Giving Little by Little: Dynamic Voluntary Contribution Games

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Abstract

Charitable contributions are frequently made over time. Donors are free to contribute whenever they wish and as often as they want, and are frequently updated on the level of contributions by others. A dynamic structure enables donors to condition their contribution on that of others, and, as Schelling (1960) suggested, it may establish trust thereby increasing charitable giving. Marx and Matthews (2000) build on Schelling's insight and show that multiple contribution rounds may secure a provision level that cannot be achieved in the static, one-shot setting, but only if there is a discrete, positive payoff jump upon completion of the project. We examine these two hypotheses experimentally using static and dynamic public good games. We find that contributions are indeed higher in the dynamic than in the static game. However, in contrast to the predictions, the increase in contributions in the dynamic game does not depend critically on the existence of a completion benefit jump or on whether players can condition their decisions on the behavior of other members of their group.

Keywords: Dynamic Public Goods Game, Voluntary Contribution Mechanism, Information, Reciprocity.

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1 Introduction

One of the primary motivations of the seminal paper by Bergstrom, Blume, and Varian (1986) was the observation that while standard theory predicts that public goods should be undersupplied by voluntary contributions, there are nevertheless many instances where such goods are voluntarily provided. This observation has led to a voluminous theoretical and experimental literature aimed at understanding the factors that influence voluntary provision of public goods. Various mechanisms and techniques have been proposed and explored, and it has been suggested that perhaps it may be easier to overcome free-riding when contributions are made in a dynamic as opposed to the static game environment explored by Bergstrom, Blume, and Varian. This paper contributes to this literature by testing two explanations for why contributions may be greater in a dynamic environment.

In a static game, each player makes a single contribution decision and that decision must be made without knowledge of the decisions made by others. By contrast, in a dynamic game, players make decisions in multiple rounds and may condition each decision upon the level of total contributions in the previous round, a state-variable that is periodically updated.

There is good reason to think that charitable giving is best viewed as a dynamic rather than a static game. Certainly, most charities do not require that contributions be made at a single date in time – rather, fund-drives typically last for some duration of time, and a target goal is set in advance. Further, charities find it useful to periodically update potential donors on the level of contributions received *during the fund-drive*. For instance, the United Way is fond of using "thermometers" showing progress made during a campaign toward the target goal.

Why might contribution decisions differ in a dynamic setting, with multiple contribution opportunities, as opposed to a static setting, with a single contribution opportunity? Schelling (1960) suggested one possibility: dynamic environments allow for smaller, history-contingent contributions that aid in the establishment of trust. Specifically, Schelling writes (1960, pp. 45-6):

> "Even if the future will bring no recurrence, it may be possible to create the equivalence of continuity by dividing the bargaining issue into consecutive parts. If each party agrees to send a million dollars to the Red Cross on condition the other does, each may be tempted to cheat if the other contributes first, and each one's anticipation of the other's cheating will inhibit agreement.

> But if the contribution is divided into consecutive small contributions, each can try the other's good faith for a small price. Furthermore, since each can keep the other on short tether to the finish, no one ever need risk more than one small contribution at a time. Finally, this change in the incentive structure itself takes most of the risk out of the initial contribution; the value of established trust is made obviously visible..."[1]

Marx and Matthews (2000) build on Schelling's insight regarding the importance of history dependent contributions, and develop a theory of how agents might *complete* funding of a public good in a finite horizon game. Elegantly they show that if agents are payoff maximizers, the equilibria of the multiple contribution-round (dynamic) finite game will differ from the one-round (static) game only if a discrete benefit 'jump' is realized upon completion of the public good project. In particular, in the presence of a benefit jump, dynamic play may sustain equilibria that complete the public good (via history-dependent trigger strategies), even when no such equilibria exist in the static, one-round version of the game.

A discrete completion benefit arises when the full benefits of a project are not experienced until the project is completed. For example, contributions to the homeless may have some immediate beneficial effect, but a substantial and discrete increase in benefits from contributions may not be achieved until sufficient funds have been collected to build a homeless shelter. Similarly, a completed collection of paintings may result in a larger overall benefit than the sum of the benefits associated with each individual painting. Public radio fund-raising campaigns that promise to end early if their target is reached before the drive is over provide an endogenous and discrete completion benefit.

In this paper we report on a laboratory experiment designed to investigate these two theories. Specifically, we study the Marx and Matthews' environment and ask whether the mechanisms suggested by Schelling and Marx and Matthews may cause voluntary contributions to differ when the contribution game is dynamic rather than static. Consistent with their hypotheses, we compare behavior when individuals with a given endowment

[1] While Schelling may have been the first to write about this possibility, the practice of soliciting small contributions over time with feedback on the historical contributions of others appears to have been well-known to charitable organizations. For instance, the March of Dimes organization collected dimes for polio research using coin cards and transparent coin canisters initially in door-to-door "marches" and later in public settings, especially near cash registers at retail establishments throughout the U.S.

simultaneously contribute in either one or multiple contribution rounds. In the presence of a completion benefit, greater giving in the dynamic than static games would be consistent with both Schelling and Marx and Matthews. To distinguish between the two hypotheses we examine the role played by a discrete benefit jump upon completion of the project in securing greater giving in the dynamic game, and we explore the role played by feedback.

Our main finding is that contributions are significantly larger in the dynamic multiple-round version of the game as compared with the static one-shot version of the game. However in our environment we do not find that Schelling's or Marx and Matthews' explanations can account for these differences. While in the dynamic game subjects appear to condition their giving on the giving of other members of their group, other findings are less supportive of the theories. First, in contrast to Marx and Matthews, the existence of a positive completion benefit is not a critical determinant of contributions being greater in the dynamic game. Second, when we eliminate feedback on group contributions in the dynamic game, so that the information becomes analogous to a static game, contributions exceed those of the static game but are similar to those in the dynamic game with feedback. It is difficult to reconcile this finding with Schelling's hypothesis. We conclude with a discussion of alternative explanations that may help account for the difference in giving between the dynamic and static game environments.

2 Theoretical Analysis

Here we describe a simplified version of the Marx and Matthews (2000) model which we will use in our experimental design. There are n identical individuals, $i \in \{1, ..., n\}$, who participate in a fund-drive lasting T periods. In any period $t \in \{1, \ldots, T\}$, they must decide how much to contribute to the public good. Let $g_i(t)$ denote individual i's contribution and define $G(t) = \sum_{i=1}^{n} g_i(t)$. Contributions are binding and non-refundable. At the end of the fund-drive, individual i consumes what remains of her initial endowment, w, and receives a benefit from the public good that depends on the aggregate contribution made by the n players over all periods of the fund-drive, $\sum_{t=1}^{T} G(t)$. Specifically, player i's payoff at the end of period T is given by:

$$U_i = w - \sum_{t=1}^{T} g_i(t) + f(\sum_{t=1}^{T} G(t)).$$

The payoff from the public good, $f(\sum_{t=1}^{T} G(t))$, increases linearly with contributions until funds are sufficient to complete the project. The project is complete once the sum of contributions reach or exceed an exogenous and known threshold, $\overline{G}$. The marginal benefit of contributing prior to reaching the threshold is λ. Upon completion, there is a discrete increase in the benefit; this increase is referred to as the *completion benefit* and denoted by $b \geq 0$. The full benefit of a completed project is B. Contributions in excess of $\overline{G}$ do not increase the payoff from the public good. That is, independent of the identity of the contributor, the payoff from the public good is given by:

$$f(\sum_{t=1}^{T} G(t)) = \begin{cases} \lambda \sum_{t=1}^{T} G(t) & \text{if } \sum_{t=1}^{T} G(t) < \overline{G}, \\ B = b + \lambda \overline{G} & \text{if } \sum_{t=1}^{T} G(t) \geq \overline{G}. \end{cases}$$

Individuals are informed of their own past contributions and of the past sums of the group contributions. Player i's personal history at the start of period t is thus: $h_i^{t-1} = (g_i(\tau), G(\tau))_{\tau=1}^{t-1}$, and a player's strategy maps the state variable, h_i^{t-1} into a feasible contribution $g_i(t) \leq w - \sum_{\tau=1}^{t-1} g_i(\tau)$. Thus with multiple contribution rounds players can condition future contributions on past contribution histories.

For this game to constitute a social dilemma, we assume that it is efficient to complete the project, but that no single payoff-maximizing individual will complete it by herself, i.e., $B < \overline{G} < nB$. This assumption causes zero-provision to always be an equilibrium outcome of the game. Note that the social dilemma assumption implies that $0 < \lambda < 1$. Thus it follows that, absent a completion benefit, i.e., $b = 0$, it is always costly to contribute to the public good, and zero-provision is the *unique* equilibrium outcome. This need not be the case when there is a completion benefit. Provided others contribute, a positive value of b may give the individual an incentive to complete the project. To see why, consider first the case where the project can be completed with just one round of contributions. Obviously an individual only contributes if the contributions by others, G_{-i}, are short of the threshold, $\overline{G}$. Furthermore, with $\lambda < 1$, contributions only occur in the static game if an individual's contribution is sufficient to complete the project. The individual's best response function can thus be derived by comparing the payoff from completing the project or giving nothing at all. The individual completes the project and contributes $g_i = \overline{G} - G_{-i}$ iff $w - g_i + b + \lambda \overline{G} \geq w + \lambda G_{-i}$. Thus the project is completed if the needed contribution, $\overline{G} - G_{-i} \leq g^* \equiv \frac{b}{1-\lambda}$. The individual's best response function is therefore:

$$g_i(G_{-i}) = \begin{cases} \overline{G} - G_{-i} & \text{if } \overline{G} - G_{-i} \leq g^*, \\ 0 & \text{otherwise.} \end{cases}$$

Given values of b and λ, in the static game there exist sufficiently low thresholds, $\overline{G}$, such that completion and zero-provision equilibria coexist, and sufficiently high thresholds, $\overline{G} > n\frac{b}{1-\lambda}$, such that zero-provision is the unique equilibrium outcome.

An intriguing aspect of Marx and Matthews' model is that an increase in the number of contribution rounds may expand the set of equilibria. Even when there are no completion equilibria in the static game, there will be a sufficiently large number of rounds at which there also will exist equilibria that complete the efficiency-enhancing project. While a variety of strategies may sustain completion, Marx and Matthews consider the so-called *grim-g strategy*, with a sequence of nonnegative contributions as the equilibrium outcome $g' = \{(g'_1(t), g'_2(t), ..., g'_n(t)\}_{t=1}^{T}$. According to the *grim-g strategy*, g' is played in every period so long as the aggregate contribution level is consistent with g'. If there is a deviation, as reflected in the aggregate contribution level, all contributions cease in the following period. Thus, Marx and Matthews' grim-g strategy builds on Schelling's insight that history-contingent giving may play an important role in increasing contributions. However, Marx and Matthews go even further. They show that while the grim-g strategy cannot by itself increase contributions in finitely repeated games, the addition of a positive completion benefit may allow completion of the public good to be sustained as an equilibrium outcome of the game. The reason is that the grim-g strategy eventually leads to a contribution level where an additional small contribution gives rise to a discrete jump in payoffs. Thus with a completion benefit the individual will eventually have an incentive to complete the project, and this incentive is not driven by the threat of future punishments. Effectively, the grim-g strategy decreases both the cost of contributing and the benefit of free-riding in any given round.[2]

[2] Compte and Jehiel (2004) consider a dynamic voluntary contribution game similar to the game of Marx and Matthews. At each stage of the game one player decides whether to terminate the game by making no further contribution, or to make another contribution. There is some maximum accumulated contribution, K. In their game the payoff to player i if the game is terminated with a total accumulated contribution $k < K$ is b_iK. If the maximum contribution is achieved at the time the game is terminated the payoff to i is a_iK, where $b_i \leq a_i < 1$. When a exceeds b there is a discrete jump in the payoff. The contribution by one player increases the termination payoff of the other player. If the termination payoff of player 2 is sufficiently high, then player 1 cannot expect to induce by his current contribution a future contribution of player 2. But without that future

To better comprehend the effect of additional contribution rounds, consider the following parametric example of a voluntary contribution game, which we also adopt in our experimental design. Individuals are matched in groups of three. Each member of a group is given an initial endowment of 6 'chips', and she is free to anonymously allocate any number of these chips to the 'group account' or to her own, 'private account'. After all members of the group have made their decisions, the total number of chips in the group account is announced to all members of the group and individual payoffs are privately revealed to each group member. An individual gets 10 cents for each chip that remains in her private account. The payoff from the group account depends on the total number of chips contributed to the group account by any of the three individuals. For each chip in the group account, up to 11 chips, the individual and each member of her group receives 5 cents (the value of 1/2 chip) so $\lambda = 0.5$. If the group account contains $\overline{G} = 12$ or more chips, each member receives a fixed payment of 70 cents from the group account. Thus, the completion benefit is 10 cents for each group member, which is equivalent to the value of one chip, so $b = 1$.

Consider first the static case, i.e., where there is one contribution round $T = 1$. The maximum contribution any member is willing to make in one round is 2 chips ($\frac{b}{1-\lambda} = \frac{1}{.5} = 2$). With three individuals contributing, and given $\overline{G} = 12$, it follows that no-contribution is the unique equilibrium outcome of the static game.

Note, however, that an increase in the number of contribution rounds may enable us to sustain completion equilibria as well. Consider, for example, the case where $T = 4$, i.e., there are four rounds in which any individual can contribute. After every round of contributions all members of the group are informed of the aggregate contribution to date. One example of a completion equilibrium is where each individual contributes one chip per round provided that the most recent aggregate contribution is consistent with the continuation of this strategy. If there is a deviation, then the individual chooses not to contribute in subsequent rounds.

To see that such strategies constitute a Nash equilibrium, consider the benefit from deviating conditional on others playing the proposed equilib-

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contribution, player 1's current contribution is not profitable. Therefore, there is an upper bound on the amount of new contribution a player will make at any stage at which that player decides to make a contribution rather than to terminate the game. Compte and Jehiel show that if $a > b$ then this upper bound is positive and the accumulated total increases gradually. However, if $a = b$ for every i then no player will agree to make the last contribution so that in equilibrium no contribution is made. Hence in their model a completion benefit is also needed to secure provision in the dynamic game.

rium strategy. The payoff to a player who follows the equilibrium strategy is 90 (70 cents for completion benefit + 20 cents for the 2 chips remaining in the private account). As Table 1 shows, the payoff to a player from deviating is always less than 90, regardless of the round in which the deviation occurs.

Table 1: Deviation Payoff Calculations

Deviation occurs in:	Benefit from deviating Group + Private (cents)
Round 1	$5 \cdot 2 + 10 \cdot 6 = 70$
Round 2	$5 \cdot 5 + 10 \cdot 5 = 75$
Round 3	$5 \cdot 8 + 10 \cdot 4 = 80$
Round 4	$5 \cdot 11 + 10 \cdot 3 = 85$

Summarizing, in our dynamic game example with positive completion benefit ($b = 1$) and $T = 4$ rounds, there are both completion and no-contribution equilibria, while there is only a no-contribution equilibrium in the static, $T = 1$ round game. Of course, there are many different completion equilibria of the dynamic game with positive completion benefit, all of which Pareto dominate the no-contribution equilibrium.[3]

If dynamic rather than static play leads individuals to complete the project, then this is of substantial importance to practitioners seeking to maximize contributions to their charity. Unfortunately, theory cannot help us determine which of the two types of equilibria is more likely to occur. It is therefore an empirical question whether contributions are larger in the dynamic than in the static game. Similarly it is an empirical question whether a potential increase in contributions in the dynamic game requires the presence of a completion benefit as in Marx and Matthews or if, following Schelling, an increase in contributions in the dynamic game is due to the repeated opportunities to give and reduced price of trust afforded by the dynamic environment. We now turn to addressing these two empirical questions.

[3] Other examples of symmetric contributions $(g_i(1), g_i(2), g_i(3), g_i(4))$ that can be sustained by a grim-g strategy are: $(2,1,1,0)$, $(1,2,1,0)$, $(1,1,2,0)$, $(2,2,0,0)$, $(3,1,0,0)$. Similar profiles where the contributions are postponed to later rounds can also be sustained. Note that the preference for contributing rather than deviating only is strict in every round for the two first contribution profiles.

3 Experimental Design

The experimental parameters were chosen to provide a careful test of the theory of Marx and Matthews. The completion benefit was selected to secure an environment where completion equilibria only exist in the dynamic game and not in the static game, and to secure that some completion equilibria are strictly preferred to those of no contribution.[4] A difficulty inherent in securing a strict preference is that it gives rise to multiple completion equilibria, and thus may make it more difficult for participants to coordinate on a particular equilibrium. To limit the set of completion equilibria and thereby the coordination problem, we opted to examine contributions in small groups with limited initial endowments over a limited number of rounds.

Specifically, we use the same parameterization of the game as in the example of Section 2, i.e., $n = 3$, $\lambda = .5$, $\overline{G} = 12$ chips, and the value of each chip allocated to an individual's private account is 10 cents. The remaining parameter values are the focus of our 2×2 experimental design. The first treatment variable is the number of contribution rounds, T. We consider both the static case, where $T = 1$, and the dynamic case where $T = 4$. The second treatment variable is the value of the completion benefit. We consider the case where there is a positive completion benefit, $b = 1$, as well as the case where there is no completion benefit, $b = 0$. While increased giving in the dynamic case, $T = 4$, when $b = 1$ is consistent with both Schelling and Marx and Matthews, we use the dynamic case when $b = 0$ to distinguish between the two theories. Recall from the discussion above that when $b = 0$, no-contribution is the unique payoff-maximizing equilibrium outcome of both the dynamic and static games. Thus we can use the dynamic game treatments ($b = 0$ vs. $b = 1$) to determine whether a potential increase in contributions in the dynamic game (relative to the static game) is due to the completion benefit and the expanded set of equilibria it allows (Marx and Matthews hypothesis), or simply due to the increased number of contribution rounds, with the completion benefit being irrelevant (Schelling's

[4] Note that for the theory to predict different sets of equilibria in the dynamic and static game, the completion benefit can neither be too large nor too small. Conditional on the time horizon, the number of contributors, and the marginal return from the public good, any completion benefit between 5 and 20 cents ($b \in [.5, 2]$) admits completion equilibria in the dynamic game, but not in the static one. If the benefit exceeds 20 cents ($b > 2$) there also exist completion equilibria in the static game, and if the benefit is less than 5 cents ($b < .5$) completion equilibria cease to exist in the dynamic game (given that the smallest unit of contribution is 1). Thus the 10 cent completion benefit ($b = 1$) is *not* a knife-edge case.

hypothesis). We refer to the four main treatments of our experiment as: *1. static with completion benefit; 2. dynamic with completion benefit*; *3. static without completion benefit*; and *4. dynamic without completion benefit.*[5]

All sessions of the experiment were computerized and were conducted in the Pittsburgh Experimental Economics Laboratory. Participants were recruited from the University of Pittsburgh and Carnegie Mellon University. Each session involved exactly 15 inexperienced subjects. A session proceeded as follows. Subjects were seated at computers and were given a set of written instructions, a payoff table, a record sheet, and a short quiz. The experimenter read the instructions aloud to all participants. The payoff structure was written on the board, and the payoff table was projected on an overhead screen for all to see. Once the instructions were finished participants were asked to complete a written quiz. The quiz was collected, an answer key was given to each participant, and the answers were reviewed using an overhead projector. Subjects then began the experiment. They were asked to record all decisions in the experiment on a record sheet. They played a total of 15 games. All games in a session were played under the same treatment condition. Each game consisted of 1 or 4 rounds, depending on the treatment. Prior to each new game, subjects were randomly and anonymously matched with two other participants, with the stipulation that no one was matched with the same participant twice in a row. Subjects' identities were never revealed to one another. Following completion of the 15th game, subjects were paid their earnings from all games played and also received a $5 show-up payment; payments were made anonymously by subject number.

We conducted four sessions of each of the four main treatments, for a total of 240 participants. The experiment typically lasted between 60-90 minutes and participants' earnings averaged $15.25 (standard deviation of $0.81, maximum of $17.95, and minimum of $12.90). A copy of the instructions for the dynamic game with completion benefit is provided in the Appendix; other instructions are similar. The only change for the static treatment with completion benefit is that participants were given only one round to contribute, and in the treatments without completion benefit the only change is that the payoff at completion was 60 cents rather than 70

[5] As described later, we also conduct a fifth treatment, aimed at further testing Schelling's hypothesis. In this fifth treatment, subjects played a dynamic game with no completion benefit and no feedback on group contributions between rounds. Absent feedback the information of the multiple-round game is equivalent to that of the static game. To capture the multiple-round feature of the game we nonetheless refer to it as a 'dynamic' game.

cents ($b = 0$ rather than $b = 1$).

4 Hypotheses

Marx and Matthew's point predictions for the environment that we examine are very stark. While some equilibria complete the project in the dynamic game with a completion benefit, there is a unique zero-provision equilibrium in the two static treatments as well as in the dynamic treatment without a completion benefit.

All previous voluntary contribution experiments have used payoff structures that differ from the one used in this study; our choice of a different payoff structure is necessitated by our wish to examine Marx and Matthews hypothesis. A consequence, however, is that our findings will not be directly comparable to the findings of prior studies. Nonetheless, prior voluntary contribution experiments have elements in common with our design and those prior studies suggest that we should be unlikely to find strong support for the equilibrium point predictions of the theory we are testing. For example, absent completion our static treatments are very similar to the frequently studied linear voluntary contribution mechanism (VCM). The only difference is that, while in our setting the return from giving changes once the threshold is reached, in a linear VCM the marginal return from contributing to the public good is some constant λ, which is independent of the contribution level.[6] With $\lambda < 1$ the unique equilibrium prediction of the linear VCM is zero contributions to the public good. In sharp contrast, experimental investigations of the linear VCM consistently find that contributions are substantial and significantly greater than zero.[7]

If the contribution patterns of previous studies extend to the environment examined here, then we may observe positive contributions in all four of our treatments. To investigate the effect of dynamic play we focus instead on the comparative static predictions. The primary question of inter-

[6] If we had set $\lambda = 0$ for group contributions below the completion threshold, our payoff structure would be identical to a provision-point mechanism (see e.g., Isaac, Schmidtz, and Walker (1989), Bagnoli and McKee (1991), and Croson and Marks (1998) for examples of studies using that type of mechanism). Such a change in the payoff structure changes the characteristics of the equilibria substantially. In a social dilemma with a provision point mechanism there are multiple equilibria in both the static and dynamic games.

[7] These contributions may either reflect "mistakes" or "other regarding preferences" or both. Ledyard (1995, pp. 170-2) estimates that mistakes account for 20-25% of these contributions. The notion that an individual's preferences are not restricted to a player's own monetary payoff is a topic that has been heavily explored in recent years. See, Camerer (2003) for a review of this literature.

est is whether consistent with our two hypothesis contributions are larger and completion is more likely in dynamic as opposed to static contribution games. To distinguish between the 'completion benefit' hypothesis by Marx and Matthews and Schelling's 'small-price-of-trust' hypothesis, we focus on the role played by the completion benefit. While the 'completion-benefit' hypothesis predicts that contributions will only be larger in the dynamic game when there is a positive completion benefit, Schelling's 'small-price-of-trust' hypothesis suggests instead that dynamic play may increase contributions independent of whether there is any completion benefit.

Based on past experimental literature on multiple contribution rounds there may be reason to anticipate greater contribution in the dynamic than static games irrespective of the completion benefit. While the literature on sequential versus simultaneous games present mixed results on the effect of simply introducing a time dimension to giving. For example, Andreoni, Brown and Vesterlund (2002), Gaechter and Renner, (2003), and Potters, Sefton, and Vesterlund (forthcoming) find that sequential moves do not increase contributions, whereas Erev and Rapoport (1990) and Moxnes and Van der Heijden (2003) find greater cooperation with sequential moves. The evidence is clearer on actual dynamic interactions, that is, where participants have multiple contribution rounds and receive feedback on past interactions. Although some of these studies solely examine behavior in the dynamic game, they do nonetheless suggest that giving in the dynamic game may exceed that of the static game (see e.g., Dorsey,1992, Kurzban, McCabe, Smith and Wilson, 2001, Goren, Rapoport, and Kurzban, 2004, Guth, Levati, and Stiehler, 2002). For example, Dorsey (1992) only contributions in the dynamic games, but the parameters are similar to those of previous static studies, and the results suggest that contributions are larger with dynamic contributions.

As in this study, two recent studies directly compare the effect of dynamic play. While very different from our setting, their findings nonetheless suggest that contributions may be larger in a dynamic game. Andreoni and Samuelson (2006) show that cooperation and earnings increase when the stakes of a one-shot prisoner's dilemma game are split between two plays of the prisoner's dilemma game.[8] Choi, Gale and Kariv (2006) study a thresh-

[8] One of the findings of Andreoni and Samuelson (2006) is that when splitting the bargaining issue over two consecute periods it helps to start small. Kurzban, Rigdon and Wilson (2006) extend this finding to trust games and show that the ability to sequentially build trust reduces the hold-up problem in investment games. Note that the payoffs, number of players, number of contribution rounds, as well as the predicted equilibria in both of these studies differ substantially from our model.

old public good game and also find greater contributions in the dynamic than in the static version of that game.[9]

Although the potential finding that dynamic play influences behavior independent of the completion benefit is not consistent with the predictions of Marx and Matthews, it need not imply that the expanded set of equilibria does not influence behavior. To examine if the completion benefit nonetheless affects behavior we also subject the data to a series of alternative tests. First, comparing the two dynamic treatments we determine if as predicted contributions are greater with a completion benefit than without. Second, we determine if the difference between static and dynamic play is greater with a completion benefit than without one. Third, examining the last round of the dynamic game when the sum of past contributions are close to the threshold we determine if contributions are more likely in the presence of a completion benefit

5 Results

5.1 Positive completion benefit, $b = 1$: Dynamic versus Static Games

Every session of a treatment consisted of fifteen repetitions of the same game. With five 3-player groups interacting in each game of a session, we observed a total of 75 group contributions in each experimental session. We treat data from each individual session as an independent observation.

Table 2 reports the number (percent) of groups (out of 75) in each session who had final contributions that either reached the threshold of 12 or came close, where 'close' is defined as an end-of-game group total of 10 or more chips.[10]

[9] They have many possible equilibria in both their static and dynamic treatments. By contrast, in three of our treatments, there is a unique zero contribution equilibrium. Multiple completion equilibria exist only in our fourth treatment, the dynamic game with a completion benefit. Thus if an expansion in the set of equilibria influences behavior, contributions should be unambiguously greater in our dynamic game with a completion benefit.

[10] Contributions close to the threshold are included because it may be argued that the members of the relevant group understood the efficient equilibria, but failed to coordinate on who should contribute towards the end of the game.

Table 2: Number (percent) of the 75 Observations where the Group Contribution Exceeds a Specified Level, $b = 1$

	Groups with			
	12 or more chips		10 or more chips	
	Static	Dynamic	Static	Dynamic
Session 1	0 (0.0)	8 (10.7)	1 (1.3)	19 (25.3)
Session 2	0 (0.0)	11 (14.7)	1 (1.3)	28 (37.3)
Session 3	0 (0.0)	13 (17.3)	0 (0.0)	29 (38.7)
Session 4	0 (0.0)	6 (8.0)	0 (0.0)	11 (14.7)
Average	0 (0.0)	10 (10.6)	0.5 (0.7)	22 (29.3)

Consistent with Marx and Matthews' hypothesis, not a single group contribution of the static game with completion benefit ever reached the threshold of 12 chips. Indeed, only a couple of groups in the static treatment even came close to achieving the completion equilibrium. On the other hand, in the dynamic game treatment with a completion benefit, more than 10 percent of the groups reached the threshold of 12 chips, and almost a third contributed 10 or more chips. Treating each session as an observation we can easily reject the hypothesis that groups are no less likely to reach the threshold in the static game than in the dynamic game in favor of the alternative that the threshold is more likely to be reached in the dynamic game than in the static game (one-sided $p = 0.014$).[11]

Pooling the data from the four sessions of each of the two treatments, Figure 1 illustrates the distribution of group contributions. Once again we see that there is a change in behavior when the number of contribution rounds is increased. While more than 35% of the groups in the static game never succeed in contributing, this number is less than 15% in the dynamic game. Group contributions are larger in the dynamic treatments, and the associated cumulative distribution function (CDF) first order stochastically dominates that for the static treatment. These results are consistent with both the 'small-price-of-trust' and the 'completion-benefit' hypotheses.

[11] Unless otherwise noted all reported test statistics are Mann-Whitney U-tests.

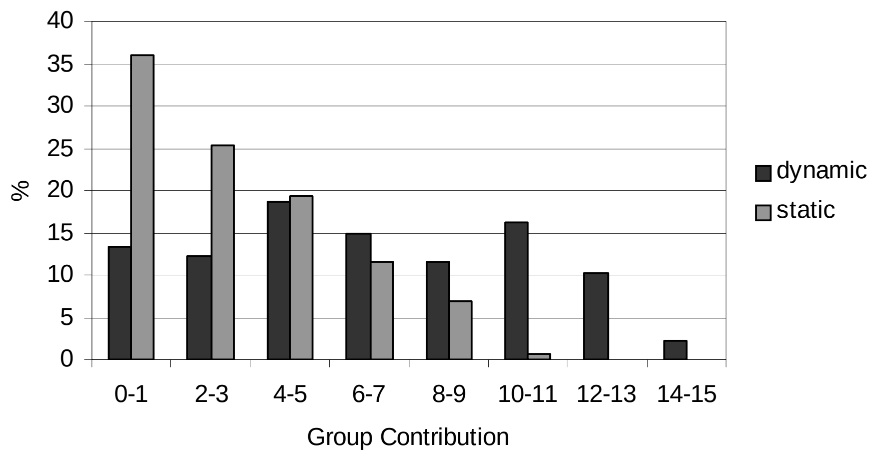

Figure 1: Distribution of Group Contributions, $b > 0$.

It is, however, clear that in both the static and dynamic games, a substantial portion of the observed group contribution levels are inconsistent with the predicted equilibrium outcomes for payoff-maximizing contributors (group contributions of 0 or 12). Perhaps the intermediate group contribution levels in the dynamic game are evidence of the coordination problem that arises from the multiple equilibria that are present in the dynamic contribution game.[12]

The data above suggest that, in the dynamic game, the average group contributions are larger than those of the static game. We now determine the magnitude of this difference and whether it is significant. Table 3 reports average group contributions for each session and treatment. Whether we look at all 15 games, the first 5, or the last 5, the result is always the same: average contributions are larger in every session of the dynamic game as compared with the static game. Thus we easily reject the hypothesis that in the static treatment average contributions are greater than or equal to those in the dynamic treatment (one-sided $p = 0.014$).[13] The difference is both statistically and economically significant. During the last five games,

[12] Recall that there are multiple completion equilibria in this game and that no-completion always remains an equilibrium possibility.

[13] The results are similar if we instead use random effects to determine the effect of dynamic play on contributions. Regressing individual contributions by game on a dummy for whether the game was dynamic, we consistently find that the coefficient on the dynamic dummy variable is statistically significant ($p = 0.001$ for all 15, first 5 and last 5 games).

the average contribution in the dynamic game is nearly three times larger than that of the static game. While one might have expected that, over time, participants would learn to take advantage of the socially efficient equilibria, we see instead that contributions decrease with experience.[14] Note however that the difference between the static and dynamic game is maintained over the course of the experiment.

Table 3: Average Group Contribution by Session, $b > 0$

	Average group contribution					
	All 15 games		First 5 games		Last 5 games	
	Static	Dynamic	Static	Dynamic	Static	Dynamic
Session 1	2.75	6.29	4.04	8.48	1.92	4.36
Session 2	3.03	7.43	3.56	10.24	2.28	5.04
Session 3	2.80	7.25	4.6	8.84	0.96	6.16
Session 4	3.49	5.05	5.56	6.16	2.16	4.32
Average	3.02	6.51	4.44	8.43	1.83	4.97

Recall from our example in Section 2 that one strategy that can support a completion equilibrium in the dynamic game has each player contribute one chip per round. This symmetric sequence of contributions is not the only one that can support a completion equilibrium, but in the absence of any communication among group players, it would seem to be a natural, focal candidate to examine. And, indeed, there is evidence that some groups succeed in having a per round group contribution of 3 units.[15]

A common condition by which various, alternative grim-g strategies secure completion is that individual i's contributions depend on past increases in the group total by other members of the group (excluding member i).[16] The same holds for Schelling's 'small-price-of-trust' hypothesis where continued contributions by others will cease if others stop giving. To examine the potential effect of dynamic play, we therefore examine the frequencies with which players contribute any positive number of chips to the group account in round t, conditional on either 1) their group's contribution, excluding their own individual contribution, *increased* in the previous

[14] Voluntary contributions typically decrease over the course of a repeated static public good game experiment, however even with many repetitions they do not disappear.

[15] The second most frequent per-round contribution is 1. The fraction of people contributing 1 is 32% in round 1, 29% in round 2, 24% in round 3, and 14% in round 4.

[16] Of course, we cannot rule out the possibility that contributions when $G_{-i} = 0$ are part of a dynamic equilibrium strategy. However, it seems unlikely that subjects would be able to coordinate on such turn–taking strategies.

round $t-1$, $G_{-i}(t-1) > 0$, or 2) their group's contribution, excluding their own, individual contribution, *did not change* in the previous round, $G_{-i}(t-1) = 0$. Both hypotheses suggest that individuals are more likely to give when $G_{-i}(t-1) > 0$ than when $G_{-i}(t-1) = 0$. Using data from all games of a session, Table 4 reports the conditional frequencies by session for rounds 2, 3, and 4 of the dynamic game with completion benefit. We see that subjects are two or three times more likely to contribute if $G_{-i} > 0$ than if $G_{-i} = 0$. This difference is statistically significant in round–by–round or in all–round, pairwise comparisons using the session–level data in Table 4 (one-sided $p \leq .057$ in all cases).

Table 4: Frequency with which Players make Non-Zero Contributions in Period t Conditional on $G_{-i}(t-1)$. Dynamic $b > 0$ Session Level Data

		Round 2	Round 3	Round 4	All Rounds
$G_{-i}= 0$	Session 1	0.100	0.148	0.097	0.118
	Session 2	0.235	0.220	0.198	0.211
	Session 3	0.176	0.236	0.150	0.184
	Session 4	0.175	0.111	0.028	0.087
	All Sessions	0.170	0.167	0.110	0.141
$G_{-i}> 0$	Session 1	0.378	0.385	0.198	0.335
	Session 2	0.545	0.373	0.261	0.414
	Session 3	0.476	0.418	0.344	0.422
	Session 4	0.358	0.316	0.238	0.317
	All Sessions	0.443	0.376	0.266	0.377

In summary, consistent with the two hypotheses, we find that in the presence of a completion benefit, individuals condition their contributions on past contributions of others and that overall contributions are larger in the dynamic game than in the static game.

5.2 No completion benefit, $b = 0$: Dynamic versus Static Games

To distinguish between our two hypotheses we examine behavior in the dynamic and static games without a completion benefit. We focus on the 'completion-benefit' hypothesis that in this case there should be no difference in contribution behavior between the dynamic and the static game.

The reason, again, is that independent of past and future play it is a dominant strategy not to contribute. Thus the unique equilibrium outcome of the static or dynamic game without a completion benefit is no-contribution, and we can use the behavior in these two treatments to determine which of our two theories best explain the differences in behavior between the static and dynamic game *with* a completion benefit.

Table 5 (the analogue of Table 2) reports the number (percent) of groups (out of 75) in each session who had final contributions that either reached the threshold of 12 or came close, i.e., an end-of-game group total of 10 or more chips. *In contrast to the theory by Marx and Matthews, we find that absent a completion benefit, behavior in the dynamic game is still different from behavior in the static game. In particular, groups in the dynamic game are more likely to reach the threshold than groups in the static game.* We can, again, easily reject the hypothesis that groups are at least as likely to reach the threshold in the static game as in the dynamic game (one-sided $p = 0.014$). Only one group in the static game managed to achieve the threshold of 12 chips (this occurred in the very first game of Session 1). Across the four sessions of the dynamic game, an average of 6 percent of groups achieved the completion equilibrium and another 10 percent came close.

Table 5: Number (percent) of 75 Observations where the Group Contribution Exceeds a Specified Level, $b = 0$

	Groups with			
	12 or more chips		10 or more chips	
	Static	Dynamic	Static	Dynamic
Session 1	1 (1.3)	2 (2.7)	2 (2.7)	9 (12.0)
Session 2	0 (0.0)	5 (6.7)	1 (1.3)	12 (16.0)
Session 3	0 (0.0)	8 (10.7)	0 (0.0)	15 (20.0)
Session 4	0 (0.0)	3 (4.0)	1 (1.3)	11 (14.7)
Average	0.25 (0.3)	4.5 (6.0)	1 (1.3)	11.75 (15.7)

Pooling the data from the four sessions we also note that the distributions of group contributions differ between the static and dynamic games. As shown in Figure 4, almost half of the static groups never contribute, while the number is less than 20 percent for the dynamic groups. Group contributions tend to be larger in the dynamic treatment without a completion benefit, and the CDF of group contributions in the dynamic game first order stochastically dominates that of the static game.

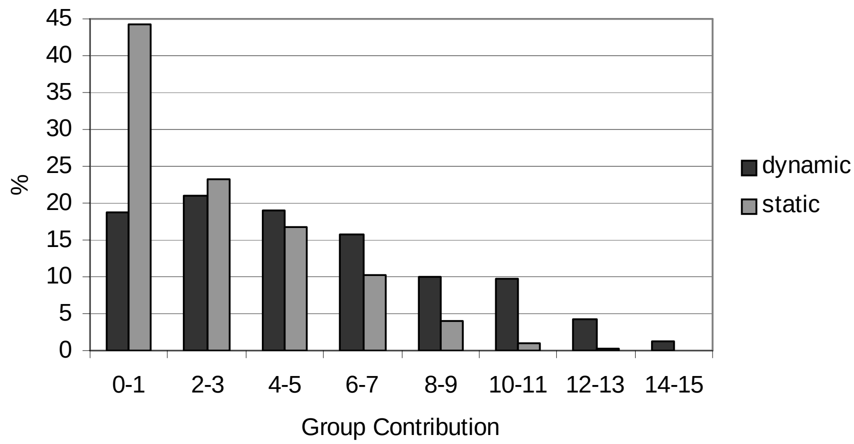

Figure 4: Distribution of Group Contributions, $b = 0$

Table 6 (the analogue of Table 3) reports average group contributions for each session and treatment. Whether we look at all 15 games, the first 5 or the last 5, average contributions are smaller in the static game than in the dynamic game. *Thus, consistent with Schelling's hypothesis, we may reject the hypothesis that average contributions in the static game are greater than or equal to those in the dynamic game (one-sided* $p \leq 0.057$*).*[17] Similar to the completion benefit sessions, we observe a decrease in contributions with experience, and the effect of multiple contribution rounds is maintained throughout.

Table 6: Average Group Contribution by Session, $b = 0$

	Average group contribution					
	All 15 games		First 5 games		Last 5 games	
	Static	Dynamic	Static	Dynamic	Static	Dynamic
Session 1	3.64	4.47	4.68	6.00	2.80	2.64
Session 2	2.04	5.37	4.72	7.72	0.36	3.92
Session 3	2.51	6.05	3.88	7.92	1.08	4.52
Session 4	2.39	4.75	3.64	7.32	0.92	1.92
Average	2.65	5.16	4.23	7.24	1.29	3.25

[17] The results are similar if we instead use random effects to determine the effect of dynamic play on contributions. Regressing individual contributions by game on a dummy for whether the game was dynamic, we consistently find that the coefficient on the dynamic dummy variable is significant ($p = 0.00$ for all 15, first 5 and last 5 games).

To examine the effect of dynamic play we compare the frequencies by which players contribute a positive number of chips to the group account in round t, conditional on other group members increasing their contribution in the previous round, $G_{-i}(t-1) > 0$, and not changing their contribution in the previous round, $G_{-i}(t-1) = 0$. Under Schelling's hypothesis, players should condition on this information. Using data from all games of a session, Table 7 (the analogue of Table 4) reports the conditional frequencies by session for rounds 2, 3, and 4 for the dynamic game without a completion benefit. *Consistent with Schelling's hypothesis, subjects are much more likely to contribute if* $G_{-i} > 0$ *than if* $G_{-i} = 0$. This difference is statistically significant in round–by–round or in all–round, pairwise comparisons within treatments using the session–level data in Table 7 (one-sided $p \leq .057$ in all cases). Thus even when there is no completion benefit participants are more likely to contribute when others contributed in the previous round. Please note that reciprocity would generate a similar pattern of behavior. In our experiment it is not possible to determine whether trust or reciprocity is causing participants to contribute more when others have done so in the past. Kurzban et al (2001) argue that reciprocal behavior may cause greater cooperation in dynamic games.

Table 7: Frequency with which Players make Non-Zero Contributions in Period t Conditional on $G_{-i}(t-1)$. Dynamic $b = 0$ Session Level Data

		Round 2	Round 3	Round 4	All Rounds
$G_{-i}= 0$	Session 1	0.081	0.074	0.034	0.057
	Session 2	0.115	0.188	0.117	0.140
	Session 3	0.279	0.136	0.114	0.148
	Session 4	0.098	0.049	0.030	0.047
	All Sessions	0.135	0.106	0.071	0.094
$G_{-i}> 0$	Session 1	0.448	0.368	0.188	0.364
	Session 2	0.428	0.287	0.295	0.351
	Session 3	0.418	0.336	0.290	0.362
	Session 4	0.362	0.282	0.115	0.293
	All Sessions	0.413	0.319	0.233	0.344

5.3 Comparison between treatments with ($b = 1$) and without ($b = 0$) completion benefits

We next compare contribution behavior between static (dynamic) treatments when there is or is not a completion benefit. The relevant data are reported in Tables 2 through 7. Although the completion benefit implies a larger potential payoff, in the static game it has no theoretical effect on the equilibrium level of contributions. Comparing behavior in the *static games with and without a completion benefit (b=1 or b=0)* we cannot reject the hypothesis that these groups are equally likely to reach the threshold (two-sided $p = 0.343$), nor that they are equally likely to come close to the threshold (two-sided $p = 0.486$). Similarly we cannot reject the hypothesis that there is no difference in the average group contributions (two-sided $p \geq 0.343$ for all 15, first 5 or last 5 games).[18]

In the dynamic game, the completion benefit expands the set of equilibria to include full completion. If this expanded set of equilibria affects behavior then average contributions are predicted to be larger when there is a completion benefit. When comparing behavior in the *dynamic treatments with and without a completion benefit* we find some evidence of a completion-benefit effect. While we can reject the hypothesis that groups without a completion benefit are at least as likely to reach the threshold as those with a completion benefit (one-sided $p = 0.043$), we cannot reject the hypothesis that they are at least as likely to come close to the threshold (i.e., contribute 10 or more chips, one-sided $p = 0.293$).[19] Although the magnitudes are not large, we find that over all 15, the first 5 and last 5 games the completion benefit increases average contributions in the dynamic game (one-sided $p = 0.057, 0.1$ and 0.057, respectively).[20]

Since the return from contributing is greater in the presence of a completion benefit, it is not straightforward to compare contribution levels with and without a completion benefit.[21] As an alternative assessment of the 'completion benefit' hypothesis one may ask whether the effect of dynamic

[18] The results are similar if we instead use random effects. Regressing individual contributions by game on a dummy for the completion benefit we find that the coefficient on completion benefit is insignificant ($p \geq 0.217$ for all 15, first 5 and last 5 games).

[19] Due to ties these p-values are approximate.

[20] Using random effects we get the same result. Regressing individual contributions per game on a dummy for the presence of a positive completion benefit, the coefficient on the completion benefit dummy is significant (for all 15 games $p = 0.033$, the first 5 games $p = 0.105$, and for the last 5 games $p = 0.015$).

[21] Isaac and Walker (1988) show that contributions in a linear VCM increase with the return to giving.

play is greater with a completion benefit. Specifically, is the increase in contributions when moving from a static to a dynamic game greater when there is a completion benefit? The results from our study suggest that this increase in contributions is not sensitive to the completion benefit.[22]

To further determine the effect of the expanded set of equilibria in the dynamic game with a completion benefit we focus on behavior in the last contribution round. Intuitively, in the dynamic game the completion benefit should have its greatest effect in the last round of those games in which aggregate contributions have reached at least 6 by the end of round 3, and each individual has at least 2 chips in their private accounts. The reason is that each individual is willing to contribute as many as two chips to complete the project. Thus it is possible to complete the project in the last round provided that six chips have been contributed and each player has 2 chips available. We look for the effect of the completion benefit by comparing round 4 contributions with and without the completion benefit conditional on the cumulative contributions in round 3 having reached either 6 or 9 chips. Although we find larger, round-4 contributions when there is a completion benefit (mean of 0.38 vs. 0.30 when $5 < \sum_{t=1}^{3} G(t) < 12$, and mean of 0.41 vs. 0.38 when $8 < \sum_{t=1}^{3} G(t) < 12$) these differences are not significant in either of the two cases (one sided p-values 0.3429 and 0.7571).

In summary, contributions are significantly higher in the dynamic game than in the comparable static game, and players condition their behavior on changes in the level of group contributions in the dynamic games. In the presence of a completion benefit, these findings are consistent with both of our hypotheses. However the observation that dynamic play has a similar effect in the absence of a completion benefit and that the increase in contributions from static to dynamic moves does not appear to depend on there

[22] Since we conducted a between-subject comparison of the dynamic and static treatments, there is no natural pairing between the sessions we conducted under each treatment. To achieve a quantitative measure of the effect of dynamic play we therefore look at all the possible differences between the four sessions under dynamic play and the four sessions under static play when $b = 1$ and then when $b = 0$. Conditional on the completion benefit, there are 24 possible differences between the static and dynamic treatments. When testing whether the effect of dynamic play is greater with a completion benefit we find the p-values of the $24^2 = 576$ possible combinations. Whether one looks at all 15, the first 5, or the last 5 games, the result is always the same: the median and the mean of the distribution of one-sided p-values equals 0.1714. The result is the same if we instead use regressions with random effects to determine whether the influence of dynamic play is greater when there is a completion benefit. Regressing contributions on dummies for whether the game was dynamic, there was a completion benefit, as well as the interaction between two, we find that the coefficient on the interaction is insignificant whether we look at all 15, first 5 or the last 5 games ($p \geq 0.156$).

being a completion benefit is more supportive of Schelling's hypothesis. Our experimental design does not enable us to determine why the presence of a completion benefit does not cause a greater increase in contributions from dynamic play. There are however several reasons why participants may have failed to benefit from the existence of a completion equilibrium. First, the important role played by the completion benefit relies on a player's ability to apply backward induction. Experimental evidence that players can backward induct more than 1 or 2 rounds is scant see e.g., Rosenthal and Palfrey (1992), Neelin, Sonnenschein, and Spiegal (1988). Second, for a participant to play according to the strategies that sustain a particular completion equilibrium, she must not only understand the rather complicated underlying incentives, but she must also believe that her group members understand these incentives, and that they, despite the multiplicity of equilibria, will coordinate on the equilibrium this particular participant has in mind. Given that behavior appears to be more in line with the 'small-price-of-trust' hypothesis we choose to investigate that hypothesis in greater detail.

5.4 A further test of Schelling's hypothesis

According to Schelling, having multiple contribution rounds enables donors to build up trust as they only need to sacrifice small contributions to test how cooperative other members of the group are. This 'small-price-of-trust' hypothesis relies critically on players' receiving feedback on the aggregate group contribution levels; without feedback, the possibility of sustaining trust is greatly weakened, (though tacit coordination schemes cannot be ruled out).

We developed a fifth treatment to determine whether the 'small-price-of-trust' hypothesis is the likely explanation for greater giving in the dynamic games. This fifth treatment is identical to the dynamic treatment without a completion benefit, except that the individual donor receives *no feedback* on what the other members of her group contribute over the course of each 4-round game. However, players *are* informed of the cumulative group contribution at the end of the fourth round of each dynamic game. Thus, the available information is equivalent to that given in the static game with no completion benefit.[23]

We compare contribution behavior in the dynamic $b = 0$ game with and

[23] Removing or limiting the feedback that players receive, while seemingly unnatural, is increasingly being used by researchers to test learning theories, which make heavy reliance on such feedback. See, e.g., Weber (2003). As Schelling's hypothesis does not depend on the existence of a positive completion benefit we chose to set $b = 0$ in this treatment.

without feedback. If the 'small-price of trust' hypothesis is what causes greater giving in the dynamic game, then the absence of feedback ought to reduce contributions. As we did for each of our other four treatments, we recruited 60 new participants and conducted four sessions of this fifth treatment – the dynamic contribution game with no completion benefit and no feedback between rounds.[24] The frequencies for various group contribution levels in the three $b = 0$ treatments – the static, dynamic with no feedback (NFB), and dynamic with feedback (FB) are shown in Figure 7. The general impression this figure conveys is that group contributions in the dynamic game with no feedback are, on average, 'intermediate' between those in the static game and those in the dynamic game with feedback. Table 8 reports average contributions from these four sessions. Comparing these to the results in Table 6 we see, first, that although the dynamic games without feedback are strategically equivalent to the static ($b = 0$) games, contributions in the former are significantly larger.[25] Second, and more importantly, in contrast to the 'small-price-of-trust' hypothesis we find that average contributions in the dynamic game with and without feedback do not differ from one another.[26]

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[24] Given the information equivalence to the static game the multiple-round game is not a dynamic game, however to capture the multiple opportunities to give we nonetheless refer to it as such.

[25] Using session level data one-sided $p \leq 0.057$ for all 15, first 5 and last 5 games. An analysis based on random effects yields the same result, as the coefficient on static is negative and significant ($p \leq 0.019$ for all 15, first 5 and last 5 games).

[26] Over all 15 games average group contributions are slightly larger and marginally significant with a one-sided $p = 0.10$, however this difference is not significant for the first 5 games (one-sided $p = 0.207$) nor for the last 5 games (one-sided $p = 0.343$). Thus, we easily reject the two-sided hypothesis that feedback has no effect. The result is the same using random effects. Regressing individual contributions over the 4 rounds on a dummy for Feedback, we find a marginally significant coefficient over all 15 games ($p = 0.087$), but the coefficient is not significant for the first 5 nor for the last 5 games ($p = 0.11$ and $p = 0.247$, respectively).

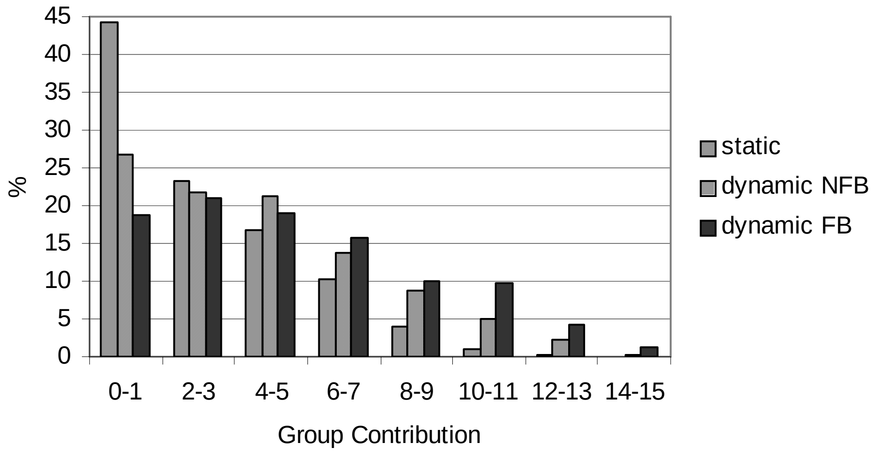

Figure 7: Frequency of Group Contributions, $b = 0$

Perhaps a more appropriate test of Schelling's hypothesis is to compare contributions in the first contribution round of the four-round game. As suggested by our initial quote, Schelling argued that the benefit of observed dynamic play is that it removes most of the risk from the initial contribution. In the presence of feedback there is a larger incentive to contribute and test the trust of others, thus an alternative test of the hypothesis is that contributions in round 1 are larger with than without feedback. However, as with the aggregate contributions, we do not find that the average first-round individual contribution significantly depends on the availability of feedback.[27]

[27] Over all 15 games average round-1 group contributions are slightly larger and marginally significant with a one-sided $p = 0.10$, however this difference is not significant for the first 5 games (one-sided $p = 0.207$) nor for the last 5 games (one-sided $p = 0.343$). Certainly we can reject the two-sided hypothesis that feedback has no effect. The result is similar using random effects. Regressing individual round-1 contributions on a dummy for Feedback, the coefficient on Feedback is insignificant whether it is for all 15, first 5 or just the last 5 games ($p \geq 0.142$).

Table 8: Average Group Contribution by Session in the Dynamic Game with no Feedback, $b = 0$.

	Average group contribution		
	All 15 games	First 5 games	Last 5 games
Session 1	2.71	4.12	1.24
Session 2	4.19	6.00	2.92
Session 3	4.47	6.44	3.04
Session 4	5.24	7.84	2.88
Average	4.15	6.10	2.52

While the average group contribution data lend little support to the 'small-price-of-trust' hypothesis, the conditional contribution data paints a different picture. Specifically the hypothesis implies that players in a dynamic game with feedback will condition their behavior in rounds 2, 3 and 4 on the information they receive prior to the play of each of these rounds. If they do not then this would serve as further evidence against the 'small-price-of-trust' hypothesis. Recall that in the two feedback treatments subjects are more likely to contribute when $G_{-i}(t-1) > 0$ than when $G_{-i}(t-1) = 0$. For comparison Table 9 reports the conditional frequencies by session for rounds 2, 3, and 4 when there is no feedback ($b = 0$, NFB). Not surprisingly we cannot reject that the frequency of contributing conditional on $G_{-i} = 0$ is the same as when $G_{-i} > 0$ (e.g., using data for all rounds, one-sided $p = 0.243$; similar results obtain in round–by–round comparisons).

Feedback influences the conditional contribution data, and in support of the 'small-price-of–trust' hypothesis Section 5.3 showed that dynamic play does not have a more significant role in the presence of a completion benefit. However, since the overall level of contributions in the dynamic games with feedback and without are not significantly different, it is difficult to argue that the increase in contributions we observe when moving from a static to a dynamic contribution game is caused by the small price of trust.

Our finding that feedback has a limited effect on contributions in the dynamic game, does not imply that feedback generally will play a limited role in generating contributions. As suggested by a reviewer, it may be that we by selecting a course endowment of six tokens have limited the participants' message space, and thereby the possibility for finding an effect of feedback. It may be of interest in future research to determine whether feedback has a greater effect when participants instead have finer endowments of, say, 60 tokens.

Table 9: Frequency with which Players make Non-Zero Contributions in Period t Conditional on $G_{-i}(t-1)$. Dynamic $b = 0$ No Feedback Session Level Data

		Round 2	Round 3	Round 4	All Rounds
$G_{-i} = 0$	Session 1	0.182	0.140	0.202	0.175
	Session 2	0.184	0.179	0.208	0.191
	Session 3	0.134	0.115	0.136	0.128
	Session 4	0.150	0.151	0.216	0.177
	All Sessions	0.160	0.145	0.189	0.166
$G_{-i} > 0$	Session 1	0.203	0.134	0.211	0.185
	Session 2	0.236	0.271	0.259	0.253
	Session 3	0.151	0.117	0.061	0.121
	Session 4	0.276	0.267	0.221	0.260
	All Sessions	0.221	0.204	0.201	0.211

5.5 Why are contributions higher in the dynamic game?

In designing this experiment we sought to test two mechanisms by which contributions in a dynamic public good game might exceed those in a static game. We have not found strong evidence to suggest that either mechanism is causing the increase in contributions. That by itself is an important finding. However, it leads naturally to questions as to what alternative factors or mechanisms might account for our findings.

While theories other than those by Schelling and Marx and Matthews may suggest larger contributions in the dynamic than static games, these generally rely on the fact that individuals in the dynamic game can condition their contributions on the past contributions of others.[28] However any theory that relies on conditional contributions will have difficulty explaining why average contributions in our no-feedback treatment are similar to those in the dynamic game with feedback ($b = 0$). Understanding why contributions in the dynamic game without feedback exceed those of the static game may therefore be the key to understanding why in our environment dynamic play generally increases contributions.

Of course tacit collusion may be one reason for the greater than expected contributions in the dynamic game without feedback. Another reason may

[28] e.g., Romano and Yildirim, 2001, show that contributions in a dynamic game may be larger than in a static game if individual best response functions are increasing in the contributions of other donors.

be that, while the game theoretically is identical to the static one, it offers four times as many opportunities to give. With every opportunity to give there is also an opportunity for trembles or mistakes, and indeed in our environment trembles are likely to cause contributions to increase. For example, suppose that in each round, with some probability, a player randomly contributes one more or one less chip than their strategy prescribes for that round. If most strategies prescribe contributing zero chips, then the associated trembles will consist of positive deviations in terms of chips. With four times as many opportunities to contribute in the dynamic setting, trembles alone may cause group contributions to be higher in the dynamic than in the static setting.

The conditional frequencies reported in Tables 4, 7 and 9 may be seen as supportive of the notion that trembles play an important role in all three dynamic games. Independent of the treatment, when $G_{-i}= 0$, an average of around 10–15% of subjects contribute something in every round. If contributions are made any time there is an opportunity to give, then contributions may be larger in the dynamic than in the static game. Thus, although the conditional contribution frequencies indicate that behavior is sensitive to feedback, persistent mistakes may swamp any effect such differences may have on aggregate contributions.

Of course it need not be an error to contribute when one is informed that $G_{-i}= 0$. Rather it may be seen as an attempt to secure cooperation in subsequent rounds. Supportive of this argument is the observation (Tables 4 and 7) that the average contribution when $G_{-i}= 0$ decreases towards the end of the game, this decrease is however not significant.

While our experimental design follows Marx and Matthews very closely, the zero contribution equilibrium prediction may enhance the role played by trembles; by contrast, if all equilibria were interior, trembles might lie on either side of an equilibrium and thus play a more diminished role.[29] Future studies of dynamic versus static contribution games may therefore benefit from examining environments where all equilibria are interior equilibria.

Finally, as mentioned earlier it may be that the limited effect of feedback is due to the coarse endowments participants received. Perhaps finer endowments would expand the message space and result in feedback having more of an effect.

[29] See Laury and Holt (forthcoming) for a review of the experimental investigations of contributions in static games when there is an interior Nash equilibrium.

6 Conclusions

Most fund-raising drives do not preclude individuals from making more than one contribution. Indeed, most fund-raisers repeatedly appeal for contributions from the same pool of donors and provide frequently updated information on the level of contributions received. Schelling hypothesized that players might give more in the dynamic contribution game because the multiple opportunities to give allows players to make smaller contributions and observe the decisions of others before making any further contributions. Effectively, the cost of cooperation is lowered. Marx and Matthews (2000) go further and show that in dynamic voluntary contribution games a positive completion benefit is required for there to exist equilibria where players complete funding of the project. Depending on the size of the completion benefit, these equilibria may not exist in a static (one-round) version of the same contribution game, and in the case where the completion benefit is zero, the unique equilibrium of both the dynamic and static games is for no individual to contribute.

In conducting both static and dynamic public good game experiments we find that contributions are indeed larger in the dynamic game than in the static game, and that in the dynamic game some groups manage to successfully complete funding of the project. These results are of interest to both practitioners and theorists. While in the presence of a completion benefit the effect of dynamic play is consistent with both Schelling and Marx and Matthews, that is not the case absent a completion benefit. Despite some evidence of a completion-benefit effect, we find that this discrete increase in payoffs does not play the critical role that it does in the theory of Marx and Matthews. In particular, contributions in the dynamic game were always greater than contributions in the static game, regardless of whether there was or was not a positive completion benefit. Furthermore the increase in contributions from the static to dynamic games did not depend on the completion benefit.

The evidence in support of the completion benefit hypothesis is also weak when examining the conditional contribution data. While subjects in the dynamic games are clearly conditioning their decisions on the group's total contribution when feedback is given, this effect is the same whether or not there is a completion benefit, suggesting that the small-price-of-trust is what is driving the larger contributions in the dynamic games. However, in contrast to the 'small-price-of-trust' prediction, we do not find that first-round contribution levels in the dynamic, $b = 0$ treatment without feedback differ from those observed in the dynamic, $b = 0$ treatment with feedback.

While overall contributions in the dynamic treatment without feedback do not differ from the dynamic treatment with feedback, they are significantly larger than in the static, $b = 0$ game. Thus, in contrast to the individual contribution frequencies, the average contribution data suggest that the 'small-price-of-trust' hypothesis is not what is driving the increase in contributions between the static and dynamic game. Of course, there may be other parameterizations of the voluntary contribution game in which a positive completion benefit and feedback play a greater role. However, for the parameterization we consider, the best predictor of whether contributions would be greater is that the game is dynamic rather than static.

We conjecture that the key to understanding the difference between the static and the dynamic games may lie in explaining the persistent, positive contributions by 10–15% of subjects when there has been no change in contributions to the group total by other members of the group. Such contributions lead to larger aggregate contributions in the dynamic game with its multiple periods of giving as compared with the static game. To better understand what causes dynamic play to increase contributions it may be of interest to examine an environment where there are interior equilibria. We leave an exploration of such an environment to future research.

Appendix: Instructions Used in the Experiment

The instructions used in the *dynamic with completion benefit* treatment (with feedback) are reprinted below. Instructions for the other treatments are similar.

WELCOME

This is an experiment in group and individual decision making. Please do not talk with one another for the duration of the experiment. If you have any questions, please raise your hand.

In this experiment you will participate in 15 sequences. At the start of each sequence everyone is randomly assigned to a group of 3 individuals. You will not be matched with any member of your group twice in a row. The 2 other members of your group will never know your identity nor will you know their identity. All decisions you make in this experiment are anonymous.

Each sequence consists of four rounds. You will be matched with the same two people for all four rounds of a sequence. At the beginning of a sequence each group member will get 6 'chips' in his or her private account. In every round each of you must decide how many of your chips you want to contribute to the group account. Chips not contributed to the group account remain in your private account. At the beginning of each round you will be told how many chips remain in your private account and how many chips are in the group account. The number of chips in the group account equals the sum of chips contributed by you and the other 2 group members in all previous rounds of the sequence. All members of your group will see the number of chips in the group account on their computer screens, but no member of your group will know how many of the chips in the group account came from anyone other than him/herself. After each round, please record the number of chips remaining in your private account and the chips in the group account under the appropriate headings on your record sheet.

Your earnings from each sequence will be determined after the four rounds of decisions. Your payment depends on the number of chips remaining in your private account, and the total number of chips you and the other group members have contributed to the group account at the end of the four rounds. For each chip remaining in your private account at the end of round 4 you earn 10 cents. For each chip in the group account, up to 11 chips, you and each member of your group will receive 5 cents. If the group account contains 12 or more chips you and each member of your group will receive a fixed payment of 70 cents from the group account. Your total payoff for each sequence is the sum of your earnings from the private and the group account, and will be indicated on your computer screen. Please record this number on your record sheet. Earnings from the group account depend only on the total number of chips in that account. It does not depend upon how many chips you contributed to the account.

We have attached a simple payoff table to make it easy for you to calculate your total earnings from the group and private accounts. The rows of the table indicate the total contribution to the group account by you and the other members of your group. Since each of you can contribute a maximum of 6 chips any number between 0 and 18 chips can be contributed to the group account. The columns indicate your total contribution to the group account. For every chip contributed to the group account you will have one less chip in your private account. The bottom of the table shows the number of chips remaining in your private account. Suppose you have contributed 3 chips to the group account and that the total number of chips in the group account is 6. Finding the appropriate column and row we see that your payoff would be 60. Now if you look along the gray diagonal, you can see how your payoff changes as you change your contribution holding the contribution by others unchanged. For example, your payoff would be 55 if you increased your contribution by one and brought the total group contribution to 7. On the other hand your payoff would increase to 65 if you decreased your contribution by one and reduced the total to 5. Note that when you increase your contribution by 1 chip you increase the payoffs of each of the other group members by 5, and when you decrease your contribution by 1 chip you decrease the payoffs of each of the other group members by 5. As a second example, suppose you contribute 2 chips and the total group contribution is 11 then your payoff is 95. Looking along the diagonal we see that your payoff would increase to 100 if you increased your contribution by 1 chip, holding the contribution by others constant. Once the total contribution to the group account passes 12 chips, any additional chips in the group account will not increase your return from the account. This is indicated by the horizontal dotted line.

Your earnings from the experiment are the sum of the earnings from all 15 sequences plus a $5 show up fee. As we go along please report the sum of your earnings in the cumulative earnings column on your record sheet. At the end of the experiment you will be asked to come to the side room where you will be paid in private.

ARE THERE ANY QUESTIONS BEFORE WE BEGIN?

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