Institutions and the Free Rider: The Assurance Problem in Collective Action

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Political and economic theory make extensive use of the one-period Prisoners' Dilemma (PD) to model public goods problems and collective action generally. While the PD provides important insights into the breakdown of social institutions, it gives no explanation of how or why institutions are developed in the first place. Recent work on repeated PDs has emphasized the role of expectations in this process. This paper presents a related approach: the Assurance Problem (AP). The AP suggests that interdependent choice creates incentives to establish and maintain institutions that coordinate expectations based on rules of fair-mindedness. With such coordinated expectations, voluntary contributions to public goods may be utility-maximizing strategies.

In political and economic theory, models of public goods and collective action make extensive use of the one-period Prisoners' Dilemma, in which "free riding" dominates regardless of the expected decisions of others. Although these models provide important insights into why social institutions break down, they give no explanation of how or why institutions begin and are maintained. Instead, they imply that within any group, no internal incentives exist to initiate or maintain institutional agreements.

This paper makes use of a different description of individual motivation, which has alternative implications for theory. The Assurance Problem (AP) shares certain analytical features with the Prisoners' Dilemma (PD), but is based on the assumption that individual decisions are condi-

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tioned on the expected decisions of others, rather than being separable from them. This raises the question of how these expectations are coordinated over time.

I will argue here that the incentive to develop political and economic institutions lies in the coordination of expectations. Institutions which successfully perform such coordination provide assurance in the face of uncertainty regarding the expected actions of others. Institutions are defined, following Schelling (1960), as the behavioral rules that coordinate patterns of political and economic relationships. These include the general social rules which Lewis (1969) and Russell Hardin (1982) abstractly term "conventions," as well as more concrete rules in organizations and decision-making units, such as firms and political groups (see Rawls, 1971, p. 55).

By structuring individual expectations so that group actions can be coordinated, these rules provide information that helps to predict others' behavior. The assurance that others will contribute to public goods, it is argued below, can significantly influence many individuals to contribute as well. Moreover, the incentive to initiate institutional agreements fostering such prediction exists whenever coordination can raise the welfare of a group. The PD leads to the conclusion that public goods will never be supplied without outside enforcement. However, the coordination game described by the AP suggests that there are incentives to develop and maintain institutions characterized by rules which make voluntary contributions to public goods a utility-maximizing strategy. The essence of the AP is that institutions which promote fairmindedness can provide the assurance which makes contribution to the public good more attractive than a free ride.

The first section of this paper discusses the problem of public goods at a general level, noting current problems of theory in explaining observed reality. A review and contrast of the PD and AP follow, arguing that the AP is descriptive of many public goods decisions. Next, I develop the AP in decision-theoretic terms, and discuss how institutions provide information to Bayesian decision makers in a static and dynamic framework. The fourth section then relates the AP to several recent experimental results. The paper concludes by briefly suggesting some general implications for the future direction of public goods research.

The Problem of Public Goods

We live in a world of interdependent individuals, each of whom holds expectations about the behavior of others. All economic and political judgments are based in large part on these expectations (see Schick, 1972). Paradigms of rational choice too often retain the assumption that individual decisions are unaffected by others' choices. This tendency is especially notable in the wide area of theory devoted to the problem of public goods. Public goods are characterized by jointness of supply and are consumed within a well-defined group. Within the group, it is not possible to exclude anyone from individual use or consumption. If there are no exclusive use rights imposed from the outside, interdependent consumption decisions are necessary.[1]

These interdependent decisions are troubling both in theory and in practice because they create incentives to free ride at the group's expense. Pollution, overpopulation, and social organization often appear to support the free rider hypothesis. How is a clean environment to be achieved, for example, when individual firms can benefit by polluting while passing the cost of clean air (a public good) to society as a whole? The prevailing answer, most forcefully advanced by Olson's *The Logic of Collective Action* (1965), is quite pessimistic: "*rational, self-interested individuals will not act to achieve their common or group interests*" (p. 2; emphasis in original). This pessimism is founded in economic theory, which asserts that in public goods situations an asymmetry exists between individual benefit and collective harm, so that it is always advantageous to free ride (Samuelson, 1954). In more recent work, Olson has proposed the challenging hypothesis that the decline of entire economic and political systems occurs because of the tendency of special interests to free ride on national economies (1982).

Olson himself recognizes the possibility of contributions to public goods and has done much to stimulate investigations into the conditions under which they are likely to occur. Unfortunately, the model of choice most often used to analyze the public goods problem is the single-period Prisoners' Dilemma (PD), in which the dominant strategy is always to free ride (Mueller, 1979). It is ironic that game theory, the most useful tool in analyzing strategic interdependence, finds its most popular expression in the single-period PD, in which expectations of others' actions are obviated by dominant strategies. This was certainly not the intention of its originators, who proposed it as a means of going beyond the "Robinson Crusoe economy" (Von Neumann and Morgenstern, 1953, p. 9). If individualistic free riding is a dominant strategy, then without a coercive state apparatus that sets incentives and enforces contributions, no public goods will be provided. The logic of the PD makes many public choices seem to be between "Leviathan and oblivion" (Ophuls, 1973).

[1] The literature on public goods is expansive and of increasing importance in a number of social science disciplines. See Mueller (1979, pp. 1–18) for an overview of the issues and Dawes (1980) and Edney (1980) for a number of applications outside of economics and public choice theory.

In reality, we observe substantial voluntary contributions to public goods without outside enforcement (Keating et al., 1981; Mitchell, 1979). Experimental investigations also question the validity of the free rider hypothesis and the impossibility of voluntary provision of public goods (Alfano and Marwell, 1981; Marwell and Ames, 1979, 1980, 1981; Smith, 1980; Schneider and Pommerehne, 1979; Sweeney, 1973; Bohm, 1972; Fleishman, 1980; Chamberlain, 1978; Oliver, 1980). These investigations suggest that although some ("weak") free riding may occur, individuals often contribute resources to public goods voluntarily.[2] Such results raise questions about the pessimistic view that no contributions will be made (the "strong" free rider hypothesis) or that those who do contribute are simply irrational. However, a rigorous analytical explanation of voluntary contributing behavior does not exist.

In a little-noticed paper devoted primarily to the issue of group size and the likelihood of contribution, Frohlich and Oppenheimer (1970) suggest an approach to the free rider problem which places central emphasis on the interdependence of individual decisions. This approach has interesting implications when it is integrated with other results developed by Sen (1967, 1969, 1977) and Brams (1975). A synthesis of these arguments suggests that self-interested motives in an interdependent choice problem may lead to the development of institutions which promote fairmindedness, leading in turn to utility-maximizing contributions to public goods. In the analysis to follow, it is shown that under such circumstances free riding is an option, but hardly an imperative. There may be numerous incentives internal to any group to contribute voluntarily to collective or public goods.

This intuitive point may be formally contrasted with the implications of the PD in terms of the Assurance Problem (Sen, 1967). The AP has implications similar to recent results which involve repeated plays of the PD (Axelrod, 1981; Axelrod and Hamilton, 1981; R. Hardin, 1982; Schotter, 1980; Taylor, 1976). In repeated plays of the PD, it can be shown

[2] Some attempt has been made on theoretical grounds to explain voluntary contributions within the logic of the free rider. Vickrey (1961), Clark (1971), Groves (1969, 1973), and Groves and Ledyard (1977), for example, define situations in which private incentives are compatible with truthful revelation of demands for a public good, so that no incentive to free ride exists (Smith, 1980). However, these efforts are vulnerable to a wide-reaching impossibility result developed by Gibbard (1973) and Satterthwaite (1975), which demonstrates that strategic incentives to understate one's demand will confound truthful preference revelation (see Ledyard and Roberts, 1974). Even in cases not covered by this impossibility result (i.e., Groves, 1973), Walker (1980) has shown that a dominant strategy of truthful demand revelation can generally be obtained only by sacrificing Pareto-optimality. It would seem that individually incentive compatible mechanisms, characterized by dominant strategies for each actor, are not capable of providing Pareto-optimal allocations of collective goods.

that under special conditions expectations of others' cooperative behavior and fear of retaliation can create an incentive to cooperate. However, as recently explicated by Wagner (1983), even in its repeated version the PD fails to capture a variety of incentives which may be important to explanations of public goods contributions. Wagner notes (p. 331) that this was recognized by early developers of the repeated PD game, including Martin Shubik, who remarked that "for most problems of interest the model is not rich enough to capture a useful abstraction of human affairs" (1970, p. 190).

While this remark applies to any game-theoretic modeling effort, the approach described in this paper gives formal expression to certain motivations — sometimes referred to but never fully explored — as explanations of public goods provision (see Sugden, 1982, p. 342). These include uncertainty, expectations of fairness, and the role of institutions in coordinating these expectations over time. The AP also provides a rationale for the Bayesian process which seems to describe a variety of real world cases of voluntary public goods provision.

In the AP the particular outcome depends crucially both on prior expectations and on a preference for coordinating one's own actions with the actions of others. These expectations are formed by institutions that facilitate the coordination of behavior by providing prior information. If public goods problems are perceived by many people as APs, this has implications for the structure of incentives likely to yield voluntary contributions. Where people are motivated to contribute if this behavior is also expected of others, institutions which convince them that these expectations are justified can promote voluntary provision of public goods. This does not imply that voluntary contributions can supply all necessary public goods. However, that significant incentives exist, internal to any group, to contribute voluntarily, implies that public goods can in some cases be provided without coercion or selective side-payments from outside the group. This introduces a note of optimism into the analysis of collective action and focuses attention on the role of institutional agreements in fostering this type of behavior.

The Prisoners' Dilemma and the Assurance Problem: A Review

The PD as applied to public goods is a formal expression of the apparent illogic of collective action, expressing a set of preferences in which free riding will always dominate (see Buchanan, 1975; Bacharach, 1977; Dawes, 1980; Mueller, 1979; Taylor, 1976). An often-cited example is the "tragedy of the commons," in which the private benefits of grazing an additional head of cattle on a common range exceed the private cost because the costs of maintaining range quality (the public good) can be shifted to the group as a whole (see Edney, 1980; G. Hardin, 1968; Muhsam, 1977; Runge, 1981). The tragedy of overgrazing results from each person's incentive to free ride regardless of the expected actions of others. Even if an agreement is struck which specifies that all will refrain from further grazing, the strict dominance of individual strategy makes such a contract unstable.

As a general description of publicness, this model forms the basis of a large literature for which the analytical foundation is the PD. Where publicness exists, an analogy is drawn to two prisoners who are interrogated separately and promised high payoffs to turn state's evidence. The temptation to defect is argued to be overwhelming.[3] In the tradition of Hobbes, this result argues for coercive enforcement from outside the group or the introduction (from outside) of private side payments or selective incentives to cooperate (Moe, 1980; Sen, 1965; Taylor, 1976). No incentives to cooperate can emerge from within the group if Pareto-inferior outcomes are to be avoided.

More formally, in a two-person PD the preferences of the players are strictly ordered, with a Pareto-inferior equilibrium resulting from the pursuit of self-interest. If two individuals (1 and 2) choose exactly one of two strategies (0 and 1), the payoff p^k to each player ($k = 1, 2$) is a well-ordered function of the strategy choices of the players.[4] Let strategy 0 be free rider behavior and strategy 1 be some positive contribution to a public good. If these individual strategies are given as i and j, then the payoff to the players may be expressed as

$$p^k = F^k(i,j), \text{ for } k = 1, 2; \; i = 0, 1; \text{ and } j = 0, 1. \tag{1}$$

For player one, the preference ordering yielded is

$$F^1(0,1) > F^1(1,1) > F^1(0,0) > F^1(1,0), \tag{2a}$$

where $>$ is read "strictly preferred to." In words, the first player prefers to free ride while the second contributes, above all other options. The second player, analogously, most prefers to free ride while the first contributes. Hence, the second player's preference ordering is

$$F^2(1,0) > F^2(1,1) > F^2(0,0) > F^2(0,1). \tag{2b}$$

Of the four possible outcomes, three are Pareto-optimal: (0,1), (1,1), and

[3] This result mirrors the general impossibility of individually incentive-compatible, dominant strategy mechanisms yielding Pareto-optimal allocations of public goods.

[4] The formal exposition of the PD and AP described here follows Sen (1969).

(1,0). One is Pareto-inferior: (0,0), since by (2a) and (2b), $F^k(1,1) > F^k(0,0)$ for (k = 1,2). This Pareto-inferior point is also a unique Nash equilibrium, since $F^1(0,0) > F^1(1,0)$ and $F^2(0,0) > F^2(0,1)$ from (2a) and (2b). A third result is that there is an incentive always to choose $F^k(0,0)$ *no matter what the other player is expected to do.*

Each player thus finds that 0 (free riding) is a dominant strategy. In the case of player 1, since $F^1(0,j) > F^1(1,j)$ for (j = 0,1), free riding always dominates contributing, and likewise for player 2. Finally, it should be noted that (0,0) can be avoided only if a rule or some other selective incentive to do otherwise is imposed from outside. Any internal agreement between the players is unstable in light of (2a) and (2b) (Sen, 1969). In this scenario, the strict dominance of individual strategy implies the "separability" of individual decisions (Davis and Whinston, 1962; Runge, 1981). The result is that expectations of other people's actions do not make a difference to the incentives of individual members of a group.

In general, however, information concerning these actions is a necessary ingredient even in private decisions. With public goods, jointness in supply makes this interdependence even stronger. Wherever benefits and costs are a function of the total actions of the group, it seems implausible that decisions to contribute are unaffected by expectations of the decisions of others (see Elster, 1979; Nurmi, 1977). Formally, in all nonseparable cases, optimal choices are defined in terms not only of one's own choice variable but also the choices of others (Baumol, 1976).

If the decision to contribute to a public good is conditional to the expected contributions of others, this interdependence is described by an ordering of payoffs which is logically distinct from the PD. One such ordering is the Assurance Problem (AP). In the AP, the payoff to the players is a function of joint choice, as in any public goods problem. Let 0 again represent free rider behavior and 1 a positive contribution to a public good. Preference orderings in the AP take the form

$$F^1(1,1) > F^1(0,0) > F^1(0,1) = F^1(1,0) \text{ for player 1;} \qquad (3a)$$

and

$$F^2(1,1) > F^2(0,0) > F^2(1,0) = F^2(0,1) \text{ for player 2.} \qquad (3b)$$

These orderings state that the strategy of joint contribution by both players is most preferred. Joint free riding is next. Least preferred are those outcomes in which strategies are not coordinated. The AP implies that people prefer to act together in public goods situations. "I'll give my share if you give yours" captures its basic sentiment. In this sense, it describes preferences which reflect a kind of fairmindedness. It should be emphasized that this does not ascribe altruistic or selfless motives to the actors. Fairmindedness is defined simply as the preference for equal contribution, whether this contribution is large, small, or zero. It is this desire for coordinated action which is at the base of the AP. This preference can be either in favor of or against contribution—depending on what is expected of others. Altruistic behavior, in contrast, often involves a desire to contribute regardless of the expected actions of others.

It seems intuitive that willingness to contribute in a public goods situation often depends on the expectation that the contributor will not be the odd man out. Rules reflecting this fairmindedness are also simple and may quickly become "prominent," in Schelling's (1960) sense, as responses to problems of social coordination. An example concerns the enforcement of pollution control laws, in which many industries appear willing to comply if others will too. If others are not expected to comply, it seems unfair to many firms that they do so alone. A similar situation may characterize tax compliance. Again, if others are expected to pay their taxes, so will most individuals. But where noncompliance is the rule, it does not seem fair to many that they pay as part of a minority. While there are obvious exceptions, the AP seems a sufficiently plausible description of such motives to merit further investigation.

In the AP, the Pareto-optimal outcome is joint contribution (1,1). All others are Pareto-inferior. Second, both joint free riding (0,0) and joint contribution (1,1) are equilibria. The reason is that for (0,0), $F^1(0,0) > F^1(1,0)$ from (3a), and $F^2(0,0) > F^2(0,1)$ from (3b). For (1,1), $F^1(1,1) > F^1(0,1)$ from (3a), and $F^2(1,1) > F^2(1,0)$ from (3b). Third, there is no strictly dominant strategy for either player. Fourth, through a collective agreement, each player can be better off by establishing or committing himself to a rule, in recognition of mutual interdependence, than by framing a decision independent of others. In the two-person case, if each is assured that the other will follow the optimal contributing strategy 1, then that person will follow it too, yielding (1,1) as the equilibrium outcome. If free riding is expected, however, a Pareto-inferior free rider equilibrium (0,0) will result. Where expectations are not coordinated, the least-preferred outcome of a mismatch (0,1) or (1,0) may occur. In contrast to the PD, multiple equilibria are possible—the free rider equilibrium is no longer unique.

The choice of strategy is thus secondary to the question of correct prediction for each and every player. This is so because both the Pareto-optimal equilibrium of mutual contribution and the Pareto-inferior but second best free rider equilibrium result from coordinated expectations involving mutual predictability. As predictability falls, the likelihood of least-preferred mismatches rises. Given the capacity to forecast the behavior of others, a strategy of joint contribution is the Pareto-optimal equilibrium. This situation of interdependent choice defines the problem of public goods as uncertainty over others' actions, linking it to the important emphasis on expectations in the literature on repeated PD games.

The AP provides a rationale for why tit-for-tat should so often emerge as the most robust strategy in experimental tests of the repeated PD (see Axelrod and Hamilton, 1981). The tit-for-tat strategy provides the simplest and most direct example of the sort of fairmindedness described by the AP, since one gives exactly as one gets. Below, it is suggested that although the payoffs in these experiments may take the form of the PD, their outcomes can be explained by preferences which more closely approach the AP. The AP also illustrates why matching behavior may have considerable appeal as a general response to problems of collective action (see Guttman, 1978). Finally, the AP is relevant to an emerging body of fairness theory devoted to social choice functions characterized by principles of equal division of resources (see Baumol, 1982). The AP acknowledges that incentives exist to free ride if this behavior is expected of others, but implies that the assurance that others will contribute their fair share increases the likelihood that one will contribute too. The problem is: how can one predict the actions of others with assurance?

Assurance As a Decision Problem

Statics

Assurance is a matter of degree. The ability to predict the behavior of others is subject to varying limits of confidence. In this section, it is rigorously shown how political and economic institutions can increase this mutual predictability, reducing uncertainty and stabilizing expectations by coordinating individual choice (see Marchand and Russell, 1973; Ullman-Margalit, 1977; and Valavanis, 1968). Adhering to such institutions can be its own reward, leading to stability over time if others are expected to adhere to them too (Akerlof, 1980).

The model developed below describes how institutions predict the parameters of individual expectations. These parameters are the probabilities that other individuals will take particular actions. Institutions help to predict these probabilities in much the same way as a regression equation predicts the values of parameters in a set of sample data. In this sense, institutions organize, process, and store the essential information required to coordinate human behavior. In the AP, the static relationship between institutions and expectations may be reduced to the claim that institutions order expectations by providing information, which allows more accurate predictions of individual actions.

The AP may be expressed as a decision problem in which self-interested behavior defines a set of choice rules. As originally suggested by Frohlich and Oppenheimer, consider an individual (the first player) who must decide how much to contribute to a public good. Possible contributions are given along the left column of the matrix below (figure 1) with a representative donation of D. The total resources contributed by others in a group of fixed size, with a representative donation of i, are given along the top row. Both the first player and others can free ride at 0, or can jointly contribute any amount up to a level of full provision equal to 1 for the first player and k for all others. In contrast to the PD, no single strategy is dominant for the first player. It depends on what this player predicts the others will do.

FIGURE 1

THE FIRST PLAYER'S DECISION MATRIX:
HOW MUCH TO CONTRIBUTE TO A PUBLIC GOOD?

TOTAL RESOURCES CONTRIBUTED BY OTHERS

FIRST PLAYER'S POSSIBLE CONTRIBUTIONS

	0	• • •	i	• • •	k
0	U_o		U_i		U_k
• • •					
D	$U_D - D$		$U_{D+i} - D$		$U_{D+K} - D$
• • •					
1	$U_1 - 1$		$U_{1+i} - D$		$U_{1+K} - 1$
	P_o		P_i		P_k

PROBABILITY THE FIRST PLAYER ASSIGNS TO TOTAL CONTRIBUTIONS BY ALL OTHERS

The bottom row of the matrix gives the probability assigned by the first player to the contribution of others at any level such as i. The costs and benefits of alternative joint actions are expressed in terms of utility units. In the representative case of contributions by the first player at level D and by others at i, the total payoff is the utility of D plus i units, minus the D units the first player contributes. Assume that all of the players have twice differentiable concave utility functions defined over the public good in question. The problem for any one of them is to maximize the expected utility of his or her donation strategy. Evaluating each row in the matrix, the first player will choose the largest expected utility given for donation D and i as V_D. Thus, for a representative donation such as D, the first player maximizes the weighted sum of joint contributions to the public good, given as

$$V_D = \sum_{i=0}^{k} U_{D+i}\, p_i - D \tag{4a}$$

This decision rule, however, does not convey the full problem of the first player. The probability of particular contributions by others is only an estimated value, which may be expressed as $(\hat{p}_i)$. Without additional information, the ability of any player to predict these probabilities may be problematic. This prediction problem is analogous to a problem of regression analysis in which varying degrees of confidence exist about particular parameter estimates, depending on the number of observations, relationships among the variables, and other factors. Overall, this confidence may be expressed in terms of measure analogous to R^2 in a typical regression exercise. The row of estimated probabilities $(\hat{p}_0 \ldots \hat{p}_i \ldots \hat{p}_k)$ defines a probability density function (PDF) over the random variable of others' contributions. The first player's confidence in these estimated probabilities is a measure of his or her ability to predict the contributions of others.

The more information player 1 has about player 2 and others' ability to predict his actions, and vice versa, the more mutual confidence or assurance exists that the predicted distribution of probabilities equals the actual distribution. A lack of information about the likely actions of others corresponds to Theil's (1971) measure of uncertainty as entropy.[5] This is defined for an individual player in the AP as

$$E_i = -[\hat{p}_i \log \hat{p}_i + (1-\hat{p}_i)\log(1-\hat{p}_i)], \tag{4b}$$

where $\hat{p}_i$ is the estimated probability that the other players will contribute to the public good at some level i. In a dichotomous case in which the alternatives are either to free ride or contribute, the entropy associated

[5] The entropy concept used here was proposed by Betancourt and Clague (1978) as a basis for examining predictions of factory performance.

with the distribution $(\hat{p}_i, 1-\hat{p}_i)$ takes its maximum value at $\hat{p}_i = 1/2$ and its minimum value at $\hat{p}_i = 0$ or $\hat{p}_i = 1$.

A measure which conveys the role of institutions in providing assurance is defined by the information contained in the predicted probability $\hat{p}_i$, given as

$$I_i = \frac{1-E_i}{E_{max}}, \tag{4c}$$

where E_{max} is the maximum entropy associated with the probability distribution. A summary measure of the amount of information contained in a set of predictions is therefore

$$I = \frac{(I_1 - I_2)}{N}, \tag{4d}$$

where I_1 is the sum of information from correct predictions, I_2 is the sum of information from incorrect predictions, and N is the number of observations. I can range from -1 to $+1$, depending on whether all probabilities are correctly predicted or all are incorrectly predicted. Normalized over the unit interval, this measure indicates the likelihood of accurately predicting others' actions. Ranging from 0 to 1, this likelihood may be defined as Φ, a weight reflecting the assurance with which correct mutual assessments of contributions can be made.

Where Φ is less than one, individuals are less than perfectly assured that the predicted probability of contribution equals the actual probability. This lack of assurance will make coordinated action more difficult. Suppose that I think it likely that others will contribute at some level i. My problem is how much assurance institutions provide that my own contribution plus that of others will result in provision of a particular amount of the public good $D + i$. The higher the prior estimate of contribution $\hat{p}_i$ and the higher the capacity Φ (resulting from institutional agreement) to predict this probability, the more information conveyed by the institutions in force.

This situation was described in a slightly different context by Keynes (1936, pp. 152–60), whose analysis of the role of convention in financial markets emphasized not only the probability of movements in share prices but also the assurance with which these probabilities were held. To illustrate the point, Keynes employed the parable of a beauty contest then regularly held in the *Sunday Times*, in which prizes went to those who selected the candidate for queen thought most beautiful by the rest of the contestants. Instead of selecting the candidate who was probably most beautiful, attention was given to what the choices of others would be, which in turn was strongly influenced by conventional standards of beauty. In this sense, Keynes argued that the price level of shares depends on the impact of convention (and thus government institutions) on each market participant's calculation of what other participants expected the price level to be (see Ackley, 1983, pp. 4–5).

A similar situation describes the problem of public goods in the AP, since it is institutions which provide the assurance that the probable level of contribution expected will in fact result. By influencing the conventional opinion, institutions can lead to a set of expectations in which continuing contributions (or continuing free rider behavior) are self-reinforcing. Estimates of the probable contributions of others are thus conditional on the information provided by institutions.

Consider a two-person example of a decision process in which the first player must evaluate the likely response of a second player in an AP situation. Here we assume for simplicity that both players hold preferences satisfying the ordering of the AP. As above, the two strategies open to them are to free ride or to contribute, given, respectively, as 0 and 1 for both players.[6] The first player is the decision maker. The constraint on both players is the relation between utilities presented in (3a) and (3b): joint contribution is preferred to joint free riding if others are expected to contribute; joint free riding is preferred to joint contribution if others are expected to free ride; both of these outcomes are preferred to the mixed cases in which the players fail to match behavior. Whether others will or will not pursue a particular strategy is a probabilistic judgment. However, estimates of these probabilities are conditional on the information held by the players. Institutional agreements provide this information, reflected by Φ, the weight attached to a particular estimate of probable action by the other player.

Consider the case in which the only free parameter in the model that influences the decision is Φ. This situation would result if the entropy of the underlying probability estimates was at a maximum, so that $\hat{p}_0 = \hat{p}_1 = 1/2$. Existing institutions convey this information with assurance measured by the value of Φ, the likelihood of correct prediction. Since Φ is defined along the unit interval, the likelihood of incorrect prediction by both players is given by $(1-\Phi)$. This is a revised version of "Newcomb's Problem." Unlike that problem, which is a game against nature, here the

[6] For consistency, I continue the same notation of 0 for free riding and 1 for contributions by the first and second player as used in introducing the PD and the AP. Conventional notation is to use D to represent defection and C to represent contribution. The notation used here retains D and i as representative donations or contributions by the first player and others to emphasize the fact that intermediate contributions short of full provision are possible.

decision involves symmetrically situated players simultaneously deciding under uncertainty (see Brams, 1975). Although improved information conveyed by institutions can increase the predictive accuracy of the players, allowing coordinated behavior, this behavior can also lead to a Pareto-inferior free rider equilibrium. Hence, the question is whether the estimated probabilities of contribution versus free rider behavior together with the utility functions of the players and the assurance conveyed by institutional agreements will lead both players to contribute. We can represent the situation with the decision tree below (figure 2).

The top branch of the tree results from the second player's correct prediction of the first's decision to contribute, yielding a Pareto-optimal equilibrium (1,1). The outcome is weighted by Φ, the likelihood or assurance that both the first player's decision and the decisions of others are mutually predictable. The second branch results from incorrect prediction of the same behavior by the second player, leading this player to free ride while the first contributes, and an outcome of (1,0). In this case, the outcome is weighted by $(1-\Phi)$, the likelihood of incorrect prediction. The third branch results from correct prediction of free rider behavior, and the Pareto-inferior equilibrium (0,0). Here the outcome is weighted by the likelihood of correct prediction. The fourth branch results from incorrect prediction of the same behavior, and (0,1). The outcome is weighted by the likelihood of incorrect prediction.

The first player thus decides to contribute or free ride, based on both the estimated behavior of others and the degree of mutual assurance each player holds that prior predictions of one another's behavior will be accurate. The first player's utility from these outcomes is described in the next column to the right, consistent with the decision matrix discussed above. At far right is the expected utility of this payoff, weighted both by the prior probability of contribution (here .5 due to maximum entropy) and by the assurance of correct prediction, given by Φ and $(1-\Phi)$.

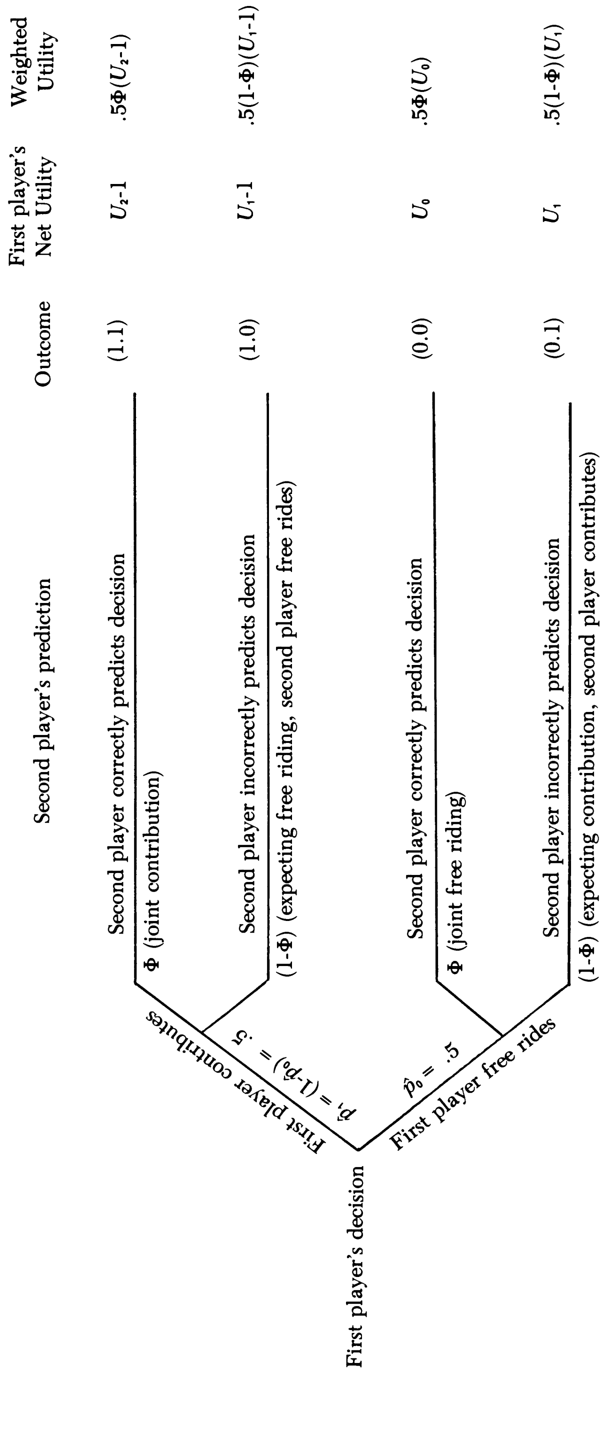
Combining the utility maximization outlined above with this set of choices, the first player must decide whether free riding or contributing is the best strategy. As the diagram makes clear, correct prediction is necessary but not sufficient to guarantee a Pareto-optimal equilibrium (1,1), since it can also lead to the Pareto-inferior pair (0,0). Therefore, an incentive exists not only to develop institutions which increase the assurance of correct prediction Φ, but which also explicitly prescribe contributions to public goods.

The decision tree above may be used to calculate the expected value of contribution. Under maximum entropy, where $(\hat{p}_1 = \hat{p}_0 = 1/2)$, this is

$$V_1 = .5\Phi(U_2 - 1) + .5(1 - \Phi)(U_1 - 1); \quad (5)$$

FIGURE 2

DECISION TREE FOR THE TWO-PLAYER ASSURANCE PROBLEM



while the expected value of free riding is

$$V_0 = .5\Phi(U_0) + .5(1 - \Phi)(U_1). \tag{6}$$

The value of contribution is thus the weighted sum of utilities which exceeds the value of free riding whenever

$$V_1 > V_0, \text{ or}$$

$$[\Phi(U_2 - 1) + (1 - \Phi)(U_1 - 1)] > [\Phi(U_0) + (1 - \Phi)(U_1)], \text{ or} \tag{7a}$$

$$\Phi(U_2 - 1 - U_0) > (1 - \Phi)(U_1 - U_1 + 1), \text{ or} \tag{7b}$$

$$\frac{\Phi}{(1 - \Phi)} > \frac{1}{(U_2 - 1) - U_0}. \tag{7c}$$

Thus, the conditions under which the value of contributing exceeds that of free riding are those in which the assurance of correctly assessing the probable actions of others, described by the left-hand side of (7c), is greatest. This is true even under conditions of maximum entropy. Where the probability that others will contribute is estimated to be high to begin with, assurance that this estimate is correct will reinforce the propensity to match such contributions. It should also be noted that the right-hand side of (7c) is smaller and the expected value of contribution correspondingly greater whenever the utility gained from joint contribution $(U_2 - 1)$ is large in relation to that gained from joint free riding (U_0).

This result may be generalized to describe the case in which multiple players in a group of fixed size contribute an amount which may range from zero (due to collective free riding) up to $k + 1$ (the maximum joint contribution). For any player, the choice is whether or not to contribute some positive level D where $0 \leq D \leq 1$. This choice is conditional on both the estimated probability of contributing behavior by others as well as the assurance, resulting from the structure of institutional agreement, that these estimates are correct. Depending on the expectations of the members of a group, contributions to public goods may settle into a multiplicity of equilibrium levels, of which the free rider equilibrium is only one.

The AP is consistent with Olson's prediction that in large groups free riding is more likely because the primary difficulty in such groups is coordination. The AP predicts that contributions will fall if contributing behavior by others is difficult to predict with assurance, even if the incentive to free ride is not dominant. In large groups, estimates of both the probability of contribution by others, as well as the assurance with which these estimates are held, are likely to be lower than in smaller, more homogeneous settings. On the one hand, the AP suggests that the strict dominance of individual strategy is an unnecessarily strong condition to explain such an outcome. On the other hand, it suggests that even in large groups, if an appropriate set of expectations exists, voluntary contributions to public goods are possible.

Dynamics

It is sometimes observed that institutions which treat free riding as unavoidable or even desirable may bring it about (Kelman, 1981). Conversely, institutions which convey an expectation of contribution may reinforce it. The manner in which institutions perform such an informational function in a dynamic context may be expressed in terms of a Bayesian learning process.[7] The particular ordering of expectations resulting from institutions is an adaptive learning response to the environment of the group. Over time and across cultures, individual contributions to public goods may be expected to change (see Herskovitz, 1960; and Benedict, 1961).

In the case above, a player was faced with the single-period problem of coordinating his or her own behavior with the expected behavior of others so as to maximize individual utility. In a dynamic setting, this judgment requires continual reevaluation of the probability that others will contribute or free ride, conditional on the extent to which institutions assure this behavior. Changing institutional agreements therefore will alter this information set.

An institution which increases the ability to predict the probabilities of contribution in period *t* provides a more well-defined prior distribution on which to base strategy in subsequent periods. This information defines the strategic domain of each player in a group, so that the AP in repeated plays becomes a game of incomplete information (see Harsanyi, 1967–68; and Kreps and Wilson, 1982). The outcome of this game is the result of joint decisions by all of the players in the first period, which in turn defines a second period game. The problem is thus to decide on a level of contribution compatible with intertemporal utility maximization in which probability estimates conditioned on institutions in any period yield decision rules for the next. These decisions are then modified in each period (see Reiter and Hughes, 1981). It is thus possible to explain the evolution of institutions that provide public goods in terms of prior information and sample information regarding group behavior. Institu-

[7] This process is carefully detailed by Harsanyi (1967–68). Such a process has also been related to iterated PD games. See Adams and Rosencrantz (1980) and Grofman and Pool (1975).

tions evolve and survive depending on their success in coordinating these expectations over time.[8]

In a dynamic context, the incentive to develop and maintain institutions is not only the provision of information, but also a reduction in the costs of acquiring this information anew in each period. Institutions provide this prior information in shorthand, so that each such decision does not require a search for the state of mutual expectation. By maintaining a structure within which sample information drawn from experience can be processed, institutions provide order and security in an uncertain world (Boland, 1979). Where sample information significantly alters the distribution of expectations, these expectations must be revised (see Winkler, 1980). Thus, not only do expectations affect contributing behavior—over time, contributing behavior affects expectations (Dawes et al., 1977). This dynamic and interactive process constitutes the learning process in an environment of collective choice.

A description of institutions as providers of prior information in a sequential Bayesian process also suggests a precise definition of institutional equilibrium. An equilibrium concept provides a notion of consistency in which the things which agents take as given are consistent, or at least not inconsistent, with maximizing behavior on the part of the other agents (Prescott and Townsend, 1980; Rothschild, 1973). A set of expectations providing for this consistency may be described in terms of a joint probability density function for all individuals in a group that remains unchanged over time (Hahn, 1973; Radner, 1968). In such an ideal equilibrium, each agent knows what to expect of others in the relevant future.

This raises the further issue of the stability of particular institutional equilibria, a topic beyond the scope of this paper. Even without major shocks to a set of expectations, institutions may be hypothesized to be subject to degradation over time. This process will create increasing uncertainty (entropy), or what Buchanan (1975) terms the erosion of rule abiding capital. If contributions to public goods depend on institutions' capacity to predict behavior, then these institutions must be continually maintained in the face of normal degradation.

In summary, there may be significant incentives internal to any group to develop institutions which promote voluntary contributions to public goods. If the AP accurately describes the motivation behind many actual public choices, voluntary contributions to public goods may be perfectly consistent with utility-maximizing behavior. Moreover, since institu-

[8] This description is similar to the game of matching behavior proposed by Guttman (1978) and an alternative developed by Thompson and Faith (1981), but imposes fewer requirements on the information set of the players.

tions can provide the assurance which will increase the utility of contributions, an incentive exists to develop rules and agreements over time which explicitly prescribe contributing behavior. Outside enforcement may be an effective (but more costly) means of insuring the same or additional contributions. But without a climate of expectations supportive of voluntary contribution, even the most draconian enforcement measures may fail to produce public goods. If such a climate fades, rebuilding it depends on the development of new agreements, in which outside enforcement can play only a supporting role.

The AP also suggests that in a variety of public goods experiments, even where the objective ordering of payoffs would seem to support free rider behavior, the prior impact of institutions on the structure of expectations may make contribution a strategy pursued by many. The role of such institutionally fostered fairmindedness may provide insight into a variety of recent experimental results.

Experimental Evidence and the Assurance Problem

A number of disciplines have examined problems of free rider behavior on an experimental basis. Economics, political science, sociology, and psychology have all contributed to this growing literature, which would be impossible to survey here.[9] Procedures vary, but they generally involve a structured attempt to replicate the conditions of the PD. Some studies are only one-shot, while others iterate the PD over time, allowing analysis of learning behavior. All such studies share a structure of payoffs in which subjects receive higher individual payoffs to free ride than to contribute, and in which all are jointly better off if they contribute than if they free ride.

Among the results considered most challenging to those who defend the universality of free rider behavior are those of sociologist Gerald Marwell and his coauthors (Marwell and Ames, 1979, 1980, 1981; Alfano and Marwell, 1981).[10] Their major finding, replicated many times, was that

[9] John Fleishman and an anonymous reviewer made me aware of new areas of research in sociology and psychology. I have partially relied on Fleishman's analysis in an unpublished manuscript (1981) in presenting the findings described. Much more literature in the experimental area deserves systematic treatment which cannot be done justice here.

[10] Previous experiments testing this behavior (Smith, 1980; Schneider and Pommerehne, 1979; Sweeney, 1973; Bohm, 1972) suffered from restrictions to groups of relatively small size, as well as complex designs which ran individuals through multiple trials, each of which involved somewhat different experimental conditions. Marwell and Ames sought to correct for these restrictions. In the experiment, subjects could divide resources in the form of money-valued tokens between a group exchange and an individual exchange. The group exchange represented a public good and the individual exchange a private good. Tokens invested in the individual exchange earned a certain amount, independent of the behavior of

subjects voluntarily contributed significant amounts of available resources to a representative public good, in many cases without enforcement or structured incentives from outside the group. They reported:

> Over and over again, in replication after replication, regardless of changes in a score of situational variables or subject characteristics, the strong version of the free rider hypothesis is contradicted by the evidence. People voluntarily contribute substantial portions of their resources — usually an average of between 40 to 60 percent — to the provision of a public good. This despite the fact that the conditions of the experiment are expressly designed to maximize the probability of individualized, self-interested behavior. Free riding does exist — subjects do not provide the optimum amount of public good, and tend to reserve a meaningful fraction of their resources. The "weak" free rider hypothesis is supported. Nevertheless, the amount of contribution to the public good is not easily understood in terms of current theory. (Marwell and Ames, 1981, p. 17)

Results of other studies support these findings. Although group size and selective incentives can affect outcomes, experiments testing the impact of these factors indicate that the level of voluntary contribution is far from zero in large groups, even where the group numbered eighty or more (Marwell and Ames, 1979, 1980; Alfano and Marwell, 1981; Fleishman, 1980). Where selective incentives are introduced from outside the group, the extent of contribution varies positively with incentives to cooperate and negatively with incentives to defect. Even in these studies, however, the level of voluntary contribution in the absence of such selective incentives is not zero (Kelley and Grzelak, 1972; Goering and Kahan, 1976; Komorita et al., 1980).

Despite the fact that these experiments are designed as PDs, it appears that dominant strategies to free ride do not explain the results. Even if the objective structure of payoffs corresponds to the PD, expectations of others' behavior and a desire to contribute a fair amount in light of these expectations provide a plausible basis for interpreting the results in light of the AP. Taking the Marwell and Ames experiments as a specific example, if subjects expected the contributions of others to fall in the range between 40 and 60 percent of total resources, and held preferences corresponding to the AP, they would be inclined in turn to contribute approximately 50 percent of their own resources.

Fortunately, Marwell and Ames posed a number of questions designed to explore both the motivations of the subjects and their expectations of

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the other group members. In contrast, the group exchange paid its cash earnings to all members of the group according to preset formula. Each subject received a share of the return on his own investment in the group exchange, and the same share of the return on the investment of each of the other group members. The group exchange was thus not only nonexcludable, its return compared with the individual exchange was a direct function of the joint actions of all of the members of the group.

the probable actions of others. In response to questions which asked subjects to predict these actions, they found it statistically significant that the higher the level of contribution expected of others, the higher the amount contributed, and vice versa (1979, p. 1356). Although this statistical correlation proves nothing about motivation or cause, it does suggest the need for additional research.[11]

Regarding the role of institutions in establishing expectations based on fairmindedness, the Marwell and Ames experiments were even more instructive. Where subjects contributed an average of between 40 and 60 percent of their resources to the representative public good, the AP suggests that some form of implicit agreement may have influenced these expectations. Such a prior sense, if it were one of fairmindedness, would be reflected by a high level of mutual assurance that others would also contribute around a mean level of 50 percent. Two questions were asked of the subjects which concerned fairness in this investment situation. The first asked what they thought a fair investment in the group exchange would be in terms of percentage of total resources. The second asked whether the subjects were concerned with fairness in making their own investment decision.

Despite the fact that subjects participated only in one test situation, so that no cross-order feedback could result from the experiment itself, "there was surprising unanimity of thought regarding what was considered fair" (1981, p. 19).[12] Specifically, Marwell and Ames report that "we found that more than three out of four [subjects] thought that 'about half' or more of a person's resources should be contributed, and more than one out of four thought people who were fair would contribute all of their tokens" (1981, pp. 18–19). These institutional rules supported major investments in the public good and correlated closely to the levels of investment actually found. Although far from providing confirmation, these results build a strong case for more careful investigations of institutionally determined expectations of fairmindedness in public goods situations.

Other recent experiments in economic bargaining behavior reinforce this case.[13] In a series of experiments testing the assumptions of classical

[11] This result is also consistent with the tit-for-tat strategy identified in Axelrod (1981) and Axelrod and Hamilton (1981) as a stable strategy of evolutionary cooperation.

[12] The solitary exception was a subsample of economists and economics graduate students. More than one third of the economists either refused to answer the question regarding what is fair, or gave "complex, uncodable responses." They were half as likely as other subjects to indicate they were "concerned with fairness" in making their investment decision. The AP suggests that economists may well hold different prior expectations of others. If so, the expectations of the economics graduates were set according to a different rule, perhaps laid down by economic theory in the form of the free rider hypothesis.

[13] Dawes et al. (1977) showed that communication per se concerning an irrelevant topic

bargaining models in the tradition of John Nash (1950), economists Roth and Schoumaker (1983) report the failure of such models to predict equilibrium outcomes. These experiments support the hypothesis that bargaining is based on common subjective expectations about the behavior of others. These expectations provide crucial prior information leading to particular outcomes.[14] Institutional agreements strongly influence these expectations, which are set by agreements and updated in response to experience in the experiment. The most striking result, Roth and Schoumaker (1983, p. 371) report, "is that it may be necessary to incorporate the expectations of the bargainers into any description (or definition) of equilibrium outcomes, and that there may in general be multiple equilibria supported by different sets of mutually consistent expectations."

Identifying the potential relevance of the AP to these situations, Sugden (1982, p. 342) recently observed that if each person in a public goods situation does not hold Nash conjectures, and believes that his or her own contributions are conditional on the contributions of others, then "the problem is one of 'assurance' and under-provision of the public good is not necessarily entailed."

CONCLUSION: THE FUTURE OF PUBLIC GOODS RESEARCH

The role of institutions in forming expectations of fairmindedness should come as no surprise. Most problems of interest in the social sciences, including public goods, involve coordinating expectations in the

did not change the level of cooperation, compared with no communication, in a PD situation. However, the opportunity to talk specifically about the dilemma raised cooperation as high as 72 percent. Of this Fleishman (1981, p. 11) states, in support of the general hypothesis regarding increased assurance as a function of increased (in this case sample) information: "Evidently, simply getting to know each other is not sufficient to promote collective action, but talking about the situation and forming expectations of others' behavior does influence decisions to cooperate."

[14] The procedure leading to this conclusion may be described in terms of the following "thought experiment" (Roth and Schoumaker, 1983, p. 365). A randomly selected individual plays some large number of games in which he bargains over how to divide a certain sum of money. Although he is unaware of the fact, all of his opponents are confederates of the experimenter, and they allow him to obtain, say, 80 percent of the available money. After he has gone through this experience, you have the opportunity of bargaining with him on your own behalf (not as a confederate). Since his past success is common knowledge, it will be difficult to bargain on an equal basis; he has every reason to expect that you will concede to him. The rules of the game are that after completing a set of negotiations, the players separately write down their demands. They receive their demands if they are compatible, and otherwise receive nothing. The fact that this randomly selected individual now expects to get 80 percent will make it very risky for you to write down a demand of more than 20 percent.

face of uncertainty. Rules based on elementary fairness principles provide a robust and relatively simple basis for such coordination.

The general relationship between institutions and expectations is already a basic subject in macroeconomics (Lucas, 1972, 1975, 1976; Schiller, 1978; Fisher, 1980). In this literature, the animated debate over the rational expectations hypothesis (Muth, 1961) in discussions of appropriate monetary policy is one in a class of questions concerning the way in which institutions such as the Federal Reserve Board set expectations of future economic activity (Frydman, O'Driscoll, and Schotter, 1982). The relationship between institutions and expectations may be even more useful in describing the political business cycle (Keech and Simon, 1983). A broad range of public goods issues, including pollution, income tax evasion, and collective choice in voting and social movements, may be given new insights if expectations and institutions are given more systematic attention.

The research agenda on a theoretical level is to explore further the implications of expectations formation and the AP. Are expectations of fairmindedness in public goods situations compatible with rational expectations, or are they adaptive as some suggest? Is the cost of information acquisition a critical determinant of institutional agreement (see Hurwicz, 1972), and if so, how does this offset incentives to supply public goods in groups of various sizes? On a more empirical level, tests of the influence of fairmindedness in the laboratory as well as in survey research can help establish the reasonableness of the AP as a model of collective action. Much interesting research in these areas is already underway (see Schwartz-Shea and Simmons, 1982).

The AP indicates that the outcomes of public choice may be less pessimistic than the free rider hypothesis suggests. This may have some important implications at the level of both theory and policy. When account is taken of the wide range of impacts which different institutional arrangements can have on expectations and public goods provision, the internal dynamics of collective action take on a new logic and sense of possibility.

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