the cooperative. Hence, for a cost allocation to be stable (not induce defection), the following condition must be met:

(3)
$$A(q^S) \leq v(q^S) \quad \forall \; S \subseteq N.$$

If, in addition, the cooperative is constrained to break even, returning any surplus above cost to members, the following condition must also be met:[9]

(4)
$$\sum_{S \in n} A(q^S) = C(q^n).$$

Expressions (3) and (4) together define the core of the game, the set of feasible allocations that give all participants an incentive to remain within the organization. Hence, these expressions are called the "core constraints."

More than one set of cost allocations may lie within the core, and bargaining occurs within the cooperative over which set of cost allocations should be imposed. In reality, the characteristic function, $v(q^S)$, which embodies both the cooperative's cost function and the players' external market opportunities, is likely to be known only very imprecisely, so the bargaining will take place in an atmosphere of uncertainty. Co-op members may sometimes try to influence the cost allocation decisions of the board and management by issuing implicit threats and counterthreats, as each group tries to obtain the best possible allocation for itself while at the same time ensuring that other members still have an incentive to remain in the cooperative.

The ability of a member or group of members[10] to obtain concessions from other members of the cooperative depends on two factors: the costs the member could impose on other members if he were to exit the cooperative (this determinies his bargaining threat to others in the organization) and the other players' perception of the costs he would impose on himself if he were to leave (this determines how seriously his threat is taken).

The potential harm, h_o, member S can impose on others in the cooperative can be measured by how much the remaining members' cost of obtaining the cooperatively produced service would increase if S were to leave the organization:

(5) $$h_o = [C(q^{n-s})/q^{n-s} - C(q^n)/q^n]\, q^{n-s}.$$

With S in the organization, the remaining n-s members can hope to obtain their q^{n-s} units of service at a unit cost of $C(q^n)/q^n$, the average cost of production for the grand coalition. (As will become apparent below, this hope is not always realized even if the grand coalition does form.) This unit cost would rise to $C(q^{n-s})/q^{n-s}$ if S were to leave the organization.

Similarly, the harm S would impose on himself by exiting, h_s, can be measured by how S's cost of obtaining the service would increase if he left the organization:

(6) $$h_s = v(q^s) - [C(q^n)/q^n]\, q^s.$$

Equation (5) states that, ceteris paribus, the more strongly subadditive the cooperative's cost function is with respect to a member's output, the stronger that member's bargaining position. Large members in co-ops with strongly subadditive cost functions have substantial bargaining power; small members in co-ops with constant costs have practically none.[11] This suggests that cooperatives comprised of a few large members may face more disruptive, threat-filled bargaining over allocation of costs and benefits than cooperatives with many small members. Co-ops with a few large members face an allocation problem similar to the problem of allocating costs and benefits in a cartel (Kuhn).

Equation (6) suggests that a member's threat of exit will be taken more seriously the smaller the perceived cost to him of leaving the cooperative. For example, a member's ability to extract concessions from his cooperative would be lower if he faced stiff penalties for defection (e.g., forfeiture of accrued retains) than if he did not.

In the bargaining process a member may argue that he should bear only the incremental cost of providing services to him, i.e., for $S \subseteq N$,

$$(7) \quad A(q^S) = C(q^n) - C(q^{n-s}) \quad \forall\, S \subseteq N .$$

Paying according to incremental costs may appear fair and is the rule that would result form a linear programming approach to pricing co-op services (see Hardie). Unfortunately, such an allocation scheme may not always be stable, as illustrated below.

Assume that the cooperative is comprised of four groups of members, B,S, G, and P. For example, the cooperative might provide processing and marketing services to producers of Beans, Spinach, Grapes, and Peaches. Assume that the cooperative has the following subadditive cost function (zeros can be added to the figures to lend more realism):

$$(8) \quad C(q^b) = C(q^s) = C(q^g) = C(q^p) = \$300$$

$$(9) \quad C(q^{b+s}) = C(q^{g+p}) = \$410$$

$$(10) \quad C(q^{b+g}) = C(q^{b+p}) = C(q^{s+g}) = C(q^{s+p}) = \$500$$

$$(11) \quad C(q^{b+s+g}) = \$600$$

$$(12)\quad C(q^{b+s+p}) = C(q^{b+g+p}) = C(q^{s+g+p}) = \$650$$

$$(13)\quad C(q^{b+s+g+p}) = \$810\ .$$

A cost function like this might arise in the following way. If each group of producers built its own processing plant, each could process its product at a cost of \$300. If the vegetable growers (B and S) jointly processed their products they could do so at a total cost of \$410, as could the fruit growers (G and P) if they processed jointly. There would also be some savings if one group of vegetable growers (for example, B) combined with one group of fruit growers (for example, G) for joint processing. Their total cost of production, \$500, would be higher than that of the joint fruit or the joint vegetable operations, however, due to their inability to share certain costs that are joint in those operations (for example, the cost of syrup in an integrated fruit canning operation). Assume that if three products are processed jointly, the cooperative has to expand its warehouse. Suppose that this can be done on land immediately behind the current plant that would otherwise be used for burying or burning peach pits. If peaches are not processed by the cooperative, this poses no problem, and the combined cost of processing and marketing beans, spinach, and grapes becomes \$600. If, however, peaches are processed, the pits have to be hauled away, raising the price of processing any three-product combination including peaches to \$650. Finally, assume that even with hauling away the peach pits, all four products can be jointly processed in a single plant for \$810.

Because of the subadditivity of the cost function there are potential joint benefits from processing all four products in a single plant. The board and management are faced with determining a set of cost allocations, $A(q^i)$, that will cover the \$810 total cost of producing the service for all members while still giving all members an incentive to remain in the organization. Note that charging all members the same cost for the service is infeasible; if each were charged the average cost of \$202.50, B, S, and G would have an incentive to form their own cooperative and produce the service for a total cost of \$600, or an average cost of \$200. Some sort of differential pricing is required to hold the coalition together, in which P is forced to pay more than the average cost and B, S, and G pay less.[12]

Will pricing according to incremental cost work? The incremental-cost pricing rule (7) and the break-even constraint (4) imply that:

(14) $A(q^b) + A(q^s) + A(q^g) + A(q^p) = \$810$

(15) $A(q^i) \geq \$110 \ \forall i$

(16) $A(q^b) + A(q^s) \geq \$300$

(17) $A(q^g) + A(q^p) \geq \$350$.

Applying the incremental-cost rule $A(q^i) \geq \$110$ may not lead to a stable coalition. For example, the allocations $A(q^b) = A(q^s) = \$120$ and $A(q^g) = A(q^p) = \$285$ satisfy both (14) and (15), yet under this set of allocations G and P have a clear incentive to break away from the cooperative, since they could jointly produce the service for \$410, an average cost to them of \$205. The existence of costs that are joint among a proper subset of players (rather than being purely attributable or joint among all players) implies the need to test whether that subset, as well as the individual players, are paying their full incremental cost (Faulhaber).

In certain instances where the average cost of producing the service first decreases then rises, there may be no stable allocation of costs (the core may be empty). For example, if equations (11) and (12) are replaced with

(11a) $C(q^{b+s+g}) = C(q^{b+s+p}) = C(q^{b+g+p}) = C(q^{s+g+p}) = \$600$

(that is, if peach pits can be disposesd of costlessly in the three-product plant), then the binding core constraints become:

(18) $A(q^b) + A(q^s) + A(q^g) \leq \$600$

(19) $A(q^b) + A(q^s) + A(q^p) \leq \$600$

(20) $A(q^b) + A(q^g) + A(q^p) \leq \$600$

(21) $A(q^s) + A(q^g) + A(q^p) \leq \$600$ and

$$(14)\quad A(q^b) + A(q^s) + A(q^g) + A(q^p) = \$810 .$$

Adding (18) through (21) yields

$$3[A(q^b) + A(q^s) + A(q^g) + A(q^p)] \leq \$2,400,$$

or

$$(22)\quad A(q^b) + A(q^s) + A(q^g) + A(q^p) \leq \$800$$

which contradicts (14). Hence, even though there are economies in the joint provision of the service to all the participants, given this cost function the core constraints are such that there is no possible cost allocation that does not give someone the incentive to leave the cooperative.

Discussion

The model presented above illustrates the following points:

(1) In certain circumstances differential pricing of services to members is necessary to preserve the stability of the cooperative. The differential pricing must reflect both how a member's patronage affects the cooperative's cost function (this is just an extension of the service at cost principle) and the member's strategic opportunities for obtaining the service outside the cooperative.[13] This suggests that large members in cooperatives with strongly subadditive cost functions may be particularly successful in extracting price concessions from the cooperative. Small members may oppose granting price concessions to larger members, however, for fear that the concessions will simply reinforce the competitive advantages of larger operations. In addition, income-tax provisions (for example, Section 521) may limit the degree to which cooperatives can price discriminate among their members.

(2) Even if a cooperative does decide to price discriminate among members, if there are costs that are joint among a proper subset of members, the cooperative cannot simply adopt an incremental-cost rule for setting prices, as this can give some members incentives to leave the organization. Setting cost allocations can thus be a complex process, and it is problematic whether a feasible allocation could

be determined on a simple one-member, one-vote basis.

(3) Although differential pricing of services to members may be necessary to preserve the stability of cooperatives that have highly heterogeneous memberships, instituting such pricing usually requires a vote of the board, which, if elected on a one-member, one-vote basis, may be controlled by smaller-volume patrons. If small patrons steadfastly oppose differential pricing, large members may exit the cooperative unless voting rules are changed to increase the political power of the larger patrons. Caves and Petersen (appendix A, p. 1) report some evidence that such a reallocation of political power has occurred in cooperatives with heterogeneous memberships, noting that the one-member, one-vote rule prevails in only 71 percent of large, predominately federated cooperatives (whose members are likely to be diverse) compared with 92 percent of local cooperatives.

(4) In situations where a cooperative's average cost of providing a joint service first decreases then increases, there may be no allocation of costs that gives everyone an incentive to stay in the organization. This suggests that cooperatives need to be very careful in deciding when to expand their membership and/or their mix of activities, expanding only when there are clear synergies that allow the organization to hold down its average costs. The impossibility of finding a stable allocation of costs among a heterogeneous membership may prevent cooperatives from "doing all things for all people."

(5) If the core of the game is not empty, there may be more than one feasible allocation of costs, and the management and the board must somehow choose a fair allocation. The model presented above simply states that the final allocation must lie within the core; it does not specify where within the core the optimal allocation lies. In other words, although game-theoretic considerations establish a feasible region within which prices must be set, costs allocated, or product mix determined, exactly <u>where</u> within that region the final decision falls may depend on factors such

as the internal politics of the cooperative or the board's conception of what a "fair" solution should be. Game theorists have proposed alternative solution concepts for choosing among different allocations within a core, with each solution concept emboding a different concept of fairness (see Staatz, 1984, appendix C). For instance, the Shapley-value approach, which allocates to each coalition its "average marginal cost"[14] would, in the above example, lead to the following cost allocation:

$A(q^b) = A(q^s) = A(q^g) = \$198.33$, and

$A(q^p) = \$215.00$.

Examination of these solution concepts may be useful in helping to determine equitable cost allocations.

(6) Failure to choose an allocation that lies within the core can lead members simply to exit the cooperative. Game-theoretic analysis could help management predict which allocations would induce defection and which would not. In determining the cost functions facing cooperative participants (which in turn largely determine their characteristic functions), economic engineering approaches may be particularly useful (see French).

(7) The model suggests that if dissatisfied members do not simply leave the cooperative, bargaining over allocations of costs and benefits can be intense and bruising. Reality, however, may not be so harsh. Participants are likely to know only very imprecisely the costs (payoffs) of the alternatives open to them, and the board and management may be able to influence their estimates of those costs (e.g., through member relations programs). In this sense, uncertainty about what is in one's best interest may reduce conflict in the cooperative. To the extent that members receive nonpecuniary benefits from remaining in the cooperative, bargaining over the allocation of monetary benefits and costs in the organization may also be muted. These possibilities are examined in Section III.

(8) Another important way in which management and the board can facilitate agreement on allocation of costs and benefits is through devising ways to convert apparent zero-sum games among the membership into nonzero-sum games, thus expanding the potential core of the game. For example, allocation of receipts from a marketing pool among producers of different commodities (say, X, Y, and Z) may appear to be a zero-sum game if viewed in the context of a single year; whatever is gained by producers of X is lost to the producers of Y and Z. If, however, the producers can be convinced to take a multiyear perspective, the game becomes nonzero-sum. Unless management or the board has strict control over potential supplies, allocating excessive returns to X may lead (via the supply response for X) to excessive inventories of X in coming years, reducing the net returns available for distribution among all producers in subsequent years. A more "balanced" allocation in the current year may lead to improved profit possibilities for all producers in subsequent years, implying joint gains from a coordinated allocation strategy. Documenting the possible consequences of adopting extreme bargaining positions may be an important way in which management can facilitate agreement. Another way of converting zero-sum games to nonzero-sum games is by "logrolling"--tying the negotiation of one issue to another, so that the scope for trade-offs, given divergent member preferences, is expanded (Raiffa; Buchanan and Tullock, chapters 10-11).

II. Cooperative Behavior as a Noncooperative Game: Prisoner's Dilemmas in Farmer Cooperatives

In certain circumstances, participant behavior in a farmer cooperative more nearly resembles a noncooperative game, particularly a prisoner's dilemma.[15] In a prisoner's dilemma, the "rational" pursuit of individual self-interest leads to a Pareto-inferior outcome.

Formally, a prisoner's dilemma is defined as a game that has a payoff matrix of the form shown in Figure 1(a). Each player has two possible strategies, cooperating with the

		Player B: C	Player B: D
Player A	C	(a_{11}, b_{11})	(a_{12}, b_{21})
	D	(a_{21}, b_{12})	(a_{22}, b_{22})

where $a_{21} > a_{11} > a_{22} > a_{12}$ and $b_{21} > b_{11} > b_{22} > b_{12}$

(a) Generalized form of the game, with payoffs in expected utility

		Player B: C	Player B: D
Player A	C	(8,8)	(4,10)
	D	(10,4)	(5,6)

(b) Numerical example, with payoffs in expected utility

Figure l. Payoff Matricies for a Prisoner's Dilemma.

other player (C) or defecting (D) and acting independently.[16] Although the payoffs to each player are higher if they both cooperate (strategy pair C,C) than if they both defect (strategy pair D,D), the incentives facing the players are such that each has an individual incentive to defect even though each knows that his opponent is acting similarly. For example, in the prisoner's dilemma illustrated in Figure 1(b), the payoff to player A is always higher if he defects, no matter which strategy player B selects. If B chooses to cooperate, A's payoff increases from 8 to 10 if he defects rather than cooperates. If B chooses to defect, A's payoff increases from 4 to 5 if he also defects. B faces a similar set of incentives. If both players defect, however, they are both worse off than they would have been if they had both cooperated, as they receive payoffs of (5,6) instead of (8,8).[17]

Two characteristics of a prisoner's dilemma lead to this Pareto-inferior result. First, the players are unable to communicate with one another and make binding commitments regarding mutually advantageous joint strategies. Second, the prisoner's dilemma is usually pictured as an isolated game, played only once by the participants. The behavior of the players in this game is in no way linked to their behavior in other games--the players have no concerns about developing or preserving their reputations as reliable partners, etc. If, however, players face recurrent prisoner's dilemmas, patterns of cooperation among the players may evolve. This has been shown both experimentally and theoretically. (Raiffa, pp. 123-26; Schotter. See the discussion of "supergames" below.)

A wide variety of situations in farmer cooperatives, ranging from pricing and output decisions to problems of inducing members to participate adequately in the governance of the cooperative, appear at times to resemble prisoner's dilemmas. For example, given an inelastic demand for its product, a cooperative's revenues would increase if the cooperative restricted output; yet because the organization's net earnings are rebated to its members in proportion to their individual production, each member has an incentive to expand output, thereby undercutting the cooperative's attempt to restrict supply. Provision of certain public goods by cooperatives--more competitive input and output markets, lobbying, and so on, may also resemble a prisoner's dilemma (see Staatz, 1984, chapter 4).[18] As with all public goods, a free-rider problem exists: an individual need not join or patronize the cooperative to enjoy all these benefits. Failure to patronize the cooperative, however, may lead to a long-term decline in the organization's ability to provide these goods. Rhodes (1978) has also suggested that farmer-members may often fail to oversee and discipline cooperative management adequately due to a free-rider problem:

> Seldom does any cooperative member have an economic self-interest for trying to discipline management. His potential costs exceed his potential benefits. While all members together may have an economic incentive, the rational choice is for each individual to hope the others make the effort while he reaps the benefits (p. 223).

The usefulness of the static prisoner's dilemma model to analyze cooperative loyalty, the output decisions of farmer cooperatives, and problems of disciplining management is problematic, however, because the standard prisoner's dilemma is pictured as a one-time game, in which players are given the choice of cooperating or defecting, and in which there are clear individual incentives to defect. Because they play the game only once, players are not concerned with maintaining their reputations as reliable partners; even if they defect they will not face retribution from their partners in subsequent periods. In reality, farmers do not face a one-time decision of whether to join and support a cooperative (or to support its decisions); that choice is continually before them. Reputations clearly <u>do</u> matter; cooperatives may expel habitually "noncooperative" members even if doing so imposes some short-term cost on the remaining members.

If a single-period game (called a <u>constituent game</u>) is infinitely iterated, a new game is defined (called a <u>supergame</u>), in which the payoffs are the net present values of the stream of payoffs from the constituent games. Several authors (for example, Taylor; Schotter; Axelrod and Hamilton) have shown that even if the constituent game is a prisoner's dilemma, the supergame need not be.[19] The result depends critically on five elements:

(1) the length of the supergame (the supergame must be of infinite duration or at least of a duration unknown in advance to the players);

(2) the reaction of the players to a defection by one of their number;

(3) the rates of time preference by the players;

(4) the relative size of the payoffs for defection and cooperation in the constituent game; and

(5) the number of players in the game.

A supergame of known duration comprised of constituent games that are prisoner's dilemma is itself a prisoner's dilemma.[20] Similarly, the supergame will be a prisoner's dilemma if players who do not defect fail to punish, in subsequent iterations of the game, those who do; unconditional cooperation in a prisoner's dilemma supergame is never an equilibrium strategy.[21] In addition, even if there is punishment for defection the supergame may still be a prisoner's dilemma if players have sufficiently high discount rates; given a high discount rate, the gain to a player in the current period from defection may be greater than the discounted value of the punishments subsequently inflicted. Related to this are the relative size of the payoffs for cooperation and defection in the constituent game. The higher the return to defection relative to cooperation in the constituent game, ceteris paribus, the more likely the supergame is to be a prisoner's dilemma. Lastly, the larger the number of players, the more likely it is that a supergame comprised of prisoner's dilemma constituent games will itself be a prisoner's dilemma. For conditional cooperation to be a rational behavior in an n-person prisoner's dilemma supergame each player must know how many other players cooperated in the previous iteration of the game and each cooperating player's discount rate must lie below a certain level (Taylor, chapter 3 and pp. 92-93). Both conditions are more likely to prevail in a small group than in a large one.

If the problem of maintaining loyalty to a farmer cooperative (or to its price and output decisions) is truly a prisoner's dilemma supergame, then the above analysis suggests the following hypotheses:

(1) Cooperative loyalty is greater among those who will be farming for an indefinite period compared to those who are close to leaving farming, provided that there is no way for the individual leaving farming to continue to benefit from the existence of the cooperative (e.g., through capitalization of the value of the cooperative into the value of his land, through a "pension" provided by the retirement of his accrued equity in the organization, or through utility derived from supporting a cooperative with which one has had a long association or from passing on a viable farming operation to his heirs).[22] If those leaving farming will have no further payoffs from the cooperative once they leave, they have no incentive to remain loyal to it as they near their retirement; in the short-run, defection is always the dominant strategy.

(2) Cooperative loyalty is greater the greater are the penalties for cooperative disloyalty. Although this is hardly a surprising hypothesis, it is sometimes ignored by cooperative practitioners. If cooperatives do indeed provide public goods, then theory suggests that it may be too easy for members to leave cooperatives. Although managers of cooperatives sometimes express astonishment that members who have substantial investments in a cooperative are not more loyal to the organization, in many instances the member's return on his investment is only weakly conditional on his continued patronage (see Staatz, 1986a). Co-op members may rationally regard their investment in the organization as a sunk cost and therefore not take it into account in making current decisions. This implies that cooperative loyalty might be increased by making the return on past investment more conditional on current patronage. Doing so might also increase the use of member voice relative to exit in disciplining management (Hirschman).

(3) A farmer's cooperative loyalty decreases as he or she becomes more leveraged. Highly leveraged farmers are likely at times to face severe cash-flow difficulties and therefore have a high discount rate. As agriculture relies increasingly on purchased inputs and, as a consequence, farm borrowing increases, one would therefore expect a secular decline in cooperative loyalty. In addition, the widespread notion that young farmers as a group display less cooperative loyalty than older farmers may in part be attributable to younger farmers being more highly leveraged than their older counterparts. In a cash-flow bind, many young farmers may not be able to afford cooperative loyalty if more favorable prices or credit terms are available elsewhere.[23]

(4) Cooperative loyalty is greater in small cooperatives than in large ones. It is more likely that members of a cooperative will develop concerns for the welfare of their co-members if the group is small and they get to know each other intimately. Developing a degree of altruism regarding the payoffs to the other players in a game can transform it from a prisoner's dilemma to a game that does not have a Pareto-inferior outcome (see below).

III. Some Qualifications to the Game-Theoretic Analysis: The Roles of Transaction Costs and Ideology

Although game-theoretic analyses generate many intriguing hypotheses regarding farmer cooperatives, such analyses are built upon several restrictive assumptions. Game theory assumes that all players know (a) the rules of the game, (b) all the other players' preferences, and (c) the relationship between all the players' actions and the outcomes of the game (or at leaast a probability distribution for those outcomes). Knowledge of the relationship between actions and consequences implies that players have perfect foresight (at least up to a probability distribution) and that in cooperative games players can instantly and effortlessly evaluate the payoffs from joining all possible coalitions and engaging in all possible strategies open to them. Game theory further assumes that players face no other transaction costs in carrying out their strategies, such as the costs of building coalitions and enforcing agreements; and that the preferences of all players are immutable. These assumptions are patently unrealistic. This section analyzes how substituting more realistic assumptions regarding information costs, actors' knowledge and computational abilities, other transaction costs, and the possibility of changing players' preferences through the inculcation of a "cooperative ideology" modifies the game-theoretic analysis presented in sections I and II. The first part of this section discusses how imperfect knowledge and transaction costs affect the conclusions drawn from the theory of cooperative games, while the second part examines how the conclusions derived from the theory of noncooperative games (especially the prisoner's dilemma) are modified once one takes into account the efforts of farmer cooperatives to influence the preferences of their members.

A. Limitations of the Perfect Knowledge Assumption

Shubik has shown that the costs of gathering, storing, and processing information and negotiating an agreement in an n-person cooperative game all increase in proportion to a number raised to the nth power. For example, in a two-person cooperative game in which each player has 10 alternative strategies, each player must evaluate 100 ($=10^2$) possible outcomes of the game. If the number of players increases to 10, the number of possible outcomes to be evaluated increases to 100,000,000,000 ($=10^{10}$). Even if a player could costlessly gather information on all these possible alternatives, evaluate them, and store the results, he would also have to negotiate potential agreements with all possible coalitions, the number of which also increases as a power of n. The costs of doing all this seriously draw into question whether bargaining situations involving more than two players really resemble the scenarios portrayed by the theory of cooperative games. In Shubik's words: "By attaching even slight costs to the acts of storing, gathering, and processing information, any firm can compute that cost of getting anything like complete information will be astronomical" (pp. 148-49).

Shubik concluded that because of these information costs players often act noncooperatively, eschewing negotiation with one another over joint strategies in favor of the informationally more efficient strategy of acting independently. Cooperative games, he argued, are thus replaced by the noncooperative games that underlie them.

Whereas Shubik argued that information costs reduced the scope for agreement in cooperative games from that predicted by theory, Schotter and Schwodiauer (p. 509) held just the opposite view. Because of transaction costs, they argued, it was unlikely that all possible coalitions that might block an imputation would form; hence, the core (the zone of agreement) would be larger than theory suggests.

In farmer cooperatives both the outcome predicted by Shubik and that predicted by Schotter and Schwodiauer appear to occur depending on the circumstances. In many instances (pricing of products, for example) members do not vote on every alternative open to them; rather, the cooperative establishes a rule (e.g., that fertilizer will sell for $X per ton, subject to a possible price adjustment via a patronage refund) that provides each member with a low-cost set of expectations regarding the outcome of the cooperative's actions. Given this set of expectations, the members can then each act independently, as they would in a competitive market. They act, in other words, as they would in a noncooperative game in which the price of fertilizer was given exogenously.

In other circumstances, particularly those concerning major decisions for the cooperative, such as whether to merge with another cooperative, the members do negotiate with one another and vote. They do not consider all the alternatives open to the cooperative, however, only a select few. Although the game is still cooperative, it is a much simpler game than that predicted by theory.

Determining who establishes the rules in these noncooperative games and who selects the alternatives to be considered in the (simplified) cooperative games is important to understanding the behavior of farmer cooperatives. The rules determine what the "independent" actors in a noncooperative game have to take into account in planning their behavior and hence how they interact with one another. Similarly, the agenda that is established in a bargaining (cooperative-game) situation largely conditions the outcome of that bargaining.

Because of information costs and other transaction costs, the highly elaborated bargaining game predicted by the theory discussed in section I is replaced by two interlinked games. The first, a cooperative (bargaining) game, can be called a constitutional game. In it, the rules of the cooperative are established, including pricing rules, rules that determine who sets the agenda for subsequent bargaining issues among the members, and so on. Even in the constitutional game not all alternatives are considered; limits imposed by the external environment (competition in the industry, laws governing the structure of farmer cooperatives, and so on) and the knowledge and imagination of the members determine the alternatives considered. The second, or consequent game, consists of the noncooperative game or the simplified cooperative game discussed above. In this game, the co-op members either act independently, taking the rules or prices determined earlier as given (as in the fertilizer example above) or bargain over a restricted set of alternatives that was delimited in the preceding constitutional game.

Stating that the fully elaborated game predicted by theory is replaced by a constitutional game and a consequent game is simply another way of saying that in the presence of transaction costs there are economies in moving from decision making based on direct democracy (the fully elaborated game) to a system of representative governance (the two sub-games [Staatz, 1984, 147-48; Buchanan and Tullock, p. 6.]) In such a system the outcome of the constitutional game largely conditions the outcome of the consequent game. Therefore, understanding the behavior of a particular farmer cooperative requires an understanding of its rules for making rules and how these influence who participates in the governance of the cooperative.

It is reasonable to assume that members decide whether to participate in a cooperative's governance based on their perceptions of the costs and benefits to them of participating. The existence of transaction costs implies that participation will be concentrated among members having an intense interest in particular issues decided by the cooperative, while those having a more diffuse interest will abstain, even if in aggregate they could gain a great deal from participation. The reason for this is that the transaction cost of participating in the cooperative's governance is likely to exceed an individual's potential gain from participating if he has only a diffuse interest in the issues being decided by the cooperative. Such individuals therefore do not become involved in the cooperative's governance even though in aggregate they may represent a majority of the members.

For example, consider a cooperative that is deciding among three options: to expand its current plant at site 1, to build a new plant at site 2, or to keep its current plant at site 1 with no expansion. Expansion requires an additional subscription of capital from the members; therefore, the board will not undertake the expansion unless members express strong support for such action. Furthermore, assume that the projected net revenues from expanding the plant at the two alternative sites are comparable, so that there is no clear-cut financial advantage to expanding in one site relative to the other. Therefore, the board decides that if the members are willing to finance the expansion, the board will choose the plant location based primarily on the input it receives from members. The membership consists of two groups. One group, C, has a concentrated interest in keeping or expanding the plant at site 1, while a second group, D, has a slight (diffused) preference for building a new plant at site 2. If the board hears only from members of C, it will expand the plant at site 1, if it hears only from members of D, it will build a new plant at site 2, if it hears from neither group it will keep the current plant at site 1 unmodified, and if it hears from both groups it will decide on the plant location through a process that gives each group a 50-percent chance of getting its most-preferred alternative.

Members of C and D must decide whether to lobby for their preferred alternatives. Let the expected payoffs to individual members of C and D in the absence of transaction costs be those shown in Figure 2(a). In this situation the dominant strategy for each member is to lobby; no matter what his opponent does, the member's payoff is always higher if he lobbies. The equilibrium outcome is therefore lobbying by both C and D, with C's expected payoff equal to 9 and D's expected payoff equal to 6.

Now suppose that the cost of lobbying for each group is 3. Deducting this cost from the payoffs involving lobbying yields the payoff matrix shown in Figure 2(b). In this situation lobbying is still the dominant strategy for C--no matter what D does, C's payoff is always higher if he lobbies. D's dominant strategy, however, now becomes not lobbying. As a result of transaction costs the equilibrium outcome now involves only C's lobbying; hence, C's most preferred outcome (expansion of the plant on site 1) occurs. Hence, the existence of transaction costs reinforces the tendency of members with concentrated interests to dominate cooperative governance.[24]

This tendency is further reinforced by the value of the information generated by the cooperative during its operations. Information about developments in a subsector is valuable to farmers in that subsector and is often costly to obtain. When such information is costly, one motivation to participate in the governance of a cooperative is the prospect of gaining access to information on the subsector generated by the cooperative's management during the course of its operations.[25] The value of this information to an individual is greater the larger is his investment in the subsector and the poorer are his alternative sources of information. Large farmers may therefore have a greater incentive to run for the board, to serve on cooperative committees, and so on, than do small farmers, particularly if information on developments in the subsector are not readily available from other sources.

Another consequence of transaction costs is a tendency for decisions in a cooperative, once made, to be relatively stable. Whereas game theory predicts that

Member D

		Not Lobby	Lobby
Member C	Not Lobby	(10,5)	(3,7)
	Lobby	(15,5)	(9,6)

(a) Payoffs Without Transaction Costs

Member D

		Not Lobby	Lobby
Member C	Not Lobby	(10,5)	(3,4)
	Lobby	(12,5)	(6,3)

(b) Payoffs After Deducting Transaction Costs

Figure 2. Payoffs for Political Action in the Cooperative--Concentrated and Diffused Interests

bargainers will recontract in an eyewink should any of them perceive the least advantage in some new course of action, in reality decisions are unlikely to be revised unless the gains from revising them clearly outweigh the transaction costs of organizing to do so. Therefore, the existence of transactions costs protects the utility of those who have the initial right to decide an issue in the organization.

B. Cooperative Ideology and the Modification of Member Preferences

Game theory assumes that each player has an unchanging set of preferences. Much of the activity in farmer cooperatives, however, is aimed precisely at changing the preferences of the participants in the organization in order to modify their behavior. One of the main ways in way this is done is through attempting to inculcate a "cooperative ideology" into farmer-members, members of the board, and members of management.

In many instances the incentives facing individual participants in farmer cooperatives may induce them to behave in a way that is inconsistent with the welfare of the cooperative as a whole. Individual farmers may expand production when farmer-members as a group would benefit if output were restricted; farmers may act as free riders with respect to the cooperative's competitive-yardstick activities, leading to a long-term decline in the cooperative's ability to carry out those activities; managers may attempt to conceal their activities from the board through manipulation of information; and individual board members may attempt to use their positions to feather their own nests rather than to improve the welfare of the members. (For details, see Staatz, 1984, chapter 6.) Such a divergence between individual and group incentives is not unique to cooperatives; it is faced to some degree by all organizations. As an adaptive response to this problem, most organizations attempt to inculcate an organizational ideology--a set of shared norms and beliefs--that tend to reduce the divergence between individual and group goals (Roberts).

In terms of the game-theoretic model presented above the function of cooperative ideology is twofold. First, it aims at altering players' perceptions of the payoffs of the constituent games that they play. (Game theory assumes that players evaluate these payoffs in terms of utility, not just money.) Specifically, cooperative ideology, which is fostered both through formal programs, such as member-relations activities and board and management training sessions, and informal socialization processes, attempts to:

(1) Change farmer-members' expectations regarding the pecuniary payoffs that would be available to them with and without the cooperative. Member-relations programs often stress the importance of cooperatives in enforcing competition and suggest that if they are not supported, farmers will be much worse off in the future.

(2) Influence participants' marginal rates of substitution between the pecuniary and nonpecuniary benefits they derive from membership in the cooperative. Cooperative ideology often stresses cooperation as a goal in and of itself, being as worthy of a person's efforts as striving for material advantage. This ideology at the same time tries to reduce the marginal utility that members of the organization receive from pecuniary benefits they receive "unethically"--for example, from using their position of authority in the cooperative to benefit themselves financially at the expense of others in the organization.

(3) Induce a degree of altruism in players' evaluation of the payoffs from the constituent games, that is, broaden a player's evaluation of the outcome of a game to include not only how well he fares personally but also how well his cohorts make out. Cultivating concern for others in the cooperative may help overcome potential prisoner's dilemmas. This can perhaps be seen best through an example. Suppose that initially the payoff matrix facing two typical co-op members is that shown in Figure 3(a), which represents a prisoner's dilemma. Both player 1 and player 2 can choose between cooperating (C) and defecting (D), and each has a clear incentive to defect. When both do defect, however, the outcome (1,1) is mutually less preferred

Player 2

		C	D
Player 1	C	(5,4)	(0,7)
	D	(7,0)	(1,1)

(a) Original Game

Player 2

		C	D
Player 1	C	(4.5, 4.5)	(3.5, 3.5)
	D	(3.5, 3.5)	(1, 1)

(b) Transformed Game

Figure 3. Transformation of a Prisoner's Dilemma through the Introduction of a Degree of Altruism

than the outcome (5,4) that would have obtained had they both cooperated. Now suppose that through the inculcation of a new ideology each player develops a degree of altruism, viewing his payoffs in utility as the average payoff in the original game to both himself and his cohort. This results in a transformed game having the payoff matrix shown in Figure 3(b). In this game mutual cooperation is the equilibrium outcome. That is, through the introduction of a sufficient degree of altruism the game is transformed from a prisoner's dilemma into a game in which cooperation spontaneously occurs. (For a more detailed analysis see Taylor, chapter 4.)

The second major aim of cooperative ideology is to decrease the discount rate which members use to compare the payoffs from sequential constituent games in supergames. As mentioned above, the higher the discount rate the more likely it is that a supergame comprised of constituent games that are prisoner's dilemmas will itself be a prisoner's dilemma. For example, members with high discount rates are often "unable to afford cooperative loyalty;" therefore much of the socialization process in cooperatives aims at trying to get farmer-members and board members to take a long view of the cooperative's activities. By reducing the member's discount rate, cooperative ideology discourages short-term opportunistic behavior in favor of long-term support for mutual cooperation.

If ideology is an adaptive response by an organization to the problems it faces, then that ideology needs to evolve as the problems change. An ideology that is incongruent with the problems faced by an organization is ultimately maladaptive. But because ideology that has been incorporated into an individual's set of values seems so "natural" and self-apparent, the need for its change is often perceived only gradually, and therefore the ideology is likely to change very slowly. Attempts to change elements of an organization's ideology rapidly may meet bitter resistance from certain participants, as has occurred in some cooperatives when differential pricing of services to members was proposed, even though, as demonstrated in Section I, such pricing is sometimes necessary to preserve the viability of the cooperative.

IV. Summary and Conclusions

Game theory, with its emphasis on decision making under conditions of mutual interdependence and on the allocations of costs and benefits from joint activity, is particularly suited to examining the behavior of participants in farmer cooperatives. Many decisions in these cooperatives resemble the bargaining situations analyzed by the theory of cooperative games, where joint action yields mutual benefits but where players must agree on how to share those benefits before the joint action can be undertaken. Other decisions facing participants in farmer cooperatives, particularly those in which agreements among the participants are difficult to enforce, more closely resemble noncooperative games, especially the prisoner's dilemma supergame. Although the examples in this paper have focused mainly on the pricing decisions of cooperatives, game theory offers insights into a broad array of issues involving collective choice in cooperatives, ranging from the financing practices of the firm to member control over management (see Staatz, 1984, chapter 5).

The game-theoretic approach developed in this paper stresses that farmer cooperatives cannot always singlemindedly pursue the simple objectives posited in earlier models of cooperative behavior, such as maximization of total member profits or maximization of per-unit cooperative surplus, because doing so may result in a distribution of member benefits that creates incentives for certain members to leave the organization. For a similar reason a cooperative may not be able to serve everyone; tensions over cross-subsidies among a highly diverse membership may prove too disruptive. Rules such as "equal treatment for all" may in certain circumstances result in no service for anyone, as they precipitate the disintegration of the organization.

The game-theoretic approach also emphasizes that apparently irrational behavior by cooperatives may result from individual participants rationally pursuing their own self-interest. For example, consider intercooperative competition. Farmer cooperatives often fiercely compete with one another, even when they are owned by the same farmers (Ratchford, Swank). Although greater collaboration would seem to be in the long-term interest of the farmer stockholders, competition persists because individual incentives push managers, board members, and stockholders to encourage it. Although managers and board members may desire some reduction in intercooperative competition, they are likely to oppose taking collaboration to its logical extreme, merger, unless they are assured that they will retain positions of authority in the new organization. Farmer-members may prefer intercooperative competition for several reasons. If competing cooperatives cross-subsidize certain services (particularly if different cooperatives subsidize different services), then members can act as "cherry pickers," buying from each cooperative its subsidized services and purchasing the other services (those that provide the subsidies) somewhere else. Second, if the cooperatives' equities are not freely redeemable, then members, particularly those nearing retirement, may have no way in the short run of gaining access to their accrued investment in the cooperative except through pressuring management to liquidate some of the co-op's assets, the proceeds from which would be distributed to current patrons. (This is the "horizon problem" discussed in Staatz, 1986a.) One way of liquidating a cooperative is to push it into ruinous price wars, which generate short-term gains to the members in the form of more favorable prices at the expense of the long-term viability of the organization. Third, members who feel distant from the board and management, particularly in large cooperatives, may feel that intercooperative competition is the only way in which the board and management can be effectively disciplined. These members might prefer better direct member control of the board and management in order to ensure the firm's efficiency (but then, again, they might not, given the individual costs of monitoring the organization), but lacking direct member control, intercooperative competition may be seen as the only way to keep the people at the top on their toes. The game-theoretic approach stresses that if "wasteful" intercooperative competition is to be reduced, the incentives facing individual participants in the cooperatives must be changed.

Introducing transaction costs and the possibility that participants' preferences can be changed through the inculcation of "cooperative ideology" modifies some of the conclusions of the game-theoretic analysis and stresses the need to understand the rules for making rules in farmer cooperatives. It also stresses the important role that socialization processes and member-relations programs may play in succcessful farmer cooperatives. Many of the major conclusions of the game-theoretic analysis, however, remain valid. The concept of the core continues to be particularly important: to prevent a proposed allocation of costs and benefits in a farmer cooperative from inducing defection, careful attention has to be given to the payoffs facing individual members.[26]

Furthermore, the game-theoretic approach emphasizes that in certain circumstances what is good for the individual co-op participant (farmer-member, board member, or manager) may not be good for the organization as a whole; this is often due to the free-rider problem inherent in many of the activities undertaken by cooperatives. Therefore, if cooperatives are to succeed in fulfilling what is often an important social role, there may be a need to develop rules that limit individual choice within the organization to prevent it from being undermined. This is a delicate task because if taken to an extreme it would eliminate member exit as a means of disciplining the board and management. Nonetheless, the analysis shows that unfettered individualism in cooperatives may leave all members worse off than if defecting from the cooperative were more costly in the short run.

Footnotes

1 Some of the material in this paper appeared in John M. Staatz, "The Cooperative as a Coalition: A Game-Theoretic Approach," American Journal of Agricultural Economics 65, no. 5 (December, 1983): 1084-89. It is included here by permission of the American Agricultural Economics Association.

2 For formal definitions of the game-theoretic terms used in his paper, see Luce and Raiffa, Bacharach, Taylor, or Staatz (1984, appendix C).

3 For a compilation of these bargaining issues, see Staatz (1984), pp. 226-32.

4 If, however, retained earnings are used to retire member equities rather than to finance growth of the co-op, older members may prefer a high level of retained earnings.

5 The best-known application of game theory to analyzing the choice of constitutional issues is Buchanan and Tullock's The Calculus of Consent, especially chapters 11 and 12. There is a fundamental difference, however, between the type of game analyzed by Buchanan and Tullock and those discussed here. Buchanan and Tullock analyzed constitutional choice in a democratic entity from which exit was essentially impossible; therefore, the criterion for group choice in their model was majority rule. Exit is possible from farmer cooperatives, however; farmer-members who strongly disagree with some collective action taken by the organization (for example, its pricing practices) are free to leave the organization. The criterion for group choice in these games, like that in all "classical" bargaining games (Roth), is therefore unanimity; if all members of a potential coalition are not at least as well off as they could be in some other arrangement, the coalition will not form.

6 For a detailed discussion of the relationship between subadditivity of a cost function and economies of scale see Baumol, Panzar, and Willig, chapter 7.

7 The cost functions presented in this section represent the cost to a given group (coalition) of farm firms of obtaining a particular service. Hence, the cost function represents the cooperative's cost of producing the service plus any additional costs incurred by the member firms in gaining access to the service.

Because the cost function is subadditive, the model applies only to situations where reducing the size of the cooperative or its range of services would result in an increase in costs for the remaining members or for providing the remaining services. The model does not apply to situations where a cooperative's elimination of unprofitable lines of activities leaves the remaining patrons better off. In that situation, the dilemmas outlined below do not arise; pressure both from the patrons who generate positive net margins for the cooperative and from the competitive environment may lead management to eliminate the unprofitable activities.

8 Payoffs are usually pictured in game-theoretic models as payments to players, while here they are payments by players. Formally, the correspondence to standard theory can be made by changing signs (i.e., payoffs become negative revenues) and thereby reversing the direction of all inequalities.

9 In farmer cooperatives the entire surplus above cost is not returned to the members as cash; some is kept as operating reserves. The decision on how much of the surplus to pay out as cash is itself a bargaining issue that can be analyzed using a game-theoretic model (see Staatz, 1984, pp. 253-63).

10 In the following paragraphs the term "member" should be interpreted as signifying either a single member of a group or members acting as a coalition.

11 This conclusion is strengthened even further if we assume that small farmers are more risk averse than large farmers. If large farmers are less risk averse, they would be more willing to gamble in the bargaining process than would small farmers and would therefore drive a harder bargain, particularly if (as game-theory assumes)

the larger farmers are aware of the small farmers' utility functions, including their risk preferences (see Harsanyi).

12 Here is where the distinction made earlier between economies of scale and a subadditive cost function becomes important. Because the cost function is subadditive, it is cheaper to process all four products in a single plant, but because the average cost of processing does not decline monotonically throughout the range of production, farmer-members cannot simply be charged the firm's average cost.

13 In the above example, external market opportunities were not analyzed; the cooperative's cost function alone defined the characteristic function. Including external market opportunities in the analysis would have shrunk the core (reduced the scope for agreement within the cooperative).

14 The Shapley value for an individual coalition (player) i is defined as

$$\phi(v_i) = \sum_{K \subset I} \frac{(n-k)!(k-1)!}{n!} [v(K) - v(K-\{i\})]$$

where

n = number of players in the game,

k = number of players in coalition K,

v(k) is the characteristic function for coalition K, and

v(k- $\{i\}$) is the characteristic function for the coalition made up of all members of K who are not also members of i.

The expression $[v(K) - v(k-\{i\})]$ represents the marginal contribution of player i to coalition K. The expression

$$\frac{(n-k)!(k-1)!}{n!}$$

represents the probability that in a random build-up of the grand coalition of n players, player i will join in the coalition in the kth position. Summing the product of these expressions over all K yields the average of player i's possible marginal contributions. For further details, see Schotter and Schwodiauer or Luce and Raiffa, pp. 245-52.

15 In certain other situations, the behavior of participants resembles another type of noncooperative game, the "coordination problem." For details and an example, see Staatz, 1984, pp. 270-75.

16 Figure 1 illustrates a two-player prisoner's dilemma. Prisoner's dilemmas can also be defined for more than two players (see Taylor).

17 When there is one strategy in a game (such as defection in the prisoner's dilemma) that gives a player a higher payoff no matter what the other players do, that strategy is said to be dominant.

18 For a review of the arguments that the provision of public goods in general represents a prisoner's dilemma see Taylor, chapter 1.

19 For a mathematical demonstration, see Staatz, 1984, pp. 407-14.

20 If a player knew in advance that the nth iteration was the last, he would have a clear incentive to defect in that iteration, since in any single constituent game defection is the dominant strategy. The (n-1)th iteration would then become in effect the last game, but here again the same argument for defection would apply, and so on, all the way back to the first iteration.

21 Unconditional cooperation in a prisoner's dilemma supergame is defined as cooperating no matter how the other players have behaved in previous iterations of the game. Conditional cooperation is defined as cooperating only so long as the other players, or some critical number of them, continue to cooperate; if they defect, the other player defects (for some period) in subsequent iterations of the game.

22 For details, see Staatz, 1986a.

23 When the author suggested this hypothesis to a cooperative manager he replied, "But in the long run they can't afford cooperative disloyalty." His reply neatly illustrates the prisoner's dilemma.

Some evidence of the importance of cash-flow considerations in determining cooperative loyalty emerged from interviews with farmers. Several fruit and vegetable farmers reported selling crops produced on their own land to their co-op and crops produced on rented land to investor-owned firms (IOFs). In the presence of imperfect capital markets, the farmers needed the immediate payment for the crop provided by the IOFs in order to pay their land rent; for crops produced on their own land they could afford to accept the deferred payment typical of fruit and vegetable processing cooperatives.

24 If the cost of lobbying for each group rose above 6, it would no longer even pay C to lobby, and a new equilibrium would occur, in which neither party would lobby and the old plant would remain at site 1. This illustrates a further point discussed below: high transaction costs, by reducing the likelihood that a cooperative will frequently changes its existing policies, protect the utility of those favored by existing policies (in this case, members of C, who prefer that the plant remain at site 1).

25 Several board members interviewed by the author cited access to such information as a major benefit of serving on the board.

26 Low price is but one component of the benefits (payoffs) available from a cooperative (see Staatz, 1986b). Quality of service and provision of certain public goods (e.g., lobbying, enforcement of competition) have traditionally been major benefits of cooperatives. Nonetheless, prices are important, as the recent emergence of "superlocal" or "miniregional" supply cooperatives in the Midwest demonstrates. These are large local co-ops that have defected from their regionals to deal directly with suppliers because the prices available from the suppliers were substantially below those available from the regionals.

Citations

Axelrod, Robert, and William D. Hamilton. "The Evolution of Cooperation." Science 21 (27 March 1981): 1390-96.

Bacharach, Michael. Economics and the Theory of Games. Boulder, Colorado: Westview Press, 1977.

Baumol, William J., John C. Panzar, and Robert D. Willig. Contestable Markets and the Theory of Industry Structure. New York: Harcourt, Brace, Jovanovich, Inc., 1982.

Buchanan, James M., and Gordon Tullock. The Calculus of Consent. Ann Arbor: The University of Michigan Press, 1962.

Caves, Richard E., and Bruce C. Petersen. "Cooperatives' Share in Farm Industries: Organizational and Policy Factors." Harvard Institute of Economic Research, Discussion Paper Number 974. Cambridge: March 1983.

Clark, John Maurice. Studies in the Economics of Overhead Costs. Chicago: The University of Chicago Press, 1923.

Faulhaber, Gerald R. "Cross-Subsidization: Pricing in Public Enterprises." American Economic Review 65, no. 5 (December 1975): 966-77.

French, Ben C. "The Analysis of Production in Agricultural Marketing: Models, Methods and Progress." In A Survey of Agricultural Economics Literature, vol. I, edited by Lee R. Martin, pp. 90-206. Minneapolis: University of Minnesota Press for the American Agricultural Economics Association.

Hardie, Ian W. "Shadow Prices as Member Returns for a Marketing Cooperative." American Journal of Agricultural Economics 51 (1969): 818-33.

Harsanyi, John C. "Approaches to the Bargaining Problem Before and After the Theory of Games: A Critical Discussion of Zuethen's, Hicks' and Nash's Theories." Econometrica 24 (January, 1956): 144-57.

Helmberger, Peter G., and Sidney Hoos. "Cooperative Enterprise and Organization Theory." Journal of Farm Economics 44 (May 1962): 275-90.

_______________. Cooperative Bargaining in Agriculture. Berkeley: University of California, Division of Agricultural Sciences, 1965.

Hirschman, Albert O. Exit, Voice and Loyalty. Cambridge, Mass: Harvard University Press, 1970.

Kuhn, Alfred, "Osuukunnan kiinteijo (stabiliteetti), Olemassaolon turvaaminen ja voitonjako--peliteoreettinen malli." The Stability, Preservation, and Profit Allocation of a Cooperative: A Game-Theoretic Model. In Osuustoimannan teoriaa ja kaytantoa, edited by Alice Wesphalen, pp. 23-93. Department of Cooperatives, University of Helsinki, 1974. Translated from "Theorie und Praxis der Kooperation." Schriften zur Kooperationsforschung. A Studien Band 3 (1972). Summarized by Ollila.

Lopez, Rigoberto A. and Thomas A. Spreen. "A Conceptual Analysis of Processing Cooperatives." Selected paper presented at the American Agricultural Economics Association meetings, West Lafayette, Indiana, July 31-August 3, 1983, Mimeo.

Luce, R. D. and H. Raiffa. Games and Decisions. New York: John Wiley and Sons, 1957.

Murray, Gordon C. "Management Strategies for Corporate Control in British Agricultural Co-operatives--Part I." Agricultural Administration 14 (1983a): 51-63.

_______. "Management Strategies for Corporate Control in British Agricultural Co-operatives--Part 2." Agricultural Administration 14 (1983b): 81-94.

_______. "Towards an Agricultural Co-operative Classification." Journal of of Agricultural Economics 34, no. 2 (May 1983c): 151-61.

Ollila, Petri. "Member Influence in Cooperatives: Contributions of Scandinavian Studies to Research Conducted in the United States." Master's Plan B Paper, Michigan State University, 1983.

Phillips, Richard. "Economic Nature of the Cooperative Association." Journal of Farm Economics 35 (1953) 74-87.

Raiffa, Howard. The Art and Science of Negotiation. Cambridge, Mass.: The Belknap Press of Harvard University Press, 1982.

Ratchford, C. Brice. "Competition among Cooperatives." In Research on Cooperatives in the 1980s, pp. 83-84. U.S. Department of Agriculture, Agricultural Cooperative Service Staff Report, 1983.

Rhodes, V. James. The Agricultural Marketing System. Columbus, Ohio: Grid Publishing, 1978.

Roberts, Marc J. "An Evolutionary and Institutional View of the Behavior of Public and Private Companies." American Economic Review 65, no. 2 (May 1975): 415-27.

Roth, Alvin E. Axiomatic Model of Bargaining. New York: Springer-Verlag, 1979.

Schotter, Andrew. The Economic Theory of Social Institutions. New York: Cambridge University Press, 1981.

Schotter, Andrew, and Gerhard Schwodiauer. "Economics and the Theory of Games: A Survey." Journal of Economic Literature 18, no. 2 (June 1980): 479-527.

Shubik, Martin. "Information, Theories of Competition, and the Theory of Games." Journal of Political Economy 60, no. 2 (April 1952): 1945-50.

Staatz, John M. "The Cooperative as a Coalition: A Game-Theoretic Approach." American Journal of Agricultural Economics 65, no. 5 (December 1983): 1084-89.

______. "A Theoretical Perspective on the Behavior of Farmers' Cooperatives." Ph.D. Dissertation, Michigan State University, 1984. Reprinted as Agricultural Economics Staff Paper No. 84-27.

______. "The Structural Characteristics of Farmer Cooperatives and their Behavioral Consequences," in this volume, 1986a.

______. "Farmers Incentives to Take Collective Action Via Cooperatives: A Transaction-Cost Approach," in this volume, 1986b.

Swank, C. William. "Competition Among Cooperatives and Relationships of Operating Cooperatives, Bargaining Associations, and Farm Organizations." In Research on Cooperatives in the 1980s, pp. 80-82. U.S. Department of Agriculture, Agricultural Cooperative Service Staff Report, 1983.

Taylor, Michael. Anarchy and Cooperation. New York: John Wiley and Sons, 1976.

Zusman, Pinhas. "Group Choice in an Agricultural Marketing Co-operative." Canadian Journal of Economics 15, no. 2 (May 1982): 220-34.