The effect of group size on public good provision in a repeated game setting

Paul Pecorino*

Department of Economics, Finance and Legal Studies, Box 870224, University of Alabama, Tuscaloosa, AL 35487-0224, USA

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Abstract

The ability to cooperate in the provision of a public good is analyzed in a repeated game. Holding the level of provision fixed, with quasi-linear utility we find that the critical value of the discount parameter converges to 0 in the limit. Thus, cooperation is feasible in a large market. Next, we allow the level cooperation to be adjusted optimally as the group size increases, both for a specific form of quasi-linear utility and for Cobb–Douglas utility. In each case, we find that there are admissible values of the discount parameter such that cooperation may be maintained in the limit. © 1999 Elsevier Science S.A. All rights reserved.

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1. Introduction

It is well known that contributions to a public good are subject to a free-rider problem. Does this free-rider problem become worse as we increase the size of the group which benefits from provision of the public good? What happens when the group size becomes very large? There has been an extensive analysis of these questions in a static setting, where there is only qualified support for the
proposition that the free-rider problem becomes worse as group size increases (Sandler, 1992, pp. 52–54). In this paper, the ability to maintain cooperation when group size becomes large is analyzed in a dynamic setting in which cooperation may be maintained through the use of a simple trigger strategy.

When the discount parameter $\delta$ is sufficiently large, a trigger strategy can maintain the cooperative outcome in a repeated game setting. In such a game, a critical value of the discount parameter $\delta^*$ may be defined such that if the actual discount parameter lies above it, cooperation may be maintained. If the actual discount parameter lies below $\delta^*$, then cooperation must break down. The effects of an increase in group size $n$ on the ability to maintain cooperation can then be analyzed through its affect on $\delta^*$. If $\delta^*$ rises with $n$, then the increase in group size is said to make maintaining cooperation more difficult. If $\delta^* \to 1$ as $n \to \infty$, then cooperation becomes impossible in large markets. If $\delta^*$ converges to a number less than 1 as $n$ rises without bound, then there are admissible values of the discount parameter such that cooperation may be maintained even in large markets. To the extent that cooperation can be maintained in large markets, this violates our intuition about the ability to maintain a cooperative outcome in a large group.

In this paper, we will focus on results for large markets for three special cases of public goods provision. First, we assume quasi-linear utility, while holding the level of desired cooperation fixed. We find that the critical value of the discount parameter converges to 0 in the limit as the group size becomes large. Thus if individuals in a large economy place any weight at all on the future, cooperation is feasible in the large market. Next we consider a case where the level of cooperation is adjusted upwards to its optimal value as the group size increases. We do this for a particular specification of the quasi-linear utility function and find that $\delta^*$ converges to a number less than 1 in the limit. Thus, there are admissible values of the discount parameter (i.e., values less than 1) such that cooperation may be maintained in a large group.

Finally, we consider Cobb–Douglas preferences, where the level of cooperation is adjusted to the optimum as group size varies. In contrast to the case with quasi-linear utility, Cobb–Douglas preferences allow for income effects in the provision of public goods. As a result, the noncooperative level of provision is increasing in group size. However, we again find that there are admissible values of the discount parameter such that cooperation may be maintained in the limit.

2. Previous literature

Olson (1965) is the classic reference on relating public goods provision to group size. McGuire (1974) and Chamberlin (1974) analyze the effects of group size on provision in a static setting and find that public good provision is generally increasing in group size. The level of contributions in the noncooperative
equilibrium tends toward a finite limit as group size approaches infinity. The departure of the noncooperative equilibrium from the group optimum will grow in certain special cases, but this result does not hold in general (Sandler, 1992, pp. 52–54). Thus, in the static setting there is only qualified support for the proposition that the free-rider problem grows worse as group size increases. McMillan (1979) considers the use of trigger strategies in the context of public goods provision in a repeated game setting. See Sandler (1992) and Cornes and Sandler (1996) for recent overviews of the public goods literature.

The ability of oligopolistic firms to cooperate has been extensively studied in a repeated game setting. Friedman (1971) first analyzes trigger strategies in the context of an infinitely repeated Cournot oligopoly and finds that cooperation may be supported if the discount factor is sufficiently high. To maintain cooperation in a large market, the critical value of the discount parameter must converge to some number less than 1 as the number of firms $n$ rises to infinity. Lambson (1984), (1987) presents an analysis of large markets for both Cournot and Bertrand oligopoly and finds the restrictive conditions under which cooperation may be maintained in the limit as $n \to \infty$. The restrictive nature of the conditions Lambson derives leaves us with the presumption that cooperation must break down in large markets.

Pecorino (1998a) has examined the effect of an increase in the number of identical firms $n$ on the ability of an industry to maintain a cooperative level of tariff lobbying. His two main findings are that an increase in $n$ has an ambiguous effect on the difficulty of maintaining cooperation, and that in the limit as $n \to \infty$, the critical value of the discount parameter converges to a number less than 1. As a result, there are admissible values of the discount parameter such that cooperation may be maintained with an infinite number of firms in the industry. Both of these results are at odds with our intuition on how increases in the number of firms affect the ability to maintain cooperation in tariff lobbying.

The public goods analysis in this paper differs from the lobbying analysis in Pecorino (1998a) in two ways. In Pecorino (1998a), the industry size (measured by total industry capital) is held constant throughout the analysis. As a result, when the number of firms increases, firm size, and therefore the individual stake in the provision of the tariff, decreases. Thus, the noncooperative level of provision is decreasing in group size, and the optimal level of provision is invariant to the number of firms.

By contrast, here we have a pure public good where an increase in group size in no way diminishes the benefits received from the public good by the original members of the group. As a result, the optimal level of provision in increasing in group size, and the noncooperative level of provision is invariant to group size.

\[1\] Green (1980) constructs an example in which cooperation may be maintained in large markets for Cournot oligopoly. Lambson (1984) shows that Cournot cooperation in large markets requires very special assumptions about demand and firm cost functions.
when there are quasi-linear preferences. One consequence of this difference is that Result 1 of this paper is much stronger than the corresponding result in Pecorino (1998a). Because they cover cases where the level of public good provision rises optimally as the group size grows, Results 2 and 3 of this paper do not have direct analogs in Pecorino (1998a).

Finally, there are no income effects in the provision of a tariff (since it is not a consumption good). In essence, with the tariff, one is always analyzing a ‘quasi-linear’ case, in the sense that there are never any income effects. For more general preferences where the public good is normal, the noncooperative level of provision is increasing in group size. In our analysis in Section 6, we will allow for income effects in the provision of the public good by considering Cobb–Douglas preferences.

While the standard intuition is that it becomes harder to cooperate as group size increases, the static literature on public goods provision generally cannot address this issue. The reason is that there is no cooperation in the one period model. Rather the literature has focused on the important question of how the noncooperative level of provision changes with an increase in group size. Cooperation cannot be maintained in the single shot game because there are no future periods in which to punish behavior which deviates from a cooperative solution. In the repeated game, the difficulty of cooperation will be governed by how payoffs under defection, cooperation and noncooperation evolve as the group grows larger. These in turn will dictate the incentive to cheat, the gain from cooperation and the penalty for cheating. As we shall see, these payoffs do not systematically evolve so as to guarantee the breakdown of cooperation in large markets.

Before proceeding, it is worth making a note on the terminology used in this paper. All the games considered in this paper are noncooperative in the sense that binding contracts are not possible. However, I will refer to a noncooperative outcome as a shorthand for the single shot (or static) Nash equilibrium. I will refer to the cooperative outcome as a shorthand for an outcome of the game in which some degree of cooperation is supported as an equilibrium via a credible threat not to cooperate in future periods if anyone defects from cooperation in the current period.

In the next section, a generic repeated game is set out, allowing us to define the critical value of the discount parameter. In the ensuing sections, three special cases are analyzed. In Section 4, we examine the special case of quasi-linear utility, where the level of cooperation is held constant as the group size increases. In Section 5, the level of cooperation is maintained at the optimum as group size increases, but a specific form of quasi-linear preferences is assumed. With quasi-linear preferences, there are no income effects on public good provision, and so the level of contributions in the noncooperative outcome is independent of group size (Cornes and Sandler, 1996, pp. 61–163). In Section 6, we assume that

\[\text{The corresponding result is Result 2.}\]
preferences are Cobb–Douglas in order to allow for income effects. For all of our specifications, we find that cooperation may be maintained in the limit as group size grows large. Section 7 concludes the paper with a discussion of some the possible limitations of the model.

3. The critical value of the discount parameter

All individuals are identical, and only symmetric equilibria are analyzed. Consider the possibility of cooperation in an infinitely repeated game, where cooperation is supported through the use of a trigger strategy. In such an equilibrium, each person makes the cooperative level of public goods contribution in the current period if all individuals cooperated in the previous period. If any person defected in the previous period, then everyone reverts to the single shot Nash equilibrium forever. Assume that everyone observes, without error, the aggregate level of contributions made in the previous period. As a result, defections are always detected. Let an individual’s payout be denoted $\pi^C$ under the cooperative outcome, and $\pi^N$ under the noncooperative outcome, respectively. The payoff earned by a single individual who defects from the cooperative outcome is denoted $\pi^D$.

If a person defects from the cooperative outcome, she will earn $\pi^D$ for the current period and $\pi^N$ in all future periods. If this payoff is greater than the payoff from continued cooperation, then she will defect and cooperation cannot be maintained. Thus, a necessary condition for maintaining a cooperative outcome under a trigger strategy with infinite Nash reversion is

$$\pi^D + \sum_{t=1}^{\infty} \delta^t \pi^N \geq \sum_{t=0}^{\infty} \delta^t \pi^C,$$

where $\delta$ denotes the discount factor. Define $\delta^*$ to be the critical value of $\delta$ such that (1) holds as a strict equality. For all $\delta \geq \delta^*$, cooperation can be supported, while for $\delta < \delta^*$, cooperation cannot be supported by our simple trigger strategy.

Evaluate the summations in (1) and solve for $\delta^*$ to get

$$\delta^* = \frac{\pi^D - \pi^C}{\pi^D - \pi^N}. \tag{2}$$

Since, $\pi^D \geq \pi^C \geq \pi^N$, we have $\delta^* \leq 1$.

The effect of an increase in group size $n$ on the difficulty of maintaining

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5 Pecorino (1998b) analyzes a tariff lobbying game with asymmetric firms.

4 Even when $\delta$ is sufficiently high, the cooperative outcome is clearly not unique (e.g., noncooperation is always an equilibrium).

5 Note that the expression in (2) is standard. See, for example, Shapiro (1989) (p. 364).
cooperation will be measured through $\delta^*$. If an increase in $n$ increases $\delta^*$, then it is said to make cooperation more difficult. The major focus of this paper are limit results. If $\delta^*$ approaches 1 as the number of contributors rises without bound, then (absent the unrealistic case where there is no discounting of future payoffs) cooperation becomes impossible as $n$ grows large. If $\delta^*$ approaches a number less than 1 in the limit as $n$ grows large, then there are admissible values of the discount parameter (i.e., values less than 1) such that cooperation can be maintained in an infinitely large group.

4. A fixed level of cooperation and quasi-linear preferences

Each consumer is endowed with income $I$. The constant price of the private consumption good $Y$ is denoted $P_Y$, and the price of the public good $G$ is normalized to 1. Since all consumers are identical, we will conduct a representative consumer analysis. Preferences are described by

$$U_i = Y_i + F(G),$$

where $F'(G) > 0$ and $F''(G) < 0$. Aggregate contributions to the public good are denoted $G$ with the contribution by person $i$ denoted $g_i$. In the noncooperative outcome, the consumer’s problem is to maximize utility in (3) subject to the budget constraint

$$P_Y Y_i + g_i = I,$$  

where $G = g_i + \sum_{j \neq i} g_j$. The first order conditions to this problem imply that

$$F'(G) = 1/P_Y.$$  

From (5), we can obtain the level of noncooperative contributions $G^N$, where by the symmetry of the equilibrium,

$$g^N_i = g^N = G^N/n,$$  

and $g^N$ denotes the common level of individual contributions. Differentiate (5) to get

$$\frac{dG^N}{dn} = 0,$$  

*If we think of $I$ as representing an endowment of a primary commodity, then the constant price of good $Y$ implies that there is a constant rate of transformation between commodity $I$ and good $Y$ (i.e., we have constant returns to scale in production of good $Y$). In Andreoni (1988), this constant rate of transformation is simply set to 1 so that $P_Y = 1$. 
i.e. the level of contributions in the noncooperative outcome is invariant to group size. From (3), (4) and (6), the individual payoff in the noncooperative outcome is

$$\pi^N = \left(1/P_Y\right)(I - [G^N/n]) + F(G^N).$$  \hfill (8)

To achieve the optimal level of public good provision for the group we can choose $g$ to maximize

$$U = Y + F(ng),$$  \hfill (9)

subject to the budget constraint in (4). This makes use of the fact that consumers are identical and the equilibrium is symmetric. The first order condition to this problem implies

$$nF'(G) = 1/P_Y.$$  \hfill (10)

From (10), we can solve for the optimum level of contributions $G^O$. Differentiate (10) to get

$$\frac{dG^O}{dn} = -\frac{F'(G^O)}{nF''(G^O)} > 0,$$  \hfill (11)

i.e. the optimal level of contributions is increasing in group size.

Consider a constant level of cooperative contributions $G^C$, where $G^N < G^C < G^O$. Note that while $G^N$ is constant by (7), and $G^C$ is constant by assumption, $G^O$ is an increasing function of $n$ by (11). In the cooperative outcome, each individual contributes

$$g_i^C = G^C/n.$$  \hfill (12)

From (3), (4) and (12), the payoff in the cooperative outcome is

$$\pi^C = \left(1/P_Y\right)(I - [G^C/n]) + F(G^C).$$  \hfill (13)

An individual $i$ who defects from the cooperative outcome will cut her contribution to zero if $F'(I - (n-1)/n)G^C < (1/P_Y)$, where $[(n-1)/n]G^C$ represents contributions from all agents other than $i$. This will be the case when $n$ is large, and since we are focused on limit results, we will assume this condition holds. When agent $i$ defects, she spends all her income on the private consumption good and enjoys the payout

$$\pi^D = I/P_Y + F\left(\frac{n-1}{n}G^C\right).$$  \hfill (14)

Substitute (8), (13) and (14) into (2) to get the critical value of the discount parameter:
\[ \delta^* = \frac{F^D - [F^C - (G^C/n)]}{F^D - [F^N - (G^N/n)]} \]

where the arguments of \( F \) have been included after the second equal sign. When an individual defects from cooperation, she gains her withheld contribution \( G^C/n \). This gain is partially offset by the reduced provision of the public good under defection, i.e. \( F^D = F[((n - 1)/n)G^C] < F(G^C) \). In the limit as \( n \to \infty \), \( F^D \to F^C \) and the withheld contribution \( G^C/n \to 0 \). Thus, as group size becomes large, the gain from cheating goes to zero, while the benefit from cooperation \( = \pi^C - \pi^N = F(G^C) - F(G^N) \) remains finite. As a result, from (15) we can see that

\[ \lim_{n \to \infty} \delta^* = 0. \]

Not only are there admissible values of the discount parameter such that cooperation may be maintained in the repeated game, cooperation remains an equilibrium in a large market if individuals place any weight at all on the future. This is summarized as Result 1.

**Result 1.** With quasi-linear preferences, if we hold the desired level of cooperation fixed, \( \delta^* \) approaches zero as group size becomes large. If individuals put any weight on the future, cooperation remains an equilibrium in an economy with an infinite number of agents.

We can broaden the conditions in Result 1 and still obtain the result that \( \delta^* \) approaches 0 in the limit. The gain from defection is bounded above by \( G^C/n \). As long as the cooperative level of contributions rises less than proportionally with \( n \) (e.g., with the square root of \( n \)), the gain from defection will approach zero in a large market, as will the critical value of the discount parameter. Since the single period incentive to defect is approaching 0 as \( n \) grows large, Result 1 is not sensitive to the assumption that the punishment period is infinite.

With quasi-linear preferences, the level of contributions in the noncooperative outcome \( G^N \) is independent of group size. When \( G^C \) is held constant, this assumption ensures that \( G^N \) remains below the fixed level of \( G^C \) as \( n \) rises. With more general preferences (and assuming normality), provision in the noncooperative outcome is increasing in \( n \). However, these contributions will generally approach some finite value as \( n \to \infty \) (see Andreoni, 1988; Sandler, 1992, p. 50). If

\[ \text{In Pecorino (1998a), the gains from defection and the gains from cooperation both go to zero as the number of firms rises without bound. This occurs because firm size gets smaller as } n \text{ rises. The critical value of the discount parameter converges to a number less than 1, but it does not converge to zero.} \]
a constant level of $G^c$ is chosen to be above this limiting value of $G^N$, then Result 1 will hold for more general preferences as well. Thus, with a simple trigger strategy as an enforcement mechanism, there are a fairly wide variety of cases in which it becomes ‘easy’ to maintain a cooperative outcome as $n \rightarrow \infty$.

5. Maintaining an optimal level of provision

The previous section establishes for quasi-linear preferences that if we hold the level of cooperation constant (or let it grow less then proportionally with $n$), in large markets it is not only possible to maintain cooperation, but it is ‘easy’ (since $\delta^* \rightarrow 0$). In this section, the goal is more ambitious, as we will consider large markets where the level of public good provision is maintained at the optimal level as the group size grows. However, we will further restrict the quasi-linear utility function as follows:

$$F(G) = \frac{G^{1-\alpha}}{1 - \alpha}, \quad (17)$$

where $0 < \alpha \leq 1$. In the limit as $\alpha \rightarrow 1$, we have $F(G) = \ln(G)$. Using Eqs. (5), (8), (10), (13), (14), (17), we may obtain the following individual payoffs:

$$\pi^N = \frac{I}{P_Y} - \frac{(P_Y)^{(1-\alpha)/\alpha}}{n} + \frac{(P_Y)^{(1-\alpha)/\alpha}}{(1-\alpha)}, \quad (18a)$$

$$\pi^C = \frac{I}{P_Y} + \left(\frac{\alpha}{1-\alpha}\right)(nP_Y)^{(1-\alpha)/\alpha}, \quad (18b)$$

$$\pi^D = \frac{I}{P_Y} + \left(\frac{1}{1-\alpha}\right)(nP_Y)^{(1-\alpha)/\alpha}. \quad (18c)$$

Substitute (18a–c) into Eq. (2) to get

$$\delta^* = \frac{n^{(1-\alpha)/\alpha}[(n-1)/n]^{1-\alpha} - \alpha}{n^{(1-\alpha)/\alpha}[(n-1)/n]^{1-\alpha} - [1 - (1-\alpha)/n]} \quad (19)$$

For a large market, we have

$$\lim_{n \rightarrow \infty} \delta^* = 1 - \alpha. \quad (20)$$

Therefore, there are admissible values of the discount parameter such that full cooperation may be maintained as the group size rises towards infinity. For $\alpha = 1$, $F(G) = \ln(G)$, and $\lim_{n \rightarrow \infty} \delta^* = 0$. This analysis is summarized as Result 2.

**Result 2.** For the preferences described by Eqs. (3) and (17), there are admissible values of the discount parameter $\delta$ (i.e., values less than 1) such that the optimal
level of cooperation may be maintained within an infinitely large group. This optimal level of provision is itself increasing in the size of the group.

In Result 1, it is essentially guaranteed that cooperation remains an equilibrium in the large economy, while in Result 2 cooperation remains an equilibrium only if \( \delta > 1 - \alpha \). The differences in the results stem from the fact that, under Result 2, we are attempting to maintain the optimal level of cooperation as the group size rises. The individual contribution in the cooperative outcome \( g = (n^{1-\alpha}P_Y)^{1/\alpha} \). When we attempt to maintain the fully optimal level of provision, the individual contribution not only remains finite, but rises with \( n \) (for the preferences described by (3) and (17)). As a result, the gain from defection is rising in \( n \). Offsetting this in the limit is the rising benefit from cooperation as group size increases.

**6. Cobb–Douglas preferences**

Consider Cobb–Douglas preferences over the private and public goods:

\[
U = Y^{\alpha}G^{1-\alpha},
\]

where \( 0 < \alpha < 1 \). In the noncooperative outcome, the consumer’s problem is to maximize (21) subject to (4). The solution to this problem for all \( n \) consumers implies

\[
G^N = \frac{(1 - \alpha)n}{(1 - \alpha) + \alpha n} I, \quad \text{(22a)}
\]

\[
g^N_i = \frac{1 - \alpha}{(1 - \alpha) + \alpha n} I, \quad \text{(22b)}
\]

\[
Y^N_i = \frac{\alpha n}{(1 - \alpha) + \alpha n} \left( \frac{I}{P_Y} \right). \quad \text{(22c)}
\]

Public good provision is increasing in \( n \), but approaches a finite limit as \( n \) grows large (\( \lim_{n \to \infty} G = I(1 - \alpha)/\alpha \)). Substitute (22) into (21) to get the payout in the noncooperative outcome:

\[
\pi^N = \left( \frac{\alpha}{P_Y} \right)^\alpha (1 - \alpha)^{(1-\alpha)} \left( \frac{nI}{(1 - \alpha) + \alpha n} \right). \quad \text{(23)}
\]

Again, making use of the symmetry of the equilibrium, for the optimal provision of the public good, we can choose \( g \) to maximize \( U = Y^{\alpha}(ng)^{1-\alpha} \), subject to the budget constraint in (4). The solution to this problem implies

\[
G^C = n(1 - \alpha)I, \quad \text{(24a)}
\]

\[
g^C_i = G^C/n = (1 - \alpha)I, \quad \text{(24b)}
\]
Using (21) and (24), the payoff in the cooperative outcome is

$$\pi^C = \left( \frac{\alpha}{P_y} \right)^\alpha [(1 - \alpha)n]^{1-\alpha} I. \quad (25)$$

When individual $i$ defects from the cooperative outcome, she withholds her contribution $g = (1 - \alpha)I$ and spends all of her income on the private good. As a result, $G^D = (n - 1)(1 - \alpha)I$, $Y^D_i = I/P_y$, and she enjoys the payout

$$\pi^D = \left( \frac{1}{P_y} \right)^\alpha [(1 - \alpha)(n - 1)]^{1-\alpha} I. \quad (26)$$

Use (23), (25) and (26) in (2) to get

$$\delta^\# = \frac{(1 - \alpha + an)(n - 1)^{1-a} - \alpha^a n^{1-a}}{(1 - \alpha + an)(n - 1)^{1-a} - \alpha^a n}. \quad (27)$$

For the large market we have

$$\lim_{n \to \infty} \delta^\# = 1 - \alpha^a. \quad (28)$$

The contribution per person $g = (1 - \alpha)I$ is constant, and this suggests a constant upper bound on the incentive to cheat. This is incorrect, however, because the increase in the provision of the public good as $n$ rises implies a rising marginal utility of consumption of the private good. Thus in utility terms, the incentive to cheat is increasing in $n$. This is offset in the limit by the greater gains from cooperation in larger markets. The analysis is summarized in Result 3.

**Result 3.** For the Cobb–Douglas preferences in (21), there are admissible values of the discount parameter $\delta$ (i.e., values less than 1) such that the optimal level of cooperation may be maintained within an infinitely large group. This optimal level of provision is itself increasing in the size of the group.

Based on the estimates of Reece and Zieschang (1985), Andreoni (1988) argues that a reasonable value of $\alpha$ is 0.9658, which implies the coefficient on public goods in Eq. (21) is 0.0342. If we use this estimate of $\alpha$ in Eq. (28) we get that the limit as $n \to \infty$ of $\delta^\#$ is 0.033. This suggests that if agents place even a rather small weight on the future, the optimal level of cooperation will remain an equilibrium in the repeated game with Cobb–Douglas preferences.
7. Conclusion

The results of this paper are driven by the effects on an increase in group size on the payouts $\pi^N$, $\pi^C$, and $\pi^D$. Though the preferences analyzed in this paper are not completely general, nothing about the effects of group size on these payouts suggests that cooperation must break down in large markets. In fact, under a fairly wide range of circumstances, Result 1 suggests that it becomes ‘easy’ to maintain cooperation in large markets. It is worth pointing out that, generally speaking, there are no monotonicity results for the effects of $n$ on $\delta^*$ (the derivative of $\delta^*$ with respect to $n$ is generally indeterminate). Thus, not only is cooperation possible in the limit, but there is no presumption that cooperation gets harder ($\delta^*$ rises) as $n$ rises. This, of course, is obvious for the case where $\delta^*$ approaches zero in the limit.\footnote{In this case, we are not guaranteed that cooperation becomes monotonically easier either.}

There are two ways to interpret the results of this paper. The first is to more or less accept them at face value and conclude that cooperation is feasible in large markets. Andreoni (1988) has convincingly argued that the static version of the model presented in this paper (which he refers to as an altruistic model of contributions) cannot explain the extent of private contributions to public goods (in particular, charity). He resolves this problem by developing a model in which individuals derive direct utility from their contribution to the public good. The results here suggest that, in a repeated game setting, the altruistic model of public good provision may be able to explain a high observed level of contributions. As a future extension of the model, however, it would be useful to consider the types of asymmetries among agents that are considered by Andreoni.

An alternative is to maintain that cooperation is more difficult in larger groups, but that we need to look more deeply at the reasons why cooperation must break down in the limit. These reasons do not seem to lie in the nature of the payouts in the noncooperative, cooperative and defection outcomes. One candidate is informational problems relating to the unobservability of preferences. This would tend to create a difficult and well-known problem of assigning contribution shares which each party would have to meet to avoid triggering defection. Informational problems might also interact with uncertainty in a model along the lines of Green and Porter (1984). The ability to renegotiate an agreement after a defection has taken place may also hamper the implementation of trigger strategies in practice (see Bernheim and Ray (1989); Farrell and Maskin (1989); McCutcheon (1997)).

Suppose that the additional complications referred to above prevent cooperation from ever being achieved in a repeated game setting. Then we are left with the static results which give only limited support for the proposition that an increase in group size makes the free-rider problem worse. Provision is generally increasing in the noncooperative outcome and it is not true in general that the gap between the
noncooperative and optimal provision is increasing in group size, though it is true in certain special cases (Sandler, 1992, pp. 52–54).

If the complications referred to above allow cooperation in small groups, but not large groups, then the proposition that the free-rider problem gets worse can at best still only receive very qualified support. If a small group can achieve cooperation, an increase in the number of potential group members should not (for a pure public good) undermine the ability of the original group to cooperate. The level of provision should never decrease with group size, though the gap between the actual level of provision and the global optimum may grow.

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References