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# *The Logic of Collective Action: A Retrospective View*

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Market failures and coordinated activities of groups of individuals are the topic of Mancur Olson's book The Logic of Collective Action. Basic themes and insights of Olson's The Logic are surveyed updated by analyzing some important advances in the theory. The basic premise of The Logic is that individual rationality is not sufficient for collective rationality. Three themes support this premise: (1) Group size is, in part, behind collective irrationality; (2) Group asymmetry, in terms of membership tastes and/or endowments, is related to collective irrationality; and (3) Group irrationality may be overcome through selective incentives and institutional rules and designs. New developments have included: the theory of clubs (voluntary groups who provide a public good and are able to exclude non-members), the neutrality theorem (the provision of a public good is invariant to income redistributions among a set of contributors), dynamic considerations (any collectivally rational strategy can be an equilibrium to a repeated game), strategic assumptions (non-Nash behavior could yield different outcomes), and uncertainty and collective action (uncertain benefits may yield different outcomes). The analysis yields a theory of market failure and collective action that is more applicable to specialized issues of policy reform.

# THE LOGIC OF COLLECTIVE ACTION: A RETROSPECTIVE VIEW*

> The rational individual in the economic system does not curtail his spending to prevent inflation (or increase it to prevent depressions) because he knows, first, that his own efforts would not have a noticeable effect, and second, that he would get the benefits of any price stability that others achieved in any case. (Mancur Olson, 1965, p. 166).

In the last twenty-five years, few books in economics have achieved the wide-ranging and profound impact as that of The Logic of Collective Action by Mancur Olson (1965). The book's influence is noteworthy for at least three reasons. Firstly, its analysis of collective action has transcended economics and has altered thinking about group behavior in sociology and political science (especially international relations). Prior to Olson's contribution, groups and political collectives were invariably viewed as furthering their members' and constituency's well-being. Secondly, the book has influenced thought on a host of topics within economics including the study of unions, local public goods, economic growth, macroeconomics, military alliances, jurisdictions, environmental questions (e.g., voluntary compliance), and public choice (e.g., voting behavior, pressure groups). Thirdly, Olson's book contained the rudiments of the theory of clubs, which was more formally developed by James Buchanan (1965).

Although The Logic of Collective Action (hereafter called The Logic) is rich in propositions, analysis, and applications, the book rests on a single basic premise: individual rationality is not sufficient for collective rationality. This premise stands in stark contrast to Adam Smith's invisible hand, which indicates that individual pursuit of self-interest in competitive, private goods markets will further the collective interest. Unlike the invisible hand theorem, The Logic concerns pure public goods, impure public goods, and externalities (uncompensated interdependencies). Such market failures involve quantity-constrained behavior: for example, the public good

provided by the rest of the community is not a choice variable and, consequently, represents a constraint additional to the standard resource or budget constraint (Richard Cornes and Todd Sandler, 1986, ch. 3, 5, 17). The presence of this quantity constraint can cause independent adjustment in the form of Nash behavior[1] to deviate from Pareto optimality, thereby leading to the suboptimality, characteristic of many collective-action problems.

The purpose of this paper is to distill the basic themes and insights of The Logic. In addition, the development of these themes are brought up-to-date by analyzing some important advances and clarifications of Olson's original analysis. Finally, areas requiring further study and critical evaluation are identified. There is no attempt here to provide an exhaustive survey of the literature spawned by The Logic.[2] Such an endeavor would involve many hundreds of references. Rather, we will refer selectively to either pivotal contributions or else representative articles. Even though twenty-five years have elapsed since the book's publication, the problems of collective action are no less important today than yesterday and form the basis for understanding aspects of some of the most-pressing problems confronting mankind including the preservation of the ozone layer, the prevention of global warming, the storage of nuclear waste, the proliferation of nuclear weapons, eradication of diseases (e.g., AIDS, cancer), the control of transnational terrorism, the formation of economic and military alliances, and the preservation of tropical forests and other natural habitats. Each of these exigencies requires individual agents (i.e., nation-states, firms, individuals) to form groups to pursue a shared goal. With the continuing transformation of Eastern Europe, policy reform will have to face such collective-action issues as the provision of public inputs (i.e., inputs that

are nonrivalrous and nonexcludable among economic agents), the enactment of cooperative agreements with Western nations, and the establishment of market and nonmarket structures.

The remainder of the paper is organized into eight sections. Section I indicates the three basic themes of The Logic. A brief presentation of Olson's formal model is contained in Section II, where suboptimality and the requirements of a privileged group are established. In Sections III-V, the development of each of the basic themes and their subcomponents are investigated. New developments in collective action (e.g., the neutrality theorem for pure public goods, strategic analysis) and their relationship to basic themes are studied in Section VI. Representative applications are presented in Section VII. Concluding remarks then follow in Section VIII.

## I. BASIC THEMES

For a book of the scope and intellectual achievement of The Logic, it is, indeed, a difficult task to reduce the work's message to a few simple themes. Nevertheless, I have attempted to accomplish this distillation by identifying three simple basic themes and subcomponents. Each of these themes are listed below, accompanied by any relevant subcomponent:

1. Group size is, in part, behind collective irrationality.
   a. Large groups may not provide themselves with a collective good; hence, no individual or coalition within the group may satisfy the sufficient condition of a privileged group.
   b. The larger the group, ceteris paribus, the greater the departure of Nash equilibrium from Pareto optimality.
2. Group asymmetry, in terms of membership tastes and/or endowments,

is related to collective irrationality.

a. Larger members (those with the greater endowments) will bear a disproportionate burden of collective provision. "There is a systematic tendency for exploitation of the great by the small." (Olson, 1965, p. 35).

b. Asymmetric groups are more likely to be privileged.

3. Group irrationality may be overcome through selective incentives (giving private benefit inducements) and institutional rules and design.

Before remarking briefly on each of these themes, we present a few definitions. Olson (1965) uses collective action in a general sense to refer to any problem with benefits and/or costs for more than one individual. Collective action, thus, includes externalities of all types as well as the provision of pure public goods, nonexcludable impure (partially rivalrous) public goods, and excludable club goods. Much of the confusion over the validity of Olson's themes or propositions stems from his all-encompassing notion of collective action. Although The Logic's general propositions are valid for many collective-action scenarios, researchers had wide latitude to construct specific cases that might violate the propositions; e.g., public goods with unique technologies of aggregation (Jack Hirshleifer's, 1983, weakest-link case), public goods characterized by inferior income elasticities (Cornes and Sandler, 1984a; 1986, ch. 5), or public goods with strategic assumptions at variance with Nash behavior (Joel Guttman, 1987).

A privileged group contains at least one individual or coalition whose benefits from collective action exceed the associated costs even if the costs are solely borne by the individual or coalition. When the sufficiency

condition for privileged groups is not met, but the group is sufficiently small that members take note of those who assist collective action, the group is intermediate and may still form. If, however, the group is neither privilege nor intermediate, then it is latent and does not form. From a practical standpoint, there is no operational definition given for intermediate group. By examining the net benefits for each potential participant (individual or coalition), one can determine whether the group is privileged or not, but the notion of intermediacy has never been given a clear-cut criterion for identification. If, say, a group of four is not privileged, it may still be intermediate and, thus, form. Intermediacy in these cases can only be determined by inspection to see whether the group provides itself with the collective good. Since we intend to analyze equilibria using explicit payoff criteria, we must eschew the concept of intermediate group and distinguish solely between privileged and nonprivileged or latent groups.

Theme 1 has received much attention in both the theoretical (e.g., John Chamberlin, 1974; Martin McGuire, 1974; James Andreoni, 1988a) and experimental literature (e.g., R. Mark Isaac and James Walker, 1988; Isaac, Walker, and Susan Thomas, 1984; Oliver Kim and Mark Walker, 1984). In general, the theoretical literature has identified some bounds to the underlying propositions of Theme 1, based on the distribution of collective benefits (i.e., the "technology" of publicness), income elasticity considerations, the composition of membership, the strategic assumption, intertemporal aspects, and the presence of multiple benefits. The experimental literature has provided mixed findings to date.

Theme 2 concerning asymmetry has generated an empirical literature

following Olson and Richard Zeckhauser's (1966) study of the NATO alliance, a privileged group influenced by a dominant player--the United States. The manner in which asymmetry is handled is crucial in the establishment of the associated propositions in subsequent contributions (e.g., Andreoni, 1988a; McGuire, 1974; Theodore Bergstrom, Lawrence Blume, and Hal Varian, 1986). If all goods are normal with income elasticities in the open unit interval, and if tastes are identical, then a one-parameter distribution of income can order contributors from highest to lowest based solely on income (Andreoni, 1988a). Theme 2 would then hold: wealthier participants contribute more than poorer members. Heterogeneity of tastes could complicate matters considerably unless participants can still be ordered in some single-parameter fashion that relates to size. Inferior goods can give results at odds with Theme 2 (McGuire, 1974; Cornes and Sandler, 1981, 1984a). Inferiority is also consistent with multiple equilibria and instability. In fact, asymmetric contributions may then characterize stable equilibrium for identical individuals (Cornes and Sandler, 1986, p. 78).

In terms of the policy-oriented Theme 3, much work[3] has been done in analyzing joint product models, in which the collective activity yields multiple outputs that vary in their degree of publicness. Some outputs may be private, while others purely or impurely public. Much less attention has been paid to the more important policy component of Theme 3--i.e., the design of institutional rules to provide the proper incentives to surmount collective-action impediments. In The Logic, Olson focused on the use of federated structures that fostered closer contact between participants and that reduced the size of subgroupings. Federal structures characterize labor unions and some charities (e.g., the United Fund). In recent years, investigators have

examined the effects of institutional rules on the underlying game structure (e.g., Elinor Ostrom and Shmuel Nitzan, 1990; Cornes and Sandler, 1984b; Anthony de Jasay, 1989; Joel Guttman, 1987; C. Ford Runge, 1984; Irwin Lipnowski and Shlomo Maital, 1983; Amartya Sen, 1967). Theme 3 is also associated with the use of coercion to engineer group compliance. As Guttman (1978) has recognized, coercion must itself be financed and this raises other issues concerning the manner in which resources are earmarked toward coercion. Resources devoted to coercion cannot be used for provision of the collective good.

All three themes and their components are developed further in Section III.

## II. OLSON'S MATH

Olson's (1965, pp. 22-36) formal model concerned a group sharing a public or collective good, whose rivalry aspects are never made explicit. Where possible, we employ Olson's notation:

where $Q$ = provision level of collective good;

$q^i$ = individual contribution to the collective good;

$\bar{Q}$ = the contribution of the rest of group to the collective good;

$C$ = cost of total collective provision;

$C_i$, $C_n$ = cost to the individual; cost to the coalition;

$S_g$ = "size" of group in terms of the gain per unit of provision;

$V_i$, $V_n$, $V_g$ = value to the individual; value to coalition; value to

the group;

$A_i$, $A_\Omega$ = net gain to individual; net gain to coalition;

$F_i$, $F_\Omega$ = fraction of group gain to the individual; fraction of group gain to the coalition.

$G$ = the set of group members;

$\Omega$ = subset of group members.

Given these definitions, the following identities hold:

(1) $F_i = V_i/V_g$,

(2) $V_g = S_g Q$.

Equation (1) relates to the underlying technology of publicness in which each individual receives a fraction of the group's benefit. Since (1) embodies both the utility function and the technology of publicness, the exact nature of rivalry, if any, is not clear. Equation (2) relates provision to group gains.

The sufficient condition for a privileged group is met provided that

(3) $A_\Omega = V_\Omega - C_\Omega > 0$

for at least one subset or coalition drawn from the group ($\Omega \in G$). Since (3) considers all subsets, it accounts for the case where a single individual meets the condition ($A_i = V_i - C_i > 0$).

The general suboptimality of the collective-action problem posed by Olson is established by comparing the Nash equilibrium and the Pareto optimality condition. By (1) and (2), the objective function in (3) for the Nash problem can be written as

$$\max_{q^i}[F_i S_g Q - C_i(q^i)],$$

where individual cost, $C_i$, is assumed to be an increasing linear function of provision. Furthermore, total provision for the group is the sum of the individual's provision, $q^i$, and the aggregate provision of the other individuals, $\tilde{Q}$, so that $Q = q^i + \tilde{Q}$. For independent adjustment or Nash behavior, each individual treats the optimizing provision level of the rest of the group as a parameter. The cost function for the individual and that for the group are assumed identical with constant marginal cost, so that $dC/dQ = dC_i/dq^i = k$ for all Q and $q^i$, where k is a constant. The first-order condition[4] (FOC) for the Nash problem is

(4) $F_i dV_g/dQ - dC_i/dq^i = 0,$

in which the concave funciton $V_g$ has replaced $S_gQ$. Since $S_g$ can depend on Q, $V_g$ does not have to be linear in Q. Henceforth, we assume that $V_g$ is a strictly concave function of Q. In (4), the individual's marginal benefit equals the marginal cost of provision. When (4) <u>holds for each</u> i, a Nash equilibrium is achieved. The <u>simultaneous</u> satisfaction of the system of FOCs in (4) determines an optimizing vector of $q^i$ for every i. The sum of these optimizing $q^i$s is the Nash quantity, $Q^N$, that satisfies (4) for each i. This $Q^N$ can be compared with the Pareto-optimizing quantity to establish suboptimal Nash provision.

A Pareto optimum corresponds to

$$\max_Q (V_g - C),$$

where the group's net benefits are maximized. The Pareto optimum must fulfill the following FOC:

(5) $dV_g/dQ - dC/dQ = 0.$

Denote $Q^*$ as the $\text{argmax}(V_g - C)$. If $Q^N$ is used to evaluate the left-hand side

of (5), then

$$(6) \qquad \frac{dV_g(Q^N)}{dQ} - \frac{dC(Q^N)}{dQ} > 0,$$

since marginal cost evaluated[5] at $Q^N$ equals $F_i \cdot dV_g(Q^N)/dQ$ by (4), where $0 < F_i < 1$. By (6) and the strict concavity of the objective function, we then have

$$Q^N < Q^*$$

so that the Nash quantity implies too little provision and, hence, suboptimality.[6]

Although suboptimality follows immediately from Olson's model, the effects of group size on the degree of suboptimality (i.e., the relationship between $Q^N/Q^*$ as n changes) is not dealt with explicitly, because the relationship of costs and benefits to group size is not given. Moreover, without these relationships, an explicit theory of clubs cannot be established formally (see Section VI). Comparison of Olson's model to recent treatments of collective action is also inhibited since Olson collapsed the utility function and its component arguments, including the important technology of publicness, into a benefit function. Even though Olson (1965, p. 47) raised the notion of transaction costs and their relationship to group size, the formal model does not account for these costs.

## III. GROUP SIZE AND COLLECTIVE IRRATIONALITY

There are three separate questions related to the influence of group size on collective irrationality: Will group size be a factor in determining whether any of the collective good is provided? Will collective good provision decrease with group size? Will suboptimality increase with group

size? Although each of these questions share common features, each is considered in seriatim.

## A. GROUP SIZE AND PRIVILEGED GROUPS

Whether any of the collective good is provided or not depends on the notion of privileged. Olson (1965, pp. 33-34, 48) argued that larger groups are less likely, ceteris paribus, to be privileged than a smaller group, since an individual's (coalition's) share of the group benefit from collective action declines with group size. If $F_n$ decreases with group size and if, moreover, group's benefits and costs are independent of group size, then Olson's relationship would hold (see equation (3)). If, however, an individual's cost decreases with group size, then the fall in an individual's fraction of the group gain may be offset by the decline in cost, thereby ensuring that the group remains privileged. Institutional rules may play a role here. If, say, provision costs are shared among group members regardless of the contributor, then individual cost would fall with membership size. In consequence, the requirements of being privileged may not depend on group size.

The conditions for a privileged group may also hinge on the technology of publicness and its relationship to the underlying game structure or payoff matrix (Cornes and Sandler, 1986, ch. 7; Ostrom and Nitzan, 1990; Runge, 1984). The technology of publicness refers to the manner in which individuals' provision levels are aggregated to yield group provision. Since the possible technologies are endless, we must focus on a few noteworthy cases. The most common technology is that of summation:

$$(7) \quad Q = \sum_{i=1}^{n} q^i,$$

where $q^i$ is the collective good's provision level of individual i, and n is group size. Summation implies perfect substitutability between the $q^i$s. The removal of a pollutant from a shared ecosystem may abide by (7) as may nuclear deterrence derived from a strategic arsenal. When, however, location or the identity of the provider influences the resulting level of the public good received by the group, summation is no longer an appropriate representation. For cases in which substitutability is less than perfect, then individualized weights may have to be applied to the $q^i$s or else a different functional relationship may be needed. In the case of two individuals, total provision may have the following form:

(8) $Q = w^1q^1 + w^2q^2$,

in which $0 \leq w^i \leq 1$ for $i = 1, 2$.

An important technology is that of weakest-link, in which

(9) $Q = \min(q^i, \ldots, q^n)$,

so that the smallest provision level of the group determines collective provision (Hirshleifer, 1983; Glenn Harrison and Hirshleifer, 1989). Weakest-link may apply to the scenario where a military alliance fortifies a perimeter against a common threat. If security depends on keeping the enemy from breaking through, then the poorest fortification along the front determines collective security. Prophylactic actions to forestall the advance of a disease, a plague, or pest may also abide by the weakest-link technology. Hirshleifer (1983) gave the apt example of dike building. In contrast, a best-shot technology,

(10) $Q = \max(q^i, \ldots, q^n)$,

equates provision to the largest individualized effort. The discovery of a cure for a disease is an example of best-shot, as is the more fanciful example

of dragon slaying.

For the case of two agents, the technology in (8) corresponds to weakest-link when $w^1 = 1$, $w^2 = 0$, and $q^1 < q^2$; to best-shot when $w^1 = 0$, $w^2 = 1$, and $q^1 < q^2$; and to summation when $w^1 = w^2 = 1$. The weighting scheme in (8) could, of course, be generalized to n individuals by ordering the $q^i$s from lowest to highest. Whenever the weights are interior to the unit interval, none of the three special technologies applies.

The technology of publicness is behind the notion of selective incentives and joint products. It also plays a pivotal role in determining crowding in the modern treatment of clubs (see, e.g., Sandler and John Tschirhart, 1980). Once the technology of publicness is specified, it is substituted into the individual's utility function; e.g.,

(11) $U^i = U^i[\min(q^i, \ldots, q^n), y^i]$,

where $U^i$ is the ith person's utility and $y^i$ is the ith person's private good consumption. When (11) is optimized subject to the relevant constraints, the various equilibria (Nash, Pareto) can be found.

In the case of joint products, a collective action gives rise to multiple outputs. Suppose that each unit of $q^i$ yields $\gamma$ units of a private output, x, and $\delta$ units of a pure public benefit, z. For individual i, the technology implies

(12) $x^i = \gamma q^i$,

(13) $z^i = \delta q^i$.

If the technical parameters do not differ between agents and if, moreover, total public output, Z, abides by summation, then the ith agent's utility

function can be written as

$$(14) \quad U^i = U^i(y^i, x^i, Z)$$
$$= U^i(y^i, \alpha q^i, \sum_{i=1}^{n} \beta q^i).$$

The joint product model is sufficiently flexible to apply to many situations including charity, foreign aid, police protection, education, or defense. Relevant situations involve those in which contributions to the collective action are motivated by private and public benefits.

To illustrate how the technology, the institutional rules, and/or configuration of costs and benefits affect whether the good is provided, we present a few noteworthy 2-person, normal-form games that may arise from slight variations in a basic scenario. In Figure 1, six game forms are displayed. In each of the six matrices, player 1's strategies correspond to the row, while player 2's strategies correspond to the columns. The first payoff in any box is that of player 1, while the second is that of player 2.

If benefits abide by summation, and if, moreover, individual cost of provision exceeds individual benefit, then a prisoner's dilemma may apply. Assume that each individual may provide a unit of the collective good. Further assume that each unit gives a benefit of 5 to each and every individual, contributor and noncontributor alike at a cost of 6 to just the provider. If both agents contribute, then each receives a net benefit of 4, which corresponds to 5 times the number of contributors minus the individual cost of 6. If, however, only one person contributes, then the noncontributor receives the benefit of 5 without any cost, while the contributor receives −1 after the cost is deducted. When neither contributes, the payoffs are zero. The dominant strategy, which is the best individual response regardless of the other player's strategy, is to defect and not contribute; hence, the group

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**FIGURE 1**
**EXAMPLES OF 2 X 2 GAMES**

PRISONER'S DILEMMA

| 1 \ 2 | Cooperate | Defect |
|---|---|---|
| Cooperate | a: 4, 4 | b: −1, 5 |
| Defect | c: 5, −1 | d: 0, 0 |

FULLY PRIVILEGED

| 1 \ 2 | Cooperate | Defect |
|---|---|---|
| Cooperate | a: 6, 6 | b: 1, 5 |
| Defect | c: 5, 1 | d: 0, 0 |

CHICKEN (−x < −1)

| 1 \ 2 | Cooperate | Defect |
|---|---|---|
| Cooperate | a: 4, 4 | b: −1, 5 |
| Defect | c: 5, −1 | d: −x, −x |

COORDINATION
(BATTLE OF THE SEXES)

| 1 \ 2 | Cooperate | Defect |
|---|---|---|
| Cooperate | a: 1, 1 | b: 1, 5 |
| Defect | c: 5, 1 | d: 0, 0 |

ASSURANCE 1

| 1 \ 2 | Cooperate | Defect |
|---|---|---|
| Cooperate | a: 4, 4 | b: −3, −3 |
| Defect | c: −3, −3 | d: 0, 0 |

ASSURANCE 2
(NO REFUND GAME)

| 1 \ 2 | Cooperate | Defect |
|---|---|---|
| Cooperate | a: 4, 4 | b: −6, 0 |
| Defect | c: 0, −6 | d: 0, 0 |

remains latent unless other considerations (e.g., intertemporal, enforcement) are included. In the prisoner's dilemma, individual rationality leads to collective irrationality, since the Nash equilibrium in cell d is a Pareto-inferior outcome to the mutually cooperative situation in cell a. Even if the two players communicate and agree to cooperate, the agreement is not self-enforcing because each has the incentive to defect once the other player cooperates. Unless intertemporal considerations are included (see Section VI), the prognosis is bleak even with just two players.

When, however, individual benefit exceeds individual cost and summation applies, the group is fully privileged. For instance, suppose that each unit of the collective good yields a benefit of 5 to each and every individual at a cost of 4 to the provider. Once again benefits are summed over the units provided. In the upper right-hand matrix of Figure 1, full cooperation gives each player a net gain of 6 (= 5 x 2 − 4). If one person defects, then the contributor gains 1, while the defector gains 5. The dominant strategy is to cooperate; hence, there is no collective irrationality and the group is fully privileged. With this payoff scheme, the number of players would have no effect whatsoever on whether the good is provided--group size is irrelevant. The irrelevancy of group size is driven by the linearity in benefits and costs.

The game of chicken can be generated by a slight alteration to the payoff arrangement in the prisoner's dilemma if a penalty (−x) greater than the payoff of −1 (associated with cooperating when the other player defects) is imposed on both players for mutual defection. The 2 x 2 chicken game has no dominant strategy, but it has two pure-strategy[7] Nash equilibria in cells b and c. A sufficient sized penalty eliminates the latent group outcome as an

equilibrium and, thus, ensures that some of the collective good is provided. The averting of national disasters and the provision of needed infrastructure may correspond to the game of chicken, since the status quo of no action spells significant penalties (see, e.g., Lipnowski and Maital, 1983). The confrontation of superpowers in a crisis (i.e., Brinkmanship) may also correspond to the game of chicken (Thomas Schelling, 1960). Thus, game structures very similar to the prisoner's dilemma need not imply the absence of collective provision.

Next consider a "coordination" game based on the best-shot technology. Suppose that the first unit of the collective good provided gives a benefit of 5 to each and every member, but that additional units add no benefit. Since each agent can provide only a single unit by assumption, the first unit provided denotes the best-shot, Further suppose that each unit costs 4. In Figure 1, the associated coordination game has no dominant strategy, but it does have two pure-strategy Nash equilibria in cells b and c. Mutual cooperation yields 1 to each person, as costs of 4 are subtracted from benefits of 5. The other payoffs are derived similarly. The coordination game has a payoff structure reminiscent of the battle of the sexes game (R. Duncan Luce and Howard Raiffa, 1957, p. 90).[8] For the coordination game, the players must decide how to <u>alternate</u> efforts since no provision as well as mutual provision are not the most desirable outcomes. A coordination game may result when a standard technology is being considered for a new consumer product (e.g., video recorders). In Figure 1, cooperation would then correspond to embracing 1's standard, while defection would correspond to embracing 2's standard. The adoption of a single standard is (weakly) preferred from both players' viewpoint. Although each player wants his

standard adopted, each prefers some standard to none (Joseph Farrell, 1987).[9] Coordination games need not result in a latent group.

In the bottom two matrices of Figure 1, two different "assurance" games are displayed. In the left-hand matrix, two units of the collective good gives benefits of 10 (5 per unit) to each and every player at a total group cost of 12 (6 per unit), which is equally shared. Thus, mutual cooperation yields (4, 4). If, however, only a single unit is provided, then no benefits are received and each player must split the cost of 6. The assurance game may relate to the scenario in which a minimal effort (here two units) must occur to receive benefits [see, Thomas Palfrey and Howard Rosenthal (1984) analysis of discrete public goods]. In the above example, both players must contribute if either is to receive benefits from their own actions. The fighting of a fire (forestalling a disaster) that neither player can put out (achieve) alone is an example. The assurance game has no dominant strategy, but does possess two pure-strategy Nash equilibria in cells a and d. Cell a Pareto dominates cell d, but may not be the outcome unless the players can rely on one another (de Jasay, 1989; Roy Gardner, Ostrom, and Nitzan, 1989; Runge, 1984; Sen, 1967). When one player fulfills a pledge to cooperate, the contract is, unlike the prisoner's dilemma, self-enforcing, since the other player has strong incentives to carry out his own pledge. Even without an enforcement mechanism, contracting can overcome collective irrationality in assurance situations.

The second variation of the assurance game differs in terms of an institutional rule--i.e., costs are not shared but are assigned to the provider. Although the equilibria in pure-strategy space is unaffected, there are subtle changes that become more apparent below when generalized to n

persons. In assurance 2, mutual defection is more likely especially in mixed-strategy space. This assurance game corresponds to the provision of a discrete public good without refund (Palfrey and Rosental, 1984).

Figure 2 illustrates three 2 x 2 games when weakest-link applies and each agent can contribute up to one unit of the public good. In the top matrix, each player receives benefits of 5 provided that each contributes a unit or match one another's provision. When both contribute, each receives net benefits of 1 since each agent must deduct costs of 4. If neither contributes, then the contributor loses his cost of 4 and the noncontributor gains nothing. The ordinal structure of this game is identical to assurance 2. The two pure-strategy Nash equilibria correspond to cells a and d, and involve matching behavior among agents. For identical individuals, the Nash equilibrium, matching outcome is Pareto optimal (Hirshleifer, 1983; Harrison and Hirshleifer, 1989; and Dennis Mueller, 1989, pp. 21-25). Since units provided beyond the lowest provision amount adds to cost with no resulting benefit, there is no incentive in weakest-link to outdo the smallest spender. The remaining two matrices in Figure 2 are based on the same scenario except for penalties being incurred for mutual defection. In the left-hand bottom game, a small penalty (less than unit cost) is imposed on the two players, while in the right-hand game, a large penalty (greater than unit cost) is imposed on the two players. With large penalties, cooperation is dominant and the group is fully privileged; with small penalties, mutual defection remains a pure-strategy, Nash equilibrium for weakest-link. Nature-imposed sanctions attached to the status quo can assist groups to a Pareto-optimal outcome.

Before generalizing these games to their n-person counterparts, we draw a couple of conclusions. Firstly, the above examples indicate that

FIGURE 2
FURTHER EXAMPLES OF 2 X 2 GAMES

(WEAKEST LINK)

| | | 2: Cooperate | 2: Defect |
|---|---|---|---|
| 1 | Cooperate | a<br>1, 1 | b<br>−4, 0 |
| | Defect | c<br>0, −4 | d<br>0, 0 |

(Like Assurance 2 - No Refund Game)

| | | 2: Cooperate | 2: Defect |
|---|---|---|---|
| 1 | Cooperate | a<br>1, 1 | b<br>−4, 0 |
| | Defect | c<br>0, −4 | d<br>−1, −1 |

NOT FULLY PRIVILEGED
(SMALL PENALTIES FOR STATUS QUO)

| | | 2: Cooperate | 2: Defect |
|---|---|---|---|
| 1 | Cooperate | a<br>1, 1 | b<br>−4, 0 |
| | Defect | c<br>0, −4 | d<br>−5, −5 |

FULLY PRIVILEGED
(LARGE PENALTIES FOR STATUS QUO)

collective-action problems need not imply a prisoner's dilemma. We, thus, take issue with Russell Hardin's (1987, p. 25) statement: "Indeed, the problem of collective action and the prisoner's dilemma are essentially the same. . . ." The two are not the same. Secondly, for small groups, the existence of a privileged group may depend on the technology of public supply, the payoff structure, or the institutional rules. The form of the utility function, which translates units of the collective good into a utility index may also play a role in determining whether a group is privileged.

Five of the six 2-person games of Figure 1 are generalized to n persons in Figure 3. The first two rows of the top matrix corresponds to the prisoner's dilemma where j denotes the number of contributors besides i. The columns refer to the actions of the other contributors, while the rows indicate the strategy of the ith player. The payoffs listed are those of individual i. Every unit contributed yields 5 in benefits to each and every individual at a cost of 6 to the contributor. The defect strategy dominates, regardless of the number of contributors; hence, the Nash equilibrium implies a latent group.

If, for the prisoner's dilemma, a penalty could be imposed on a defector, cooperation could be transformed into the dominant strategy. Any penalty larger than the <u>net gains from defecting</u> will work. If, say, a penalty of 1.2 is imposed, then the cooperative strategy would dominate in the top matrix of Figure 3. The greater the net gain from defecting, the larger the required penalty for defecting. The institution of the enforcement mechanism raises collective-action problems of its own. Although it is in each participant's self-interest to have an enforcement mechanism to operate on everyone else, each would prefer that the mechanism did not apply to them.

FIGURE 3
EXAMPLES OF n-PERSON GAMES

Number of Cooperators in Group Besides i

| | 0 | . . . | j − 1 | j | j + 1 | . . . | n − 1 |
|---|---|---|---|---|---|---|---|
| i Cooperates | −1 | | 5j − 6 | 5(j + 1) − 6 | 5(j + 2) − 6 | | 5n − 6 |
| i Defects Prisoner's Dilemma | 0 | | 5(j − 1) | 5j | 5(j + 1) | | 5(n − 1) |
| i Defects Chicken | −x | | 5(j − 1) | 5j | 5(j + 1) | | 5(n − 1) |

| | 0 | . . . | j − 1 | j | j + 1 | . . . | n − 1 |
|---|---|---|---|---|---|---|---|
| i Cooperates | 1 | . . . | 1 | 1 | 1 | . . . | 1 |
| i Defects | 0 | | 5 | 5 | 5 | . . . | 5 |

CCORDINATION (BATTLE OF THE SEXES)

| | 0 | . . . | j − 1 | j | j + 1 | . . . | n − 1 |
|---|---|---|---|---|---|---|---|
| i Cooperates | −6/n | | $\frac{-6j}{n}$ | $(5 - \frac{6}{n})(j+1)$ | $(5 - \frac{6}{n})(j+2)$ | | 5n − 6 |
| i Defects | 0 | | $\frac{-6(j-1)}{n}$ | $(5 - \frac{6}{n})j$ | $(5 - \frac{6}{n})(j+1)$ | | $(5 - \frac{6}{n})(n-1)$ |

ASSURANCE 1

| | 0 | . . . | j − 1 | j | j + 1 | . . . | n − 1 |
|---|---|---|---|---|---|---|---|
| i Cooperates | −6 | . . . | −6 | 5(j + 1) − 6 | 5(j + 2) − 6 | | 5n − 6 |
| i Defects | 0 | . . . | 0 | 0 | 5(j + 1) | | 5(n − 1) |

ASSURANCE 2

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One collective-action problem has merely been replaced with another. The financing of the enforcement mechanism is also a concern, since resources must be diverted from cooperative gains (if any) to underwrite the mechanism. Schemes that spread the enforcement costs over the entire group might have the best chance for institution, since individual net gains are more apt to be maintained than if only the subset of cooperating agents are made to support enforcement.

The chicken game (the first and third rows of the top matrix) differs from the prisoner's dilemma in terms of the penalty when everyone defects. There are now a plethora of Nash equilibria--each with a single contributor; hence, the group should be privileged. In the second matrix of Figure 3, an identical set of pure-strategy Nash equilibria characterizes the coordination game, in which a single individual contributes and all others free ride. The group is again privileged even though n may be a large number.

The two assurance games in Figure 3 require at least j + 1 individuals to contribute before a benefit of 5(j + 1) is gained by all n players. Each contributor beyond j + 1 adds another 5 in benefits to each and every player at a provision cost of 6. In assurance 1, costs are equally shared; in assurance 2, only the provider pays. Assurance 1 displays a greater extent of cooperation than assurance 2. For assurance 1, the cooperative strategy actually dominates defection if $n > 6/5$ <u>and at least</u> j players besides i cooperate. There are two pure-strategy Nash equilibria for assurance 1: no one contributes or everyone contributes. As n becomes infinite, the cooperate strategy weakly dominates defection since the penalty for cooperating, when less than j others cooperate, approaches zero. An increase in n augments the likelihood that the group is privileged. This is especially true if mixed

strategies were allowed. A glance at the bottom matrix of Figure 3 indicates that n has no such effect in assurance 2. For the latter game, the cooperative strategy yields a higher payoff only when the ith player is pivotal--i.e., exactly j players besides i contribute. In consequence, the Nash equilibria correspond to the scenarios in which either no one contributes or precisely j + 1 persons contribute. There are $\binom{n}{j+1}$ Nash equilibria where the collective good is realized. Although the number of Nash equilibria is larger for assurance 2 than for assurance 1, the number of contributors is smaller. If simple alterations of institutional rules can reduce the gains from defection, as in assurance 1, then cooperation is fostered. Institutional design can promote the proper incentives, thereby tipping the scales in favor of cooperation. For instance, preference-revelation mechanisms work on the principle of designing institutions so that cooperation (e.g., telling the truth) becomes a dominant strategy (Edward Clarke, 1971, 1972; Theodore Groves, 1973).

Since collective-action problems embrace a wide range of scenarios with differing technologies of public supply and resulting payoff configurations, <u>there is no simple relationship between privelege and group size</u>. For the special, but surely important case, in which per-unit provision costs exceed per-unit benefits from an agent's viewpoint, a prisoner's dilemma game applies and group latency is, indeed, a problem. If group size is to be related to latency in the Olsonian tradition, nonlinearities are needed for the benefit and cost relationships so that net gain vary with group size. When arguing that large groups are likely to be latent, Olson (1965, pp. 46-52) also indicated that transaction or organizational costs are directly related to group size. As group size increases, the transaction costs associated with

initial formation rises and impedes formation. To date, there has been almost no attempt[10] to integrate transaction costs and their relationship to group size into the analysis. Such an integration may well support Olson's hypothesis that group size inhibits formation. By introducing transaction costs, researchers could investigate why many collective-action groups (e.g., the United Nations, NATO) often provide multiple collective goods. Economies of scope that arise from transaction considerations may be behind this fact.

## B. GROUP SIZE AND PROVISION LEVELS

The discrete games presented above do not aid in discovering the relationship between group size and provision level. Appropriate models must permit contributors to choose an optimizing provision level that is continuous. For such models, total provision of a collective good need not fall with an increase in group size. When the collective good and the numeraire are normal, Chamberlin (1974, p. 712) and McGuire (1974, p. 112) proved that total provision increases in a symmetric equilibrium even though each individual's contribution falls with n. Thus, the increased provision of the entrant more than offsets the aggregate decrease in the collective provision of the existing membership. In the symmetric equilibrium case,[11] average contributions decline, while total contributions increase. This latter result is opposite to that conjectured by Olson and derives from income effects generated from the spillover of collective benefits from other participants.

The Chamberlin-McGuire result is established by aggregating individual reaction or expenditure functions over the group membership to derive an expression for total contributions. Following McGuire (1974, pp. 112-113), we assume that everyone is identical with the same endowments and tastes.

Furthermore, the private and public good are assumed normal with income elasticities interior to the unit interval. Finally, linear reaction or expenditure functions,

(15) $q^i = K - \gamma_i \sum_{j \neq i}^{n} q^j, \qquad i = 1, \ldots, n,$

are invoked for each individual. In (15), K is the isolated purchase of the collective good and $1 - \gamma_i$ is the agent's marginal propensity to spend income on the collective good.[12] In a symmetric equilibrium, the subscript on $\gamma$ and superscript on q can be dropped, thereby allowing (15) to be rewritten as

(16) $q = K/[1 + \gamma(n - 1)]$

for each agent. When (16) is summed over all agents, an expression for the Nash level of Q results:[13]

(17) $Q = nK/[1 + \gamma(n - 1)]$.

Differentiating (17) with respect to n gives

(18) $dQ/dn = K(1 - \gamma)/[1 + \gamma(n - 1)]^2 > 0$.

For normal goods, total Nash provision rises, rather than falls, with an increase in group size. As $n \to \infty$, total contributions in (17) approaches $K/\gamma$ by L'Hospital rule (McGuire, 1974, p. 112)--a finite total provision is reached in the limit. This result is easily generalized to nonlinear reaction paths, provided that all goods are normal.

In a recent contribution, Andreoni (1988) has generalized the result of McGuire-Chamberlin to a case where individuals have identical tastes but differ in their income endowments according to a continuous probability density function. The collective good is continuous and normal, and a summation technology characterizes public supply. Andreoni (1988, pp. 59-62) showed that the fraction of the population contributing to a pure public good declines monotonically with n and converges in the limit ($n \to \infty$) to zero (also

see Robert Sugden, 1982). The richest individuals are the contributors. Although average giving falls to zero, total contributions approach a finite limit as $n \to \infty$. For a stylized model where utility functions are placed along a continuum based on a single taste parameter, Andreoni (1988, p. 66) generalized the theorem to the case of heterogeneous tastes. Andreoni also proved that as $n \to \infty$, a single (identical) class of contributors will characterize the equilibrium. Clearly, the convergence of the population's fraction of contributors to zero is in the spirit of The Logic's first theme.

Since so many parameters of the collective-action problem can influence the relationship between group size and provision, it is not surprising that the experimental literature has found mixed results. Gerald Marwell and Ruth Ames (1981) found little relationship between group size and free riding, while Kim and Walker (1984) found strong evidence of a positive relationship as hypothesized in The Logic. In order to study this relationship, the researcher must be explicit about the underlying utility function, the technology of public supply, the strategic assumption (i.e., Nash-Cournot or otherwise), and the budget constraint. Even some of the best treatments to date have eliminated important interactions by assuming a separable utility function, thereby removing the all-important income effect (Issac, Walker, and Thomas, 1983; Isaac and Walker, 1988). Because of experimental cost considerations, researchers are yet to tackle really large (unsimulated) groups in an experimental environment. There is no difficulty in controlling the endowments and constraints of the subjects, but there is difficulty in controlling the distribution of tastes of heterogeneous subjects.

## C. WILL SUBOPTIMALITY INCREASE WITH GROUP SIZE?

The issue most often associated with Theme 1 of The Logic concerns

whether an increase in group size leads to a decrease in efficiency. To address this question, the equilibrium associated with independent-adjustment behavior must be compared with some standard of efficiency as group size increases. Nash-Cournot behavior is typically used as the measure of independent adjustment, while Pareto optimality is the measure of efficiency.

Given the wide array of models encompassed by collective action, the inverse relationship between group size and efficiency cannot be established in any general sense. Nevertheless, some important cases have been shown to abide by Olson's hypothesis. Mueller (1989, pp. 18-21) considered a model in which the technology of public supply is summation and all individuals are identical. When each individual's tastes are represented by a Cobb-Douglas utility function,

(19) $U = y^{\alpha}Q^{\beta}, \qquad 0 < \alpha < 1,\ 0 < \beta < 1,$

(where $\alpha$ and $\beta$ are constant exponents and superscripts denoting individuals are suppressed), the ratio of the Nash equilibrium, $Q^N$, to the Pareto optimum quantity, $Q^*$, equals[14]

(20) $Q^N/Q^* = (\alpha + \beta)/(\alpha n + \beta).$

If n equals 1, then the two equilibria coincide; if, however, n increases, then the departure of the Nash equilibrium from efficiency increases.

In the case of a common property resource (e.g., a fishing grounds), Cornes and Sandler (1983, p. 788) showed that the symmetric Nash equilibrium increasingly depart from Pareto optimality as the number of exploiters increased. Once again, a summation technology characterized the interdependency, and all exploiters were assumed identical. Markets were assumed to be perfectly competitive, and a well-behaved neoclassical production function was invoked.

Cornes and Sandler (1986, pp. 83-84) also established the inverse relationship between group size and efficiency for a quasi-linear utility function,

(21) $U = y + f(Q)$,

in which increments in income are entirely spent on the private good, so that the income elasticity of the public good is zero. In (21), the aggregate supply of the public good is the sum of the individual provision amounts. Increases in group size were shown to increase $Q^*$, while leaving $Q^N$ unchanged.

The inverse relationship between group size and efficiency is also dependent on the technology of supply. By utilizing the Cobb-Douglas utility function in (19), Mueller derived the following expression for the ratio of equilibria:

(22) $Q^N/Q^* = (\alpha + \beta)/[\alpha(1 + w) + \beta]$,

where $0 \leq w \leq 1$ and w denotes a parameter of public supply technology. In the Mueller example, the public good technology is

(23) $Q = q^1 + wq^2$,

which is a special case of (8) with $w^1 = 1$ and $w^2 = w$. Mueller's result in (22) depends on $q^1$ being less than or equal to $q^2$ and individuals being identical in tastes and endowments. The Nash equilibrium corresponds to matching behavior ($q^1 = q^2$); each individual effectively faces the social-optimizing problem. If $w = 0$, then the weakest-link applies to the problem, so that (22) implies that the Nash equilibrium is efficient.[15] In fact, Mueller (1989, p. 25) was able to generalize (22) to the case of n individuals: when $w^i = 0$ for all but the smallest contribution, the ratio, $Q^N/Q^*$, is still one. If, however, the $w^i$s are greater than zero but less than

one ($w^i = 1$ for all i implies summation), then an increase in group size would imply a decline in efficiency. The experimental literature confirmed near-optimal results for the weakest-link case (Harrison and Hirshleifer, 1989; Alphons van de Kragt, John Orbell, and Robyn Dawes, 1983).

The inverse relationship is also dependent on the notion of independent adjustment employed. Guttman (1978, 1987) specified a model that departed from an one-shot Nash equilibrium. He specifically formulated a two-stage game: in the first stage, the participants chose a flat contribution to the collective good; in the second, the participants chose matching rates based on the spillover of flat contributions from the first stage. A perfect equilibrium (i.e., each subgame has a Nash equilibrium) is found by first solving for the matching rates and then solving for the flat contributions. Guttman (1978) proved that a Pareto optimum could be achieved if all players are identical and a separable utility function represents tastes. Thus, in the absence of income effects, $Q^N/Q^*$ equaled 1 regardless of group size. A similar single-stage result was established for Kantian behavior by Sandler and John Posnett (1991).

If the standard Nash equilibrium forms the basis of independent adjustment and, moreover, the technology of public supply corresponds to summation, then Olson's inverse relationship holds for some noteworthy symmetric equilibria. In some instances, bothersome income effects must be sanitized to derive the inverse relationship.

In comparing Nash and Pareto equilibria, the ratio $Q^N/Q^*$ or some variant (see the index of easy riding in Cornes and Sandler, 1984a, p. 588) is employed. In consequence, the comparison is made in quantity space rather than utility space. In the latter, the ratio $U^N/U^*$ from a social aggregation

viewpoint must be measured. Since utility may be nonlinearly related to quantity, the comparison of $Q^N/Q^*$, while helpful in a qualitative sense, is not the true measure of inefficiency in terms of lost utility.

## IV. GROUP ASYMMETRY AND COLLECTIVE IRRATIONALITY

The second basic theme concerns disproportionate burden sharing within small group where "there is accordingly a surprising tendency for the 'exploitation' of the great by the small." (Olson, 1965, p. 35). Although Theme 2 has greater general validity than Theme 1, Theme 2 is not universally true. In The Logic, Olson (1965, p. 35) reasoned that if the largest member of a group satisfies his collective good demand, then smaller members are likely to have their own demands satisfied free without the need to contribute. This is the nearest that Olson comes to using the now-popular expression of free riding.[16] Clearly, Olson has a specific class of collective goods in mind--nonexcludable pure public goods. The disproportionate burden sharing was developed further in Olson and Zeckhauser's (1966) seminal article on burden sharing in an alliance. In that article, they utilized total benefit curves for two allies of disparate size to establish the exploitation of the large by the small. Although the diagrammatic exercise is correct, it depends on the implicit assumption of zero income effects.

The concept of size is not unambiguous in Olson and Zeckhauser (1966); some have interpreted size to depend on resources or gross domestic product (Sandler and John Forbes, 1980), while others have equated size to population (Leonard Dudley and Claude Montmarquette, 1981). In the absence of income effects, Dudley and Montmarquette (1981) have shown that if spending on the

collective good is proportional to population, the relative slopes of the players' reaction curves determine whether the large is exploited by the small. If the small player's reaction curve is sufficiently inelastic with respect to spillovers (income), then the small player might provide more than the larger. Others have demonstrated that if the small player's preferences for the public good are sufficiently strong, the natural tendency for disproportionate burden sharing needs not apply. Supply considerations can also have an effect. When, for example, the small player (nation) has a supply-side comparative advantage over the large player in producing the collective good, then the exploitation hypothesis may also fail (Olson and Zeckhauser, 1967; McGuire, 1990).

Much of the empirical literature on disproportionate burden sharing has followed Olson and Zeckhauser (1966, 1967) by examining NATO and other alliances.[17] For the most part, the NATO allies have behaved according to the exploitation hypothesis, since the larger allies (the U.S., the U.K., France, and West Germany), in terms of gross domestic product (GDP), spent a greater proportion of their GDP on defense (see Olson and Zeckhauser, 1966; Sandler and Forbes, 1980; Murdoch and Sandler, 1984). The extent of disproportionate burden sharing, however, weakened after the adoption of flexible response, which placed greater importance on conventional arsenals. The latter produces more impure public and private (country-specific) outputs than the deterrence derived from nuclear weapons. Since the defense activity gives rise to multiple outputs that vary in their degree of publicness, joint products are relevant. Sandler and associates have established that the presence of joint products, especially excludable ones, could work at odds to the exploitation hypothesis as burden sharing keys in on excludable country-specific benefits.

Changes in the strategic assumption of Nash-Cournot can also work against the hypothesis. In particular, Neil Bruce (1990, p. 189) has proven that a change in the strategic assumption, from Nash-Cournot to leader-follower, could lead to an exploitation of the small when the large country assumes the leadership role. As compared with a Nash equilibrium, a leader-follower equilibrium implies an increased (decreased) level of provision by the follower (leader), but a reduced aggregate level of provision (Bruce, 1990, pp. 185-186). If the follower is the smaller agent, then his increased share under leader-follower behavior can reverse the direction of exploitation.

The most elegant proof of the Olson exploitation hypothesis is found in Andreoni (1988a) and Bergstrom, Blume, and Varian (1986). The former showed that, if all goods are normal and income is distributed continuously, the contributors will include only the richest individuals. Moreover, as $n \to \infty$, the class of contributors will converge to a single type--the wealthiest. The richest individuals are exploited by all others. Bergstrom, Blume, and Varian (1986, Theorem 5, p. 38) demonstrated that, ceteris paribus, equalizing redistributions of endowments among a group of contributors would never increase total voluntary contributions. These Nash-Cournot results depend upon all goods being normal, and represent strong (indirect) support for Olson's conjecture that asymmetric groups have a greater likelihood of being privileged. As seen in Section III, the underlying game structure also has a role to play in whether asymmetry fosters groups being privileged.

## V. MEANS FOR OVERCOMING COLLECTIVE IRRATIONALITY

The Logic (1965, ch. VI) suggested two means for overcoming collective irrationality: selective incentives and the design of institutional

structures. By selective incentives, Olson had in mind the tying of private benefits or inducements to the provision of the collective good. Such private benefits would motivate any sized member to contribute, inasmuch as the private benefits can only be obtained by assisting provision. Although collective benefits are nonexcludable, the private benefits are excludable. The selective-incentive hypothesis spawned a large literature that equated selective incentives with a collective activity that provides joint products, some of which are agent-specific.[18] Although there is, yet, to be a general proof that the presence of joint products reduces suboptimality, there is much evidence that joint products can increase total provision (see Andreoni, 1990; Sandler, 1977) and make provision burdens coincide to a greater extent with benefits received (Sandler and Forbes, 1980; Sandler and Murdoch, 1990). A mere increase in the Nash-Cournot provision cannot by itself be equated with reduced suboptimality, since the relative position of <u>both</u> the Nash-Cournot and the Pareto-optimal equilibria must be ascertained and compared.

In recent years, researchers are beginning to appreciate the flexibility and realism of the joint-product model. There are, at least, five bases for favoring a joint-product model over the single-product alternative. First, the joint-product model is a generalization of both the pure public good and the private good model and, as such, is capable of displaying a wider range of results. If a joint-product model is used, empirical tests are now available to distinguish the appropriate model: pure or joint product (Sandler and Murdoch, 1990; Jyoti Khanna, Wallace Huffman, and Sandler, 1990). Second, the joint-product model fosters realism, since most collective-action situations yield private benefits (e.g., the control of domestic terrorism for allies, tax write-offs for contributors to a charity). In the case of charities,

private benefits have been examined empirically by Posnett and Sandler (1989). Third, if the joint products are complementary, then private outputs have a privatizing effect, not unlike the establishment of property rights. This privatizing influence reduces the motives to free ride. If, moreover, the joint products are perfect complements, then the Nash equilibrium may be Pareto optimal (Cornes and Sandler, 1986, p. 145-46). Fourth, the game structure that underlies some joint-product scenarios may eliminate defection as a dominant strategy, thereby fostering the group to being privileged. If, say, the joint products are complementary, then failure to contribute would imply that the free ride associated with defecting could yield a smaller payoff than contributing, since the complementary private good is not then available. The matrix payoff for two persons would then correspond to the fully privileged group in Figure 1, where cooperation is the dominant strategy. Substitute joint products could imply the payoff structure of chicken or the battle of the sexes. Fifth, the joint product model need not abide by the neutrality theorem,[19] which limits the effectiveness of redistribution and tax policies.

The neutrality theorem indicates that any redistribution of income among an unchanged set of private contributors of a pure public good will not affect the Nash equilibrium provision level for the group (see Gary Becker, 1974; Bergstrom, Blume, and Varian, 1986; B. Douglas Bernheim, 1986; Cornes and Sandler, 1981, 1985; Peter Warr, 1982, 1983). Two alternative proofs for the neutrality theorem are given in the mathematical appendix. When the neutrality theorem applies, suboptimal provision levels, associated with a Nash equilibrium, cannot be augmented by redistributing income from the low to the high spenders unless the set of contributors changes owing to corner

solutions. Under the assumptions of the theorem, policy-engineered asymmetry will not have a desired effect since income gainers would increase contributions commensurate to the decreases of the income losers. The neutrality theorem is considered further in Section VI.

Some researchers (e.g., Alison Booth, 1985; Sugden, 1982) have expressed doubts concerning the tying of private benefits to collective outputs as a mean of motivating collective rationality. In particular, these authors question whether the collective sector can compete against private sector firms that can provide the private benefits "separately". These critics recognize that if the collective has a monopoly over the private good provided, then their criticism does not hold. In fact, many private goods that are tied to collective provision problems (e.g., a journal given to members of a learned society, concert tickets given to supporters of a symphony) do, indeed, involve monopoly aspects. In other instances, the joint production of multiple benefits may involve a technology of supply in which the private output may not be separated from the associated collective output. When, for example, allies purchase conventional armaments, the collective output of deterrence that the armaments provide to all allies cannot be divorced from country-specific outputs arising from deployment decisions. Moreover, the defense armaments are, indeed, purchased on private markets, but that does not eliminate the collective-action problem.

Theme 3 also stressed the design of institutional structures as a means for overcoming collective action impediments. In particular, Olson indicated that large groups can foster cooperation by organizing themselves in a federal structure with small subgroups. If largeness leads to group latency and suboptimality, then the use of federated cells makes good sense, since

individual action is more readily recognized. A transaction cost approach, suggested by the seminal book by Oliver Williamson (1975), needs to be applied to study the organizational configurations of collective action groups.[20] Clearly, each configuration of a collective structure or group, whether federated or not, implies a different set of transaction costs as well as a different set of collective benefits. If the efficacy of alternative organizational structures is to be ascertained, discrete organizational forms must be compared with one another to identify the structure with the greatest net gains when provision and transaction aspects are considered. Although a federal structure may foster cooperation, collective benefits may be lost since interactions over the entire collective may be quite limited. Such issues need scrutiny if federal structures are to be promoted.

Although Olson did not mention other means for overcoming collective irrationality, many means now exist. A prime candidate involves engineering the technology of supply to eliminate defection as a dominant strategy. Institutions can be designed to create an underlying game structure that fosters cooperation.

## VI. NEW DEVELOPMENTS AND THEIR RELATIONSHIP TO BASIC THEMES

### A. THEORY OF CLUBS

In the same year as the publication of The Logic, James Buchanan (1965) published his seminal paper on the theory of clubs, which depicted how voluntary groups could provide themselves with an impure public good. If the members could exclude nonmembers, then tolls could internalize crowding externalities and achieve Pareto optimality without the need for government intervention.[21] Although The Logic is not typically credited with the

development of club theory, the rudiments of club theory can be found in Olson's (1965, ch. I) distinction between inclusive and exclusive collective goods. An inclusive collective good can be utilized or shared by an unlimited number of individuals without imposing any losses on the sharers. Pure public goods are inclusive, since additional users can take advantage of the good's benefits without rivalry in consumption in the form of crowding or congestion costs. There is no economic rationale for restricting group size in the case of an inclusive collective good. In contrast, an exclusive collective good cannot be shared by additional consumers without detracting from the derived benefits of the other users. Group size must be restricted so that rivalry costs are internalized.

With a slight modification, Olson's math (see Section II) can be extended to incorporate the theory of clubs explicitly. A costless exclusion mechanism must be assumed, and the population must be assumed identical in terms of tastes and income. Group costs are hypothesized to be equally shared among members. Moreover, the population is partitioned into a set of nonoverlapping clubs with no excluded individuals, so that the resulting solution is in the core. Individual benefits, $V_i$, are

(24) $V_i = V_i(y^i, Q, n)$,

where n is the number of members in the club. $V_i(\bullet)$ is assumed to be increasing in $y^i$ and Q, and decreasing in n. The latter relationship reflects crowding as the number of shares increases. To meet sufficiency conditions, we assume that $V_i(\bullet)$ is concave. Individual costs, $C_i$, are

(25) $C_i = C_i(y^i, Q, n)$,

where $C_i$ is increasing in $y^i$ and Q, and decreasing in n. The latter denotes the equal-sharing-of-cost assumption. $C_i$ is also assumed to be convex.

Differentiating net benefits ($V_i - C_i$) with respect to $y^i$, Q, and n yields the following FOCs:

(26) $MRS^i_{Qy} = MRT^i_{Qy}$ $\quad i = 1, \ldots, n,$ (Provision)

(27) $MRS^i_{ny} = MRT^i_{ny}$ $\quad i = 1, \ldots, n.$ (Membership)

The provision condition indicates that each member's marginal rate of substitution (MRS) between the club good and the private good must be equated to the member's marginal rate of transformation (MRT) between these goods.[22] Thus, individuals equate their marginal benefits with their marginal costs.

The novel aspect of club analysis is embodied in (27) in which optimal group size is obtained when each individual equates his MRS between group size and the private good to his MRT between the two. In (27), the marginal benefits derived from having another member is equated with the associated marginal costs. These marginal benefits are normally negative owing to crowding, and the corresponding marginal costs are also negative owing to cost reductions derived from cost sharing. Three aspects of the club's problem needs highlighting: (1) The provision and membership conditions must be <u>simultaneously</u> determined, since each expression contains identical variables; (2) Net benefits are maximized for the representative member, so that average net benefits for the club are maximized; and (3) Membership fees or tolls are set equal to the right-hand side of (27), thereby internalizing the congestion externality.

Although Olson (1965) did not explicitly extend his formal model to encompass standard club theory, the principles of club theory are addressed (pp. 30-31, 36-40). The clearest statement is:

> When an inclusive collective good is not a pure public good, however, those in the group enjoying the good would not welcome additional members who failed to pay adequate dues. Dues would not be adequate unless they were at least equal in value to the reduction in the consumption of the new entrant. (Olson, 1965, p. 40).

In a letter to Olson, Buchanan acknowledged Olson's independent development of the rudiments of club theory (Olson, 1965, p. 38).

If, at the margin, the club is breaking even in providing the collective good, the sum of the members' marginal costs must equal the club's marginal cost of provision; i.e.,

$$(28) \quad \sum_{i=1}^{n} MRT^{i}_{Qy} = MRT_{Qy},$$

where $MRT_{Qy}$ is the marginal cost of provision. Equations (26) and (28) then imply the usual Samuelson provision condition for public goods,

$$(29) \quad \sum_{i=1}^{n} MRS^{i}_{Qy} = MRT_{Qy}.$$

Thus, voluntary clubs can achieve Pareto optimality and circumvent collective irrationality if properly designed. The key is the exclusion mechanism and the use of congestion-internalizing tolls. The size of the group does not imply greater suboptimality when clubs can internalize externalities and satisfy membership conditions.

In more advanced treatments of clubs, the congestion relationship are specified in greater detail as a function of an utilization measure (e.g., number of visits) and provision levels. This more detailed specification corresponds to a technology of public supply.

## B. THE NEUTRALITY THEOREM

The neutrality theorem, which indicates that the Nash-equilibrium provision level for a pure public good is invariant to income redistributions among an unchanged set of contributors, has received much attention since Warr (1982, 1983). The theorem accounts for the interdependency among contributors and does not require that contributors possess identical tastes. The neutrality theorem is especially noteworthy since it indicates an impediment to the use of an income policy to correct the Pareto-suboptimal Nash equilibrium associated with a pure public good. If the government were to tax contributors to finance more of the public good, then government expenditures on provision would crowd out private contributions on a dollar-for-dollar basis (Russell Roberts, 1984).

Although Warr (1982, 1982) brought the neutrality theorem to the profession's attention, a closely related neutrality result appeared earlier in Becker (1974). Even before Becker, Hirofumi Shibata (1971) came very close to presenting the neutrality theorem when he (pp. 21-22) depicted the Nash equilibrium in his two-person bargaining triangle. The Shibata diagram makes it clear that income redistribution cannot affect the Nash equilibrium for a pure public good.

In recent years, the bounds to the neutrality theorem have been better drawn. Bergstrom, Blume, and Varian (1986) have proved that neutrality does not hold if the set of contributors is influenced by the redistribution or tax policy. If, therefore, the government raises revenues by taxing noncontributors and then spends these revenues on the public good, Nash-equilibrium provision will rise for normal good. Another series of articles have demonstrated that neutrality does not extend to joint products or

selective incentives (Cornes and Sandler, 1981, 1984a; Andreoni, 1987, 1989, 1990). Thus, Olson's original emphasis on these selective incentives as a policy tool appears to have been well-placed. Altering selective incentives can be an effective tool for engineering greater collective rationality. Sandler and Posnett (1991) have established that the neutrality theorem may not apply to strategic assumptions other than Nash. Bruce (1990) has, however, shown that leader-follower behavior will abide by neutrality. Neutrality also depends on the technology of public supply. For example, the best-shot technology implies a single contributor; hence, an alteration in income distribution is likely to affect who is the contributor and, in consequence, is expected to be non-neutral. In the case of weakest-link, individuals are apt to match one another's provision levels. A potential Nash equilibrium could involve everyone contributing the same level as that of the poorest individual if tastes are identical, incomes differ, and all goods are normal. Income-equalizing redistributions between group members could mean higher levels of contributions as matching rates increase along with the income of the poorest individual; neutrality may not characterize the weakest-link technology. The summation technology is a crucial ingredient in the neutrality result. Even the influence of asymmetry on collective irrationality is likely to be sensitive to the technology of supply.

Since most collective-action problems do not involve pure public goods, there is clearly room for income policy. Future work needs to investigate how to design Pareto-improving income redistributions for collective-action problems. Policies that merely increase equilibrium provision may not improve welfare, especially when noncontributors, who do not desire the collective good, are taxed.

## C. DYNAMIC CONSIDERATIONS

The Logic considered collective-action problems in a static timeless environment. In the real world, agents may interact repeatedly (e.g., Congressmen in a logrolling situation, nations along a polluted waterway). When repeated interactions are allowed, the set of Nash equilibrium strategies may be very large. The Folk Theorem of repeated games indicates that any individually rational strategy can be an equilibrium (McMillan, 1986, pp. 14-16). Consider a two-person collective-action problem with payoffs corresponding to the prisoner's dilemma. In a single play, the Nash equilibrium consists of each agent playing his dominant strategy of defecting. If, instead, the game is repeated an infinite number of times and the discount rate is not too great, then a strategy of tit-for-tat is also a Nash equilibrium as shown below (Peter Ordeshook, 1986, pp. 442-48). Tit-for-tat corresponds to choosing the cooperative strategy in the first round and then matching the opponent's choice in the preceding round. Another Nash-equilibrium strategy involves cooperating in the first play and cooperating in subsequent plays so long as the opponent cooperated in the previous round. Once the other player defects, then the strategy requires the player to defect thereafter. This strategy is also a Nash equilibrium. In essence, threat-backed cooperative strategies are equilibria, since short-run gains from defection may be less than long-run losses as threats are executed. If, however, discount rates are high, then short-run gains may exceed long-run losses, and defection is dominant.

To illustrate the tit-for-tat Nash equilibrium for a repeated prisoner's dilemma, we modify a normal game representation of Ordeshook (1986). In Figure 4, the prisoner's-dilemma, public-good game of Figure 1 for two agents

**FIGURE 4**
**REPEATED PRISONER'S DILEMMA**

| | | 2: T - f - T | 2: C | 2: D |
|---|---|---|---|---|
| 1 | T - f - T | a<br>$\frac{4}{1-r}, \frac{4}{1-r}$ | b<br>$\frac{4}{1-r}, \frac{4}{1-r}$ | c<br>$-1, 5$ |
| 1 | C | d<br>$\frac{4}{1-r}, \frac{4}{1-r}$ | e<br>$\frac{4}{1-r}, \frac{4}{1-r}$ | f<br>$\frac{-1}{1-r}, \frac{5}{1-r}$ |
| 1 | D | g<br>$5, -1$ | h<br>$\frac{5}{1-r}, \frac{-1}{1-r}$ | i<br>$0, 0$ |

PRISONER'S DILEMMA
(r is discount rate)

Strategies

T - f - T = tit-for-tat --- cooperate on first trial; then, match the opponent's choice in preceding trial.

C = cooperate in perpetuity

D = defect in perpetuity

is extended to a repeated game framework in which the game is played an infinite number of times. Each agent is permitted three intertemporal strategies: (1) tit-for-tat, (2) cooperation on every round, and (3) defection on every round. The discount rate is r, which is a fraction less than one. If both players choose tit-for-tat, then each receives the present value of $4/(1 - r)$ over the course of the entire game as each cooperates on the first and all subsequent rounds.[23] Similar payoffs characterize cells b, d, and e. If, however, the first agent uses tit-for-tat, while the second uses defection, then the first player receives $-1$ in the first round and 0 thereafter, and the second player received 5 in the first round and 0 thereafter. This follows because after the first round, the tit-for-tat strategy requires player 1 to match the opponent's repeated defections. The payoffs in cell g have a similar interpretation but with players' roles switched. When player 1 uses cooperation and player 2 employs defection throughout the rounds, player 1 receives $-1$ in every round, whereas player 2 receives 5 in every round. The present value of these perpetual payoffs are, respectively, $-1/(1 - r)$ and $5/(1 - r)$ in cell f. A similar situation characterizes cell h, but with roles switched. Mutual defection on every round in cell i yields 0 payoffs to each agent.

Nash equilibria correspond to cells a and i, provided that $4/(1 - r) > 5$, or that future benefits are not discounted too heavily [i.e., $1/(1 - r)$ is not too small]. If, in Figure 4, agent 1 plays tit-for-tat, the best response of agent 2 is to play tit-for-tat. Only cells a and i are Nash equilibria.

In Figure 5, we display repeated versions for the chicken and assurance 1 games when each agent again has three strategies as above. The chicken game corresponds to the payoff matrix of Figure 1, in which a penalty of $-x$ is

4/A

FIGURE 5
OTHER REPEATED GAMES

CHICKEN

| 1 \ 2 | T - f - T | C | D |
|---|---|---|---|
| T - f - T | a<br>$\frac{4}{1-r}, \frac{4}{1-r}$ | b<br>$\frac{4}{1-r}, \frac{4}{1-r}$ | c<br>$-1 - \frac{x}{1-r}, 5 - \frac{x}{1-r}$ |
| C | d<br>$\frac{4}{1-r}, \frac{4}{1-r}$ | e<br>$\frac{4}{1-r}, \frac{4}{1-r}$ | f<br>$\frac{-1}{1-r}, \frac{5}{1-r}$ |
| D | g<br>$5 - \frac{x}{1-r}, -1 - \frac{x}{1-r}$ | h<br>$\frac{5}{1-r}, \frac{-1}{1-r}$ | i<br>$\frac{-x}{1-r}, \frac{-x}{1-r}$ |

ASSURANCE

| 1 \ 2 | T - f - T | C | D |
|---|---|---|---|
| T - f - T | a<br>$\frac{4}{1-r}, \frac{4}{1-r}$ | b<br>$\frac{4}{1-r}, \frac{4}{1-r}$ | c<br>$-3, -3$ |
| C | d<br>$\frac{4}{1-r}, \frac{4}{1-r}$ | e<br>$\frac{4}{1-r}, \frac{4}{1-r}$ | f<br>$\frac{-3}{1-r}, \frac{-3}{1-r}$ |
| D | g<br>$-3, -3$ | h<br>$\frac{-3}{1-r}, \frac{-3}{1-r}$ | i<br>$0, 0$ |

Strategies see Figure 4.

imposed for mutual defection. The payoffs in the nine cells can be computed quite easily. Nash equilibria correspond to cells a, h, and f. The tit-for-tat strategy is again an equilibrium. In the bottom matrix, the assurance game of Figure 1 is extended to the simple repeated game scenario. Nash equilibria correspond to cells a, b, d, e, and i. Any combination of tit-for-tat and cooperation is an equilibrium strategy pair. Clearly, an infinite repeated game framework can possess many cooperative outcomes. Collective irrationality is not the necessary equilibrium even for bothersome prisoner's dilemmas.

A basic problem with infinitely repeated games concerns the existence of a plethora of equilibria. In recent years, concepts such as subgame perfect and sequential equilibria have been developed to cull equilibria strategies with noncredible threats.

Knowledge about the game's length is crucial when analyzing collective-action problems in repeated-game frameworks. If a prisoner's dilemma is repeated a finite known number of times, then the Nash equilibrium is to defect in each round. Such games are solved backwards. In the final period, defection is the dominant strategy. Given that defection occurs in the last period, the dominant strategy in the next-to-last period is also to defect. And so it goes for <u>all</u> preceding periods. Cooperation-based strategies can be Nash equilibria in finitely repeated prisoner's dilemmas, provided that the game's endpoint is unknown and discount rates are not too large. Once the endpoint is unknown, backward induction is no longer relevant, since short-run gains from defection may then entail longer-run losses. If the institutional arrangements either permit continual interactions among the participants or else leave uncertain the endpoint of the interaction, the short-run gains from

repeated defections may create even greater long-term losses as participants retaliate for the defection of others.

In a repeated game framework, uncertainty may also characterize the type of opponent that an agent is playing against (e.g., tough or weak, high or low public-good demander). The introduction of this type of uncertainty may require the analyst to refine the notion of Nash equilibrium so as to cull or remove equilibria with noncredible threats. The identification of so-called perfect Nash equilibria requires that the game be examined in extensive (game-tree) rather than normal form.

In Section III A, other game forms were shown to apply to collective-action problems. Each game form may possess a large set of Nash equilibria when played repeatedly. A game, such as chicken with high penalties for mutual defection, has a great likelihood of some public good being provided in the equilibrium. Other games, like the battle of the sexes, may permit greater cooperation in repeated frameworks than in a single shot when communication between players are permitted and mixed strategies are permitted (Farrell, 1987). The assurance games are also apt to foster cooperative outcomes in repeated plays. Although the collective-action problem does not vanish in a dynamic scenario, even troublesome games like the prisoner's dilemma may have favorable outcomes in some cases when long-term defection losses are large as shown above.

## D. STRATEGIC ASSUMPTION

The Logic implicitly assumed Nash behavior. In recent years, investigators have extended the analysis to other kinds of strategic assumptions. Guttman (1978, 1987) examined non-Nash behavior in the form of a two-stage matching game in which flat contributions are determined in one

stage and matching rates in the other. Each individual's provision level is

(30) $q^i = a_i + b_i \sum_{j \neq i} a_j$,

where $a_i$ is agent i's flat contribution and $b_i$ is his matching rate. Matching behavior, which can be fostered by institutional rules, reduces the effective price of the collective action and leads to increased provision. Federal matching grants to states is an example. A positive conjecture characterizes the strategic interaction. If individuals are identical and income effects are absent, then the resulting equilibrium will be Pareto optimal regardless of the number of individuals (Guttman, 1978). Group size may, nonetheless, still pose an impediment to collective action, since the feasibility of eliciting matching behavior surely declines with group size, especially if tastes and/or endowments differ.

Cornes and Sandler (1984b, 1986) have formulated a theory of non-Nash behavior based on a nonlinear conjectural variation,

(31) $d\tilde{Q}^e/dq = b(q/\tilde{Q})^\theta$,

where $\tilde{Q}$ denotes spillovers; the e superscript indicates "expected"; b represents a parameter; and $\theta$ corresponds to the elasticity of the conjectured response with respect to the relative importance of the agent's contribution. This nonlinear conjectural variation is capable of representing a wide variety of behavior. If individuals are identical, then (31) can be expressed in terms of groups size for symmetric equilibria, since $q/\tilde{Q} = 1/(n - 1)$. Thus, the effect of group size can be analyzed for homogeneous collectives under various strategic scenarios. The model suffers from its static assumption. More sophisticated exercises need to incorporate learning so that conjectures can be updated as information evolves. This requires that uncertainty about the behavior of others be modeled explicitly in an internally consistent

fashion. Bayes theorem can be used to update one's priors using information revealed through other players' actions in the preceding periods.

Sugden (1984) developed a theory of collective action based on a notion of reciprocity whereby individual i meets or exceeds the minimal contribution of the rest of the group. Individual i exceeds the minimal effort level if the level that he most prefers everyone to make is greater. In essence, moral constraints limit the agent's behavior since he cannot take a free ride when others contribute. Under special circumstances, the reciprocity equilibrium for identical individual will be analogous to matching behavior (Sugden, 1984, pp. 778). In most situations, reciprocity still implies suboptimal provision.

Sugden's theory of reciprocity is quite different than the model based on weakest-link. In the latter, an agent provides his optimizing choice of $q^i$ if $q^i \leq \min q_{-i}$ [where $\min q_{-i}$ is the minimal component of $q_{-i} = (q^1, \ldots, q^{i-1}, q^{i+1}, \ldots, q^n)$] or else he provides $\min q_{-i}$, depending on whichever is smaller. His demand for the public good is

(32) $q^i = \min (f^i(\bullet), \min q_{-i})$,

in which $f^i(\bullet)$ is the demand function of agent i for $q^i$ when $q^i \leq \min q_{-i}$. Unlike reciprocity, the agent never outdoes the minimal provision with weakest-link.

Much still needs to be done to study non-Nash behavior. The effects of asymmetry is especially difficult to analyze when Nash behavior is dropped, since heterogeneous tastes and/or endowments could lead to different learning patterns and, hence, diverse strategic behavior within the group.

## E. UNCERTAINTY AND COLLECTIVE ACTION

Agents are not always well-informed when making collective-action decisions. Uncertainty may arise in a discrete contribution scenario in which

a minimal number (amount) of contributors (contributions) is needed to provide the good (David Austen-Smith, 1981; Norman Frohlich and Joe Oppenheimer, 1978). If contributions are nonrefundable, then contributors must consider the various contingencies and their likelihoods. Uncertainty may, in addition, characterize the amount of spillovers (Sandler, Frederic Sterbenz, and Posnett, 1987; Jason Shogren, 1987), the price of the collective good (Mark Gradstein, Nitzan, and Steven Slutsky, 1988a), or the endowments of the contributors (Gradstein, Nitzan, and Slutsky, 1988b). This literature has investigated whether risk-averse individuals are more apt to contribute in the face of uncertainty. Also, the suboptimality of uncertainty has been compared with that of certainty. Different cases have been distinguished based on the convexity of the marginal utility function and other considerations. Although special cases have been found in which uncertainty can ameliorate the collective-action problem (see, e.g., Sandler and Sterbenz, 1990), the introduction of uncertainty does not, in general, reduce uncertainty in collective-action problems. In a striking case, Nitzan and Richard Romano (1990) demonstrated that sufficient uncertainty on the cost side can worsen Nash equilibrium outcomes in discrete, public good scenarios.

The introduction of uncertainty yields a plethora of cases and few general results. Clear-cut relationships between groups size and collective rationality and/or group asymmetry and collective irrationality are especially difficult to establish when uncertainty is present.

## VII. APPLICATIONS

Perhaps the greatest achievement of *T* Logic has been its wide-range application to all major fields of economics. Many such applications have

already been mentioned by way of illustration in the preceding sections. A few special applications are presented below to emphasize the importance of collective-action problems. Our presentation of applications is highly selective and is not exhaustive.

## A. GROWTH OF NATIONS

In 1982, Olson published The Rise and Decline of Nations in which he spelled out the macroeconomic implications of The Logic. Prior to the publication of The Rise and Decline of Nations, most of the principles of collective action had been applied to microeconomic issues. Olson (1982) argued that a nation's political stability allowed for the emergence of (mostly small) special interest groups that vied for a nation's income and resources. In stable nations, the number of such groups grew with time. The agenda of these "distributional" coalitions was to redistribute income to its members. Since most of the coalitions were small, they were not concerned with the social and transaction costs that their actions imposed on the economy. In consequence, significant social costs could arise as coalitions created excess burdens from redistributive tax policies, slowed the adoption of new technologies, or inhibited the reallocation of resources to new growth-promoting sectors. A nation's growth was predicted by Olson (1982) to suffer from such coalitions. Since these coalitions increased as a nation aged, new nations were predicted to have better growth performance than older nations. This provocative hypothesis as well as the opening quote show that many macroeconomic issues depend, in part, on collective-action considerations.

There have been numerous attempts to test Olson's hypothesis; noteworthy examples include Kwang Choi (1983), Olson (1982), Peter Murrell (1983) and Richard Vedder and Lowell Gallaway (1986). Most tests involve regressions in

which the dependent variable is some growth measure (e.g., growth in per capita income) and independent variables include an age indicator for the state or nation. The studies cited above have found a significant negative relationship between growth and the nation's age, consistent with Olson's hypothesis. Many of the tests are, however, very simplistic and do not consider alternative hypotheses that could explain growth differences between nations. Moreover, the extent and behavior of interest groups are not directly related to economic growth in the tests.

Surely more work on the aggregate impact of special-interest groups on economic growth is needed. The influence of special interest groups in developing nations is of particular interest, since wasteful activities could siphon off much-needed resources from supporting infrastructure projects.

## B. FOREIGN AID

Foreign aid poses a collective-action problem for the international community. Many developing nations must rely on other nations to provide aid to finance public investment projects. By increasing the well-being of a recipient nation, foreign aid serves as an input that produces an output that is both nonexcludable and nonrival to all nations with an interest in the recipient's well-being. That is, the recipient's well-being, produced in part by foreign aid, enters potential donors' utility functions. Moreover, once augmented, the well-being of the recipient nation is nonexcludable to all would-be donors. Foreign aid may also provide benefits to a donor that is private between nations but public within the donor nation. When the donor derives an advantage from its gift of aid and this advantage is not shared with others, private benefits may also motivate giving, much as private aspects stimulate allies' defense expenditures. First, we examine the

collective-action problem associated with foreign aid when all potential donors view the economic advancement or well-being of another, less-fortunate nation as purely public. We next introduce private motivations along with the public motivation. The collective-action aspects of foreign aid is analogous to the case of charity or philanthropy within a nation.

If foreign aid is untied, aggregate aid to a recipient represents a fungible resource. In consequence, a summation technology of supply applies, since the recipient's well-being is dependent on the sum of aid received from others. Suboptimality in the supply of foreign aid is then to be expected. Suppose that all potential donors have the same tastes but different endowments. Further suppose that a recipient's well-being is a normal good in the utility function of would-be donors, then the demand for giving will be positively correlated to income. Wealthier nations have a greater desire to give, so that the richest nations will bear the burden of foreign aid. A clear asymmetry arises and Olson's exploitation hypothesis applies. Some potential donors may contribute nothing, relying instead on the foreign aid given by the wealthier nations. Suboptimal foreign aid levels indicate the need for some policy initiated at the supranational level. The manner used to finance foreign aid at the supranational level becomes a crucial consideration owing to the neutrality theorem. If an international agency (e.g., USAID, World Bank) supplements a recipient's foreign aid from revenues collected from donor nations, then foreign aid at the supranational level would crowd out foreign aid from donors on a dollar-for-dollar basis. This then implies that agencies must seek their funding from nondonor countries if they intend to increase foreign aid by their action. Any shock to the international system, such as sharp oil price rises, that redistribute income among the set of donor

nations may yield no net change in foreign aid even if the gainers have a higher propensity to contribute. This neutrality result could be upset if the redistribution of neutrality result could be upset if the redistribution of income, no matter how it was engineered, altered the set of contributors. When foreign aid yields pure public benefits to the donors, proposed schemes to redistribute income to the underdeveloped world by taxing the resources of the wealthier nations may be self-defeating, since such taxes might reduce voluntary giving.

In many instances, foreign aid may yield both a purely public benefit to the set of donors and country-specific private benefits. Donor-specific private benefits may arise owing to a donor's relative location to the recipient. If, say, a recipient country is positioned strategically vis-á-vis a donor nation, aid-assisted growth may augment the recipient's political stability, which, in turn, fosters the donor's own security. More-distant donors may not receive any security benefits. Private benefits may arise from tying foreign aid to certain stipulations that are advantageous to the donor. For example, foreign aid may carry the condition that the donor can maintain military bases on the recipient's territory. When foreign aid possess both private and public benefits, the neutrality theorem does not necessarily apply and crowding out may not be a problem. A carefully engineered redistribution or tax scheme (see e.g., Andreoni, 1989; Sandler and Posnett, 1991) could increase overall giving if international agencies were to tap donors, who derive relatively greater private benefits from foreign aid, for resources.

There appears to be a clear analogy between charity and foreign aid. In the case of charity, private and public benefits are jointly produced by the act of giving (Posnett and Sandler, 1986; Andreoni, 1987). The extent of

crowding out can be examined for foreign aid in much the same fashion as the charities (see Burton Abrams and Mark D. Schmitz, 1978; Charles Clotfeller, 1985). Evidence of dollar-for-dollar crowding out would lend great support for treating foreign aid as a pure public good.

## C. THE COMMONS

An apt example of a collective-action problem is the commons in which a scarce resource is owned collectively by a set of agents. Common property examples include fisheries, oil pools, hunting grounds, deep-sea mineral beds, orbital bands in geostationary space, and radio-wave frequencies. The analysis of the commons demonstrates the overexploitation of the scarce fixed resource, in with the average product of the variable input, not its marginal product, is equated to the input's rental rate when access is free and the set of exploiters large. Overexploitation is relevant to a commons in both a static, steady-state framework and a dynamic analysis. To maintain simplicity, we present a static analysis.

Consider a set of exploiters consisting of a given number of profit-maximizing firms, each having free access to an exogenously fixed common property resource. We refer to this resource as a fishing ground. Each firm combines the common property resource with a single private input, fishing vessel, to produce an output of fish. With the size of the commons fixed, the total output or catch, C, depends solely on the size of the total fishing fleet, R, which represents effort on behalf of exploiters. The production function is

(33) $C = F(R)$,

which is increasing and strictly concave (i.e., $F'(R) > 0$ and $F''(R) < 0$). Other sources of supply for fish are assumed so that the price of catch is

exogenously fixed at unity. Vessels are also assumed to be sold on competitive markets but at a price of p per vessel.

To illustrate a commons problem with many of the Olsonian themes, we further assume a "pure" homogeneous commons where fish are evenly distributed throughout the fishing grounds, so that each vessel hauls in the same catch. This assumption allows the catch, c, of each firm to equal its share of total effort times the total catch:

$$(34) \quad c = [r/R]F(R)$$
$$= [r/(r + \bar{R})]F(r + \bar{R}),$$

in which r is the firm's number of vessels and $\bar{R}$ is the aggregate fleet for the other firms in the commons. Obviously, the total fleet in the commons, R, equals $r + \bar{R}$. Each exploiter's benefit equals its value of catch, which, in turn, is a fraction of the total value derived from the commons. This representation is analogous to the Olson depiction of a collective-action problem.

The Pareto-optimal solution for the commons is found by choosing the aggregate fleet size that maximizes total profit, $\pi$, for the set of exploiters:

$$(35) \quad \pi(R) = F(R) - pR.$$

The optimizing fleet size, $R^*$, for the commons is uniquely determined by the first-order conditions, $F'(R) = p$, which is independent of the distribution of vessels among the exploiters. Profit maximization is equivalent to maximizing the sum of producer and consumer surplus in this stylized problem. The fleet's marginal product must be equated to the variable input's price. This is the allocation of effort resulting from competitive exploitation in the presence of well-defined property rights.

The Nash equilibrium corresponds to the profit-maximizing choice of r on the part of the individual firms; i.e.,

$$\max_r \{[r/(r + \tilde{R})]F(r + \tilde{R}) - pr\},$$

in which $\tilde{R}$ is an exogenous parameter owing to Nash behavior. The associated first-order conditions can be written as

$$(36) \quad p = (r/R)F'(R) + (\tilde{R}/R)[F(R)/R]$$

with some manipulations. At a symmetric equilibrium involving n exploiters, we have $r/R = 1/n$ and $\tilde{R}/R = (n - 1)/n$, which means that (36) can be expressed as

$$(37) \quad p = (1/n)F'(R) + [(n - 1)/n]F(R)/R.$$

In (37), the price of a vessel is equated to a weighted sum of its marginal and average product. If $n = 1$, price equals marginal product and Pareto optimality is obtained; if, instead, $n \to \infty$, price converges to average product and profits approach zero. In the latter case, the full tragedy of the commons is experienced.

A comparison of the Nash fleet, $R^N$, for the commons that satisfies (36) with the Pareto-optimal fleet, $R^*$, shows an overexploitation in which $R^N > R^*$ when $n > 1$. Since $R^*$ is independent of the number of exploiters, while $R^N$ increases as n increases reaching the R corresponding to $p = F(R)/R$ in the limit, the ratio $R^N/R^*$ becomes larger as n rises (Cornes and Sandler, 1986, pp. 128-131). In consequence, inefficiency does worsen as n increases, consistent with Theme 1 of <u>The Logic</u>. If the size of the exploiters is unequal, then a clear asymmetry can be shown in which effort and, hence, exploitation are positively correlated to fleet size in a pure commons. Small firms are crowded out of the commons by larger firms with mightier fleets.

Institutional arrangements are clearly needed to control overexploitation in the pure commons (see, e.g., Ostrom, 1990).

If the commons were less pure, so that fish were not evenly distributed, allowing some fishing spots to be more productive than others, then firms may derive private benefits by positioning their fleets over these bountiful areas. The presence of these firm-specific private benefits can serve to lessen inefficiency. Symmetry of effort may also be lost if firms differ according to technology. Although The Logic's characterization of collective-action problems is clearly analogous to the pure commons problem above, less stylized models may yield results at odds with the Olsonian themes. As in the case of public goods, assurance and other game structures may be more appropriate for some commons problems.

The underdeveloped world appears especially prone to commons problems. A relevant example is the gathering of firewood for fuel, which has laid waste to forests throughout the developing world. When monsoons come, the loss of the forests means widespread flooding, famine, and pestilence. Within many developing nations, the property rights to the forests are allocated on a free access basis. In other cases, the forests that protect a low-land nation (e.g., Bangladesh) are found in up-land nations with no incentives to consider the hardships that their exploitation can cause another nation. Commons problems are more prevalent in the developing world, since the means for assigning and enforcing property rights are at a more primitive stage than in the developed world. The law of the sea treaty gave the rights to the seabed resources within 200 miles to coastal nations, in an effort to overcome the commons problem by making $n = 1$. Developing countries are apt to suffer under this arrangement for two reasons. Firstly, these nations do not have

the resources or technology to enforce their 200-mile rights, thus leaving them vulnerable to exploiters from within and outside the country. Secondly, the wealth of the deep seabeds, located beyond 200 miles, can be taken by those developed countries with the technology to do so. Similar problems arise with respect to polar and outer-space resources.

Many of the most-pressing problems confronting mankind (e.g., ozone depletion, carbon dioxide buildup, and acid rain) arise because the atmosphere and air sheds are commons. The buildup of carbon dioxide is especially difficult to deal with, since some nations stand to gain as the earth heats up. These potential gainers have perverse incentives that make global warming a potential windfall. The best chance for mankind to deal with this problem is now when uncertainty with respect to gainers and losers is still present. Once gainers can be identified, they have a strong incentive to work against collective interests.

## D. LABOR UNIONS

Olson (1965) devoted chapter III of The Logic to depicting labor unions as a collective-action problem, in which union members share the collective goods of higher wages and other nonpecuniary fringe benefits associated with a union shop. Olson reasoned that either membership must be compulsory or else selective incentives must be provided to motivate laborer to join. If the union cannot motivate laborers, then workers have incentives to free ride on union accomplishments. Union action to establish a closed shop, whereby only union members can be hired, is an attempt to make union-provided collective actions excludable.

In two contributions, Alison Booth (1984, 1985) has re-examined whether workers may be motivated to join even without compulsory actions. Following

George Akerlof's (1980) theory of social custom, Booth (1985) showed that codes of behavior may motivate workers to join unions even in the absence of an enforcement mechanism. Booth (1985) made the union wage, w, both nonrival and nonexcludable to all workers in the industry, but viewed reputation, r, as an excludable benefit only acquired by members. Reputation is an increasing concave function of the proportion of labor force, M, belonging to the union. This membership proportion varies between 0 (no members) and 1 (everyone in the industry is a member). Union members receive utility,

(38) $U^{in} = U^{in}[r(M), w - s]$,

in which superscript "in" denotes a member and s is the membership fee,

(39) $s = a + b/M$,

which include a fixed component, a, and a variable component b/M that falls with membership size. Nonunion workers receive

(40) $U^{out} = U^{out}(0, w)$,

in which superscript "out" depicts a nonunion worker. Since reputation can only be acquired by union membership, reputation for nonunion members is 0. An individual is motivated to join whenever net benefits from membership exists, so that

(41) $U^{in}[r(M), w - a - b/M] - U^{out}(0, w) > 0$.

Booth (1985, pp. 257-260) demonstrated, via the intermediate value theorem, that stable equilibria can exist at the corners, where M = 0, 1, as long as everyone is identical and the difference depicted in (41) equals 0 for some $M \in (0, 1)$. The stable equilibrium at M = 1 violates the free-rider tendency since everyone chooses to join. Contrary to Booth's assertion, this equilibrium is very much in keeping with Olson's view of collective-action

problems, inasmuch as reputation is, in essence, a selective incentive produced jointly, owing to social custom, with the purely public wage component. Without this excludable, jointly produced union benefit, membership would, indeed, be zero as Olson and Booth recognize. Jointly produced outputs can motivate, provided that they are excludable. These motivating benefits may, however, be rival, nonrival, or partially rival. Booth's analysis is reminiscent of club theory.

## E. INTERNATIONAL RESPONSE TO TERRORISM

Since the late 1960s, the international community has experienced an ever-increasing threat of terrorism. Terrorism is the premeditated use, or threat of use, of extra-normal violence or force to gain a political objective through intimidation or fear. Although terrorist motivations vary widely between groups (e.g., nationalism, separatism, nihilism, issue-specific concern), terrorist tactics are similar and include hostage taking, bombings, assassinations and hoaxes. Transnational terrorism concerns terrorist activities involving terrorists or government participants from two or more nations. Incidents originating in one nation and terminating in another, like a skyjacking, are transnational, as are incidents involving the demands made of an agent in a nation other than the one hosting the incident. Terrorist events that include victims, terrorists, or the institutions of two or more nations are considered transnational. These transnational terrorist incidents can be associated with numerous collective-action problems between countries owing to externalities.

If a set of nations are targeted by a state sponsoring terrorism (e.g., Iraq, Iran, Syria), then any retaliatory response on the part of one nation would confer nonexcludable and nonrival benefits to the other <u>targeted</u>

nations. Situations may arise in with the net benefits from retaliation to the retaliator are negative (i.e., retaliatory costs exceed the nation's derived benefits) if the nation is the sole retaliator. If, moreover, net benefits are positive when two or more nations retaliate, then a prisoner's dilemma game, like those in Figure 1 and 3, applies and no nation may go it alone. Unless the payoffs from the status quo of not retaliating is sufficiently negative, nations may not expend a Pareto-optimal level of retaliatory actions. When, however, a state sponsor selectively targets some nation's people and property (e.g., the people and property of the U.S. and Israel), benefits derived from retaliation may be sufficiently great to warrant an unilateral response even though the full costs are shouldered by the sole retaliator. In the case of the Libyan raid on April 15, 1986, the Reagan administration, obviously viewed these net benefits as positive. For state-sponsored terrorism, the retaliation dilemma raises many of the issues (e.g., group asymmetry, suboptimality) that Olson mentioned in The Logic.

Dwight Lee (1988) raised the further possibility that some nations may hurt the collective interests of the group in ways worse than free riding. Lee (1988) puts forward the notion of "paid riding", whereby an agent "sells" the public good of terrorism deterrence that the efforts of others attempt to create. Paid riding occurs when a country offers terrorists a sanctuary if the terrorists promise restraint on the country's own soil. The paid-rider option dominants the free-rider option of doing nothing. By selling or reducing the public good, the paid rider reduces the incentive of the retaliator to act, since the level of deterrence that its actions would achieve is partially undone by the paid rider. Thus, the retaliators net benefits are even less than with free riders and may imply that the group is

no longer privileged.

A collective-action problem may also characterize nations' deterrence expenditure decisions to curb attacks when confronting terrorists that operate on two or more nations' soil. If each nation decides its deterrence independently, then each may allocate too many resources to inducing terrorists to switch where they stage their events. This follows because the nations do not account for the negative externality (by inducing terrorists to operate on another nation's soil) that these deterrence choices create for others. If nations were to share intelligence concerning the group's true preferences for attacking alternative targets, then the overdeterrence outcome would be aggravated as nations are better able to calculate what it takes to make the terrorists go elsewhere. Piecemeal policy, in which intelligence but not deterrence decisions are shared, may make everyone worse off. Both intelligence sharing and deterrence decision pose collective-action concerns. Neither decision can be handled in isolation since each is interdependent. The problem of second best applies. A grand strategy for coordinating policy on both fronts is required to reach Pareto optimality.

## F. STRATEGIC TRADE POLICY

Collective-action problems are also relevant in the study of international trade. If perfect competition and nonincreasing returns to scale prevail so that the terms of trade cannot be influenced by a nation's actions, then the theory of comparative advantage indicates that social welfare can be maximized under a regime of free trade. Although it is in the collective interest of all nations to promote free trade, a defector may achieve individual gains at the expense of the collective by imposing protectionist policies (e.g., tariffs, quotas). Since each nation may

experience a payoff matrix in which the imposition of a tariff is a dominant strategy, a classic prisoner's dilemma may apply and distortionary tariffs may characterize the entire trading community. The study of an optimal tariff involves the choice of the Nash equilibrium tariff, whereby the externality imposed on others is ignored.

In the last couple decades, trade economists have extended the theory to include increasing returns to scale and imperfect competition in their study of free trade (Paul Krugman, 1987). The latter qualification is especially significant in terms of collective action, since imperfect competition raises a whole new set of justifications, whereby protectionist policies can yield nation-specific benefits at the expense of the international community. Strategic trade policy "holds that government policy can tilt the terms of oligopolistic competition to shift excess returns from foreign to domestic firms" (Krugman, 1987, p. 134). Industries that generate knowledge externalities (e.g., computer, aerospace) that can benefit the entire economy of the protectionist are the prime candidates for subsidies and/or other distortions that enable these industries to gain a foothold in the international market. Krugman (1987, pp. 135-37) demonstrates with a simple 2 x 2 matrix how, is the absence of a subsidy, competition between Airbus and Boeing would yield a coordination game with two pure-strategy Nash equilibria, in which one of the two firms controls the market. If, however, a sufficient European subsidy is given to Airbus, then there is only one pure-strategy Nash equilibrium with Airbus in control. Trade restrictionist policies, whether based on strategic considerations or otherwise, will lead to retaliation and could plunge the international community into another era of protectionism where all suffer.

## VIII. CONCLUDING REMARKS

If given the latitude to manipulate the technology of public supply, the utility function, provision costs, group composition, and the strategic assumption, a modeler could discover exceptions to any of the propositions of The Logic that relates group size or composition to collective irrationality. If none of the propositions of The Logic are true in general, why then has Olson's (1965) book been so influential? There are a number of factors involved. Firstly, The Logic provided a clear and concise statement of the collective-action problem, accessible to a wide audience of economists and noneconomists. Secondly, the propositions relating group size or groups asymmetry to collective irrationality are valid for some important scenarios involving the provision of a pure public good, the exploitation of a commons, and the internalization of an externality. Had Olson stated each proposition with myriad technical qualifications, readers might not have taken such an interest. Olson's broad statements provoked researchers to probe problems for exceptions. Thirdly, Olson synthesized a number of separate insights of collective action in an unified whole. A few of these insights were already known, but no previous work had managed to bring together the diverse thoughts on collective action so as to distill general propositions. Fourthly, the timing of The Logic coincided with the profession's renewed interests and efforts to understand market and government failures and what could be done about them. Fifthly, The Logic presented a wide array of applications.

Collective-action problems permeate almost every field of economics including labor economics (e.g., the study of unions), public choice (e.g., voting behavior and pressure groups), industrial organization (e.g., cartel behavior), international trade (e.g., the imposition or removal of trade

barriers), public finance (e.g., the provision of public goods), urban economics (e.g., allocation of club goods), and development economics (e.g., foreign aid). Collective action also concerns issues in other social sciences such as political science, anthropology, and sociology. With so many applications and with new ones being discovered daily, the current interest in collective action is justified. Many exigencies confronting mankind (e.g., protection of the ozone layer, avoidance of global warming, the storage of nuclear wastes, preservation of moist tropical forests, reduction of acid rain, ending the proliferation of nuclear weapons, and the management of the global commons) involve collective-action problems, each with its own unique set of agents, strategies, and technology of public supply.

Much work still needs to be accomplished in the study of collective action. Areas deserving further attention include the construction of dynamic models incorporating additional empirical methods for distinguishing the underlying gaming behavior, and the design of institutions for collective action. This latter problem requires the analysis of transaction costs, economies of scope, and the motives of the agents.

## FOOTNOTES

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1. The Nash equilibrium, associated with Nash behavior, corresponds to each individual choosing his/her optimal response with respect to the best (i.e., mutually optimizing) response of the other agent(s). In such an equilibrium, no agent would be motivated to alter his/her response.

2. The reader should consult Russell Hardin (1982) for an earlier survey of collective action and a more exhaustive list of references. Even though Hardin (1982) provides many worthwhile insights (in particular, his analysis of contracting by convention), this paper views many problems (e.g., the relationship of collective action and the prisoner's dilemma) differently. The study of collective action has advanced greatly since 1982 due, in part, to the re-emergence of game theory in economic thought.

The reader should also consult the excellent survey of public goods by Wolfgang Blümel, Rüdiger Pethig and Oskar von dem Hagen (1986). This survey also contains a very useful list of references, as does Pethig (1985).

3. See, e.g., Andreoni (1987, 1989, 1990), Cornes and Sandler (1981, 1984a, 1986), James Murdoch and Sandler (1984), Sandler (1977), McGuire (1990), and Sandler and Murdoch (1990).

4. Second-order conditions are satisfied since $C_i(q^i)$ is convex and $V_g$ is strictly concave. Thus, the objective function is strictly concave.

5. This assumes that $dC_i/dq^i = dC(Q^N)/dQ$, since marginal cost is assumed constant. With nonconstant marginal cost, the comparison of the Pareto and

Nash conditions is less clear-cut and requires knowledge of the marginal cost functions. In The Logic, Olson (1965, p. 24) did not distinguish between group and individual cost functions.

6. The more traditional approach for establishing suboptimal provision for a Nash equilibrium is to examine the maximization of utility subject to a resource constraint, in which

$$U^i = U^i(y^i, Q)$$

is the ith individual utility function. For a linear resource constraint, the Pareto optimal FOC is

$$\sum_{i=1}^{n} MRS^i_{Qy} - p_Q/p_y = 0,$$

in which $MRS^i_{Qy}$ denotes the ith individual's marginal rate of substitution between the public and private good, $p_Q$ is the per-unit price of the private good, and $P_y$ is the per-unit price of the private good. The FOCs of the Nash equilibrium satisfy

$$MRS^i_{Qy} - p_Q/p_y = 0, \qquad i = 1, \ldots, n.$$

When the $Q^N$ that solves the Nash equilibrium is used to evaluate the Pareto-optimal FOCs, the resulting positive inequality implies that $Q^* > Q^N$.

7. There is also a mixed-strategy equilibrium in which each player randomizes his strategy. A mixed-strategy equilibrium is found by allowing each player to choose his probability based on the best probability choice of the other player. We do not analyze these mixed strategies here.

8. If the payoffs in cell a were (0, 0), then the game would correspond precisely to the battle of the sexes.

9. Farrell (1987) demonstrates that with mixed strategies and preplay communication (i.e., cheap talk), repeated plays decrease inefficiency but do not eliminate it.

10. A notable exception is Jon Cauley, Sandler and Cornes (1986).

11. The technology of public supply is summation.

12. For a Cobb-Douglas utility function, $U = y^{\alpha}Q^{\beta}$, where y is the private good, and $\alpha$ and $\beta$ lie in the open unit interval, the expenditure function is linear and equal to

$$q^i = -[\alpha/(\alpha + \beta)] \sum_{j \neq i} q^j + [\beta/(\alpha + \beta)](y/p_q).$$

The reaction path is found by maximizing utility, subject to the resource constraint and the quantity-constrained level of spillins ( $\sum_{j \neq i} q^j$). Solving the associated FOCs for $q^i$ in terms of the exogenous variables yields the reaction path.

13. McGuire (1974) was very close to discovering the neutrality theorem. If, in (17), K had been written in terms of income, <u>redistribution of income</u> among an unchanged set of contributors, so that $\Sigma dI = 0$, would immediately imply $dQ = 0$ and neutrality.

14. In Mueller (1989, p. 21), this ratio is depicted as $(\alpha + n\beta)/(\alpha n^2 + n\beta)$ owing to an algebraic error when finding the Pareto-optimal provision amount. In a letter to the author, Mueller indicated his awareness of this error and also indicated the correct answer.

15. The weakest-link case is similar in its normative aspects to the perfect-complements, joint-product case (Cornes and Sandler, 1986, p. 81).

16. John McMillan (1979) provides an excellent survey on free riding. He distinguishes three separate notions on uses for the free-riding concept. Firstly, free riding refers to the suboptimality, characteristic of Nash-equilibrium levels of public goods, and, as such, is often related to the negative slope of the public good reaction path. Secondly, free riding refers to the failure of agents to reveal their true preferences. Thirdly, the term

is associated with increased suboptimality as group size increases.

17. The alliance literature is quite extensive and has shown significant growth in recent years. Contributions include Mark Boyer (1990), McGuire (1982, 1990), McGuire and Groth (1985), Rodolfo Gonzales and Steve Mehay (1990), Murdoch and Sandler (1984), Olson and Zeckhauser (1966, 1967), Glenn Palmer (1990), Sandler (1977), Sandler and Forbes (1980), Sandler and Murdoch (1990), and Richard Steinberg (1987).

18. See, for example, Andreoni (1987, 1988a, 1989, 1990), Cornes and Sandler (1981, 1984a, 1986), McGuire (1990), Erza Mishan (1969), Herbert Mohring and J. Hayden Boyd (1971), Murdoch and Sandler (1984), Posnett and Sandler (1988, 1989), Sandler (1977), Sandler and Murdoch (1990), and Sandler and Posnett (1991).

19. See Cornes and Sandler (1981), Andreoni (1987, 1989, 1990) and Sandler and Posnett (1991).

20. See, e.g., Henry Hansman (1980), Posnett and Sandler (1989), and Cauley, Sandler and Cornes (1986).

21. The theory of clubs has been surveyed by Sandler and Tschirhart (1980) and Cornes and Sandler (1986). See these surveys for over two hundred relevant citations.

22. $MRS^i_{Qy} = (\partial V_i/\partial Q)/(\partial V_i/\partial y^i)$ and $MRT^i_{Qy} = (\partial C_i/\partial Q)/(\partial C_i/\partial y^i)$. Similar expressions hold for $MRS^i_{ny}$ and $MRT^i_{ny}$.

23. This follows because $(1 - r)^{-1} = 1 + r + r^2 + r^3 + \ldots$.

## APPENDIX

Alternative Proof 1 for Neutrality Theorem

The Nash problem corresponds to

$$\max_{y^i,\, q^i} \{U^i(y^i,\ q^i + \tilde{Q}^i) \mid I^i = y^i + pq^i\},$$

in which $\tilde{Q}^i = \sum_{j \neq i} q^j$, $I^i$ is the agent's income, p is the per-unit price of q, and one is the per-unit price of the private good. The other symbols have been defined in the text. Individuals are not assumed to be identical. A Nash equilibrium corresponds to the simultaneous satisfaction of the following FOCs,

$$(1) \qquad \pi^i_Q(I^i - pq^i,\ q^i + \tilde{Q}^i) = p, \qquad i = 1, \ldots, n,$$

in which $\pi^i_Q(\bullet)$ is the ith agent marginal rate of substitution between the public good and the private good. These FOCs follow from the above optimization.

Taking a total differential of (1), while holding p constant, gives

$$(2) \qquad \pi^i_{Qy}(dI^i - pdq^i) + \pi^i_{QQ}dq^i + \pi^i_{QQ}d\tilde{Q}^i = 0, \qquad i = 1, \ldots, n,$$

in which $\pi^i_{Qy} = \partial\pi^i/\partial(I^i + pq^i)$ and $\pi^i_{QQ} = \partial\pi^i_Q/\partial Q$. We then substitute $d\tilde{Q}_i = dQ^N - dq^i$ into (2) and solve for $dq^i$ to yield:

$$(3) \qquad dq^i = dI^i/p + [\pi^i_{QQ}/p\pi^i_{Qy}]dQ^N, \qquad i = 1, \ldots, n.$$

We next sum (3) over i and solve for $dQ^N$ to give

$$(4) \qquad dQ^N = k\sum_i dI^i/p,$$

in which $k = [1 - \sum_i(\pi^i_{QQ}/p\pi^i_{Qy})]^{-1}$ and $dQ^N = \sum_i dq^i$. Neutrality follows immediately, since income redistribution implies $\sum_i dI^i = 0$, which, by (4), indicates that $dQ^N = 0$.

Q.E.D.

Alternative Proof 2 for Neutrality Theorem

The second proof follows the methodology of Bruce (1990). To simplify the presentation, we assume just two agents--i and j. Furthermore, all prices are normalized. The ith agent's problem is

$$\max_{Q,y^i} \{U^i(y^i,\ q^i + q^j) \mid I^i + q^j = y^i + Q\},$$

where $q^j$ has been added to both sides of the budget constraint. $I^i + q^j$ is known as full income, $F^i$ (Bergstrom, Blume, and Varian, 1986). The individual is depicted as choosing total contributions, Q, for the group. If $Q > q^j$, then the ith agent's demand or reaction function can be written as

(5) $\quad q^i = f^i(I^i + q^j) - q^j.$

Interchanging i and j gives the demand function for agent j in terms of full income, $I^j + q^i$, and spillins, $q^i$. To derive $dq^i$ and $dq^j$, we totally differentiate (5) and its counterpart for agent j and solve simultaneously to obtain,

(6) $\quad dq^i = [f^i_F dI^i - f^j_F(1 - f^i_F)dI^j]/\nabla,$

(7) $\quad dq^j = [f^j_F dI^j - f^i_F(1 - f^j_F)dI^i]/\nabla,$

in which $\nabla = f^i_F + f^j_F - f^i_F f^j_F > 0$ and $f^i_F = \partial f^i/\partial(I^i + q^j)$. Adding (6) and (7) yields

(8) $\quad dQ = (f^i_F f^j_F/\nabla)\sum_i dI^i,$

which implies $dQ = 0$ when $\sum_i dI^i = 0$.

Q.E.D.

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