# 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. This dynamic structure enables donors to condition their contribution on that of others, and, as Schelling (1960) suggested, may serve to overcome free-riding 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 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 appear to depend 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

Theoretical analysis of voluntary contribution games suggests that free-rider problems will hinder the financing of public goods. Nevertheless, some public goods are, in fact, financed through voluntary contributions. This observation has led to a voluminous experimental literature aimed at understanding the factors that influence the level of contributions observed in voluntary contribution games.

Surprisingly, much of the theoretical and experimental work on voluntary contributions has focused on static, as opposed to dynamic game environments. 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 should be 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, most fund-drives 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 as opposed to a static one? Or equivalently why might behavior be sensitive to there being multiple rather than just one contribution round? Schelling (1960) suggested one possibility: dynamic environments allow for smaller, history-contingent contributions that reduce the cost of free–riding. 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 contribu-

> tion 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..."

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. Specifically, 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 contribution game with the same payoffs. 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 up provide an endogenous and discrete completion benefit.

In this paper we report on a laboratory experiment designed to investigate these two theories. Specifically, we ask whether voluntary contribution decisions differ when the contribution game is dynamic rather than static, and if so, whether the differences are owing to the mechanisms suggested by Schelling and Marx and Matthews. Consistent with their hypotheses, we compare behavior when individuals with a given endowment simultaneously contribute in either one or multiple contribution rounds.[1] In the presence of a completion benefit, differential behavior in the dynamic versus static games would be consistent with both Schelling and Marx and Matthews. To

[1] Thus our study differs from the experimental literature on voluntary contributions made by "partners" vs. "strangers," where individuals play repeated static games with the same group in each game or with a new group in each game (for a review see Andreoni and Croson, 2003). Our study also differs from the voluntary contribution literature that examines the effect of announcements where individuals contribute once, but in sequence as in e.g., Andreoni (1998), Andreoni, Brown and Vesterlund (2002), Potters, Sefton, and Vesterlund (2004), Romano and Yildirim (2001), and Vesterlund (2003). See Section 2 for futher discussion of the related experimental literature.

distinguish between the two hypotheses we also examine whether a discrete benefit jump upon completion of the project is necessary to achieve a difference in giving in the dynamic game, and we also explore the role played by feedback.

Our main finding is that voluntary contributions are significantly larger in the dynamic multiple-contribution round version of the game as compared with the static one-shot version of the game. However we also find that neither Schelling's nor Marx and Matthews' explanations satisfactorily 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, our results show that the existence of a positive completion benefit is not a critical determinant of whether or not groups successfully fund a project in the dynamic game. Second, when we eliminate feedback on group contribution levels in the dynamic game, so that the information becomes analogous to a static game, initial giving remains at the high levels we observed when there was feedback. It is difficult to reconcile this finding with Schelling's hypothesis. We conclude with two alternative explanations that might account for the difference in giving between the dynamic and static game environments: one involves trembles and the other involves the theory of psychological games, where player's subjective payoffs depend on satisfying the expectations of other group members.

## 2 Related Experimental Literature

The linear voluntary contribution mechanism (VCM) has been extensively studied by experimentalists, albeit mostly in static, one–shot settings.[2] Here we review the literature related to our study.

Experiments on voluntary contributions in "partners" vs. "strangers" environments (see Andreoni and Croson (2003) for a review) introduce a dynamic element to the standard static VCM environment. These studies compare contributions when individuals remain in a fixed group of participants in every repetition of the static game (partners), with contributions when individuals play with a different group of people in every game

[2] The linear voluntary contribution mechanism is an environment where individuals are matched in groups of size $n$. Each member of the group is given an endowment and must allocate the endowment between a private and public account. Money allocated to the private account generate a dollar for dollar return. Money allocated to the public account generate a return of $\lambda < 1$ to each member of the group. A social dilemma arises when $n\lambda > 1$. See Ledyard (1995) for a survey.

(strangers). Thus, in the "partners" treatment, repetition of the static game implements a dynamic game. While one might expect the repeated interaction with fixed partners to give rise to more trusting behavior, the evidence is mixed. Some researchers have found contributions to be more generous in the "partners" treatment, while others have found contributions to be more generous in the "strangers" treatment. Our dynamic game differs from the partners treatment both in motivation and in implementation. We focus on the difference between multiple versus one contribution round, and whether or not a completion benefit makes a difference. Further, participants in our dynamic game do not have their endowment refreshed following each decision round of the dynamic game as in the repeated static game "partners" treatment.

Andreoni, Brown and Vesterlund (2002) examine a quasi-linear voluntary contribution game and examine the effect of having one versus two contribution rounds. Contributions in a two-player game are compared when individuals simultaneously decide how much to contribute, and when they contribute sequentially, with one player making her contribution decision before the other. They find no significant differences between simultaneous and sequential giving. By contrast, we examine the effect of multiple giving rounds when individuals may contribute in all rounds.

An experiment by Andreoni and Samuelson (forthcoming) shows that when the distribution of total payoffs in a twice–repeated, two–player prisoner's dilemma game can vary between the two periods, cooperative play is enhanced if the ratio of first to second period stakes is small. In contrast, we consider a public good game played by a three-player group for four, rather than just two periods. We allow the stakes in each period to be endogenously determined by the players and we compare behavior of the dynamic to the static game.

Kurzban, McCabe, Smith and Wilson (2001) is closer to our study in that individuals are free to contribute multiple times during the game. Their mechanism provides group contribution totals in real time over the 90-second period that agents have available to make contributions to the public good. They compare the case where contributions can be made or revoked anytime during the 90-second period with the "commitment" case where contributions, once made, cannot be revoked, and find that contributions are always greater in the latter case. Examining the effect of information they find larger contributions in the commitment case when group members observe the minimum contribution made among all members of their group, rather than the maximum contribution. Kurzban et al. hypothesize that announcing the minimum contribution limits the opportunities for free-riding as individuals cannot observe contributions in excess of the minimum and the commitment mechanism insures that the minimum contribution is being made by at least one participant. We view these findings as complementary to our own, but with several important differences. First, in contrast to the environments we consider with a discrete completion benefit, nonzero contributions never comprise an equilibrium in the Kurzban et al. public good game. Second, we examine the effect of multiple contribution rounds by comparing giving in the static and dynamic games. In many experiments with static, voluntary contribution games where zero contribution is a payoff-maximizing dominant strategy, many subjects make significant contributions. These contributions may either reflect 'mistakes' or 'other regarding preferences' or both.[3] For this reason we take as our benchmark the contributions observed in the static game with the same payoff function as our dynamic voluntary contribution game. Finally, we do not implement any kind of time pressure, and individual decisions in our environment are always irrevocable.

# 3 Theoretical Analysis

Here we describe a simplified version of 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 $G(t) = \sum_{i=1}^{n} g_i(t)$ the sum of all $n$ individuals' contributions made at time $t$. 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

[3] 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.

complete once the sum of contributions reach or exceed some exogenous and known threshold, $\overline{G}$. The marginal benefit of contributing prior to reaching the threshold is $\lambda$. Upon completion, there is a discrete increase in the benefit; we refer to that increase as the *completion benefit* and denote it 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 $0 < \lambda < 1$.[4] 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

[4] Absent completion the payoffs are identical to that of the linear voluntary contribution mechanism.

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 $\lambda$, 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.[5]

[5] 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 $b_i K$. If the maximum contribution is achieved at the time the game is terminated the payoff to $i$ is $a_i K$, 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 see more clearly the effect of additional contribution rounds, consider the following parametric example of a voluntary contribution game. The parameterization used here is the one we 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, 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, 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 there are four rounds in which any individual can contribute, i.e., $T = 4$. 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-

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+20). 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

| | Benefit from deviating |
|---|---|
| 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.[6] 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.[7]

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 is driven by the presence of a completion benefit or if, along the lines of Schelling, differences simply are due to dynamic play of the game. We now turn to addressing these two empirical questions.

[6] 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 cents 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.

[7] 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.

# 4 Experimental Design

In the experiment, we use the same parameterization of the game as in the example of Section 3, 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 $2 \times 2$ 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 the static game. Thus we can use the $b = 0$ treatments to determine whether a potential increase in contributions in the dynamic game with a completion benefit is due to the expanded set of equilibria examined by Marx and Matthews or simply to dynamic play made feasible by the increased number of contribution rounds (Schelling's 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.*[8]

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

[8] 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.

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. After the 15 games, the sum of each participant's earnings from all games was calculated and added to a $5 show-up payment. While preparing their payment participants were asked to fill out a brief questionnaire. Subjects were paid 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 $12.90). A copy of the instructions for the dynamic game with completion benefit is provided in the Appendix; other instructions are similar. The only change for the static treatment with completion benefit is that participants were given only one round to contribute, and in the treatments without completion benefit the only change is that the payoff at completion was 60 cents rather than 70 cents ($b = 0$ rather than $b = 1$).

# 5 Hypotheses

The null hypothesis is that there is no difference in contributions between the static or dynamic games, with or without a completion benefit. Our alternative hypothesis is that contributions will be higher in the dynamic game than in the comparable static game. Our two main explanations for this difference are 1: (Schelling) The dynamic game affords individuals more opportunities to give thereby enabling them to condition their giving on the giving of others. Consequently, the price of trust (the cost from free-riding) is reduced, and this may promote greater giving than in the comparable static game. This 'small-price-of-trust' hypothesis holds both with and without a completion benefit. 2: (Marx and Matthews) There are completion equilibria in the dynamic game with a completion benefit, but no such equilibria exist in the static game with or without a completion benefit. Consequently, contributions may, on average, be higher in the dynamic game with completion benefit than in the static game. A corollary of this 'completion-benefit' hypothesis is that absent a completion benefit there should be no difference in contributions between the dynamic and static game, and contributions should be the same as in the static game with a completion benefit. It follows that contributions in the dynamic game should be higher with than without a completion benefit.

# 6 Results

## 6.1 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 individual sessions as a single 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.[9]

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

[9] 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.

contributed 10 or more chips. Treating each session as an observation we can easily reject the hypothesis that groups are equally likely to reach the threshold in the dynamic and static games ($p = 0.028$)[10]

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 cummulative 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' hypothesis.

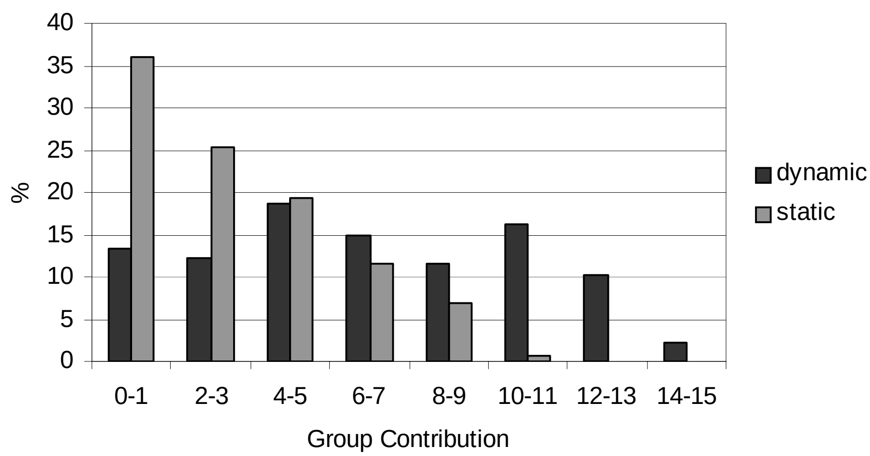


Figure 1: Distribution of Group Contributions, $b > 0$.

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

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

contribution game.[11]

The data above suggests 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. Thus we easily reject the hypothesis that average contributions are the same in the two treatments ($p = 0.028$). The difference is both statistically and economically significant. During the last five 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 participants over time would learn to take advantage of the socially efficient equilibria, we see instead that contributions decrease with experience.[12] 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 | 7.31 | 4.6 | 8.84 | 0.96 | 6.32 |
| Session 4 | 3.49 | 5.05 | 5.56 | 6.16 | 2.16 | 4.32 |
| Average | 3.02 | 6.52 | 4.44 | 8.43 | 1.83 | 5.01 |

Recall from our example in Section 3 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 seems a natural candidate to examine. And, indeed, there is evidence that some groups succeed in having a per round group contribution of 3 units.[13] A common condition by which

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

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

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

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 $i$).[14] 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 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 ($p \leq .057$ 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*

[14] 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.

*on past contributions of others and that overall contributions are larger in the dynamic game than in the static game.*

## 6.2 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 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 equally likely to reach the threshold in the dynamic and static games ($p = 0.028$). 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 lies well below that of the static game.

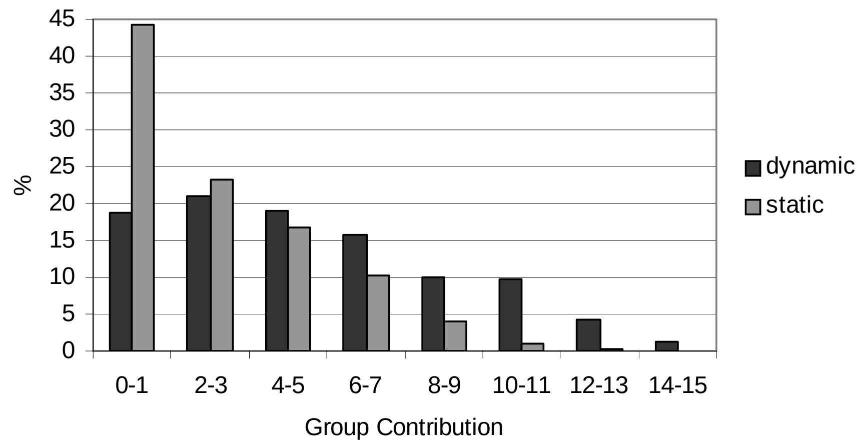


Figure 4: Distribution of Group Contributions, $b = 0$

Table 6 reports average group contributions for each session and treatment. Whether we look at all 15 games or the first 5 the result is the same: average contributions are larger in every session of the dynamic game. *Thus, consistent with Schelling we can easily reject the hypothesis that average contributions are the same in the two treatments (*$p = 0.028$*).* While the test statistic for the last five games enables us to reject the hypothesis that average contributions are larger in the static game, we cannot reject that average contributions are the same ($p = 0.114$). Similar to the completion benefit sessions we observe a decrease in contributions with experience, and that 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 |

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. By contrast, Marx and Matthews predict that in the absence of a completion benefit there should be no difference in these frequencies. Using data from all games of a session, Table 7 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, but counter to that of Marx and Matthews, 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 ($p \leq .057$ in all cases). Thus even when there is no completion benefit participants are more likely to contribute when others contributed in the previous round.

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 |

### 6.3 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 that these groups are equally likely to reach the threshold ($p=0.343$), nor that they are equally likely to come close to the threshold ($p=0.486$). Similarly we cannot reject the hypothesis that there is no difference in the average group contribution rates ($p=0.343$).

In the dynamic game, the completion benefit expands the set of equilibria to include full completion. 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 are equally likely to reach the threshold in the two dynamic treatments ($p=0.086$), we cannot reject the hypothesis that groups are equally likely to come close to the threshold (i.e., contribute 10 or more chips, $p=0.586$ ).[15] Nor can we reject the hypothesis that average contributions in the two dynamic treatments (with and without a benefit jump) are the same

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

($p = 0.114$). However, using a one-sided test, we can reject that the presence of the completion benefit causes a decrease in average group contributions in the dynamic game.[16] Although the magnitudes are not large there is some evidence that the completion benefit affects behavior.

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. 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 (0.38 vs. 0.30 when $5 < \sum_{t=1}^{3} G(t) < 12$, and 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).

Another way of addressing this question is to compare the contribution frequencies of Table 4 and 7. Specifically an additional test of the completion-benefit hypothesis is to see if the likelihood of giving when $G_{-i}(t-1) > 0$ is larger in the presence of a completion benefit. Looking at the contribution frequencies across rounds and in each individual round we cannot reject that the two frequencies are the same.[17] Thus, we cannot reject the null hypothesis that the completion benefit has no effect on the conditional contribution frequencies in the dynamic game.

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 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 is more supportive of Schelling's

[16] As our observations are not independent we can not utilize the individual observations in our data. However in game 1, where there has been no interaction between groups, we can use the group-level, end–of–game contribution amounts to test the same hypothesis. Comparing the 20-group contributions in the two dynamic treatments we cannot reject the null hypothesis that contributions are the same (using a t-test $p = 0.916$).

[17] Two sided p-values equal 0.686 for round 2, round 4, and all rounds, while $p = 0.114$ for round 3.

hypothesis. We therefore choose to investigate the 'small-price-of-trust' hypothesis in greater detail.[18]

### 6.4 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).

To test the effect of feedback we developed a fifth treatment, which 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.[19]

We compare contribution behavior in the dynamic $b = 0$ game with and without feedback. If the 'small-price of trust' hypothesis is true, 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.[20] 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 'intermediate' between those in the static and dynamic games with feedback. Table 8 reports average contributions from these four sessions. In contrast to the

[18] 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).

[19] 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 (in press, 2003).

[20] 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.

'small-price-of-trust hypothesis' we find no significant differences over the 15 games between contributions of the dynamic ($b = 0$) games with and without feedback ($p = 0.2$).

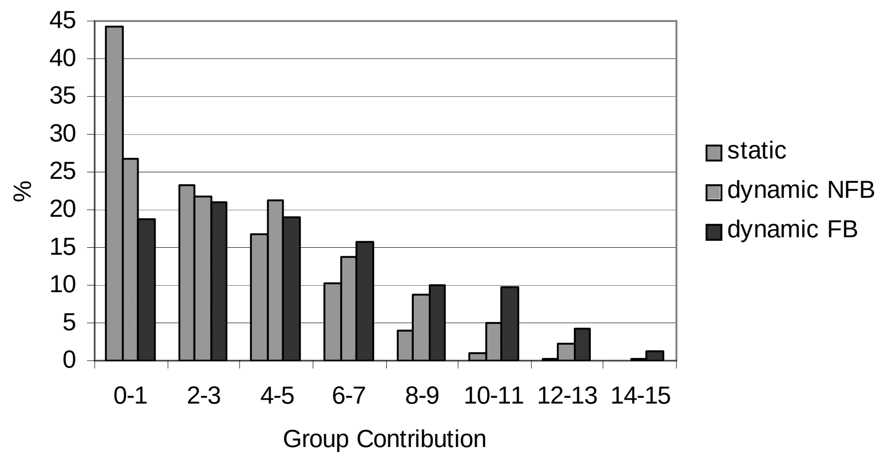


Figure 7: Frequency of Group Contributions, $b = 0$

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. Although the average individual contribution in the first round of any game is slightly larger in the presence of feedback this difference is not significant ($p = 0.2$).[21]

[21] Using group contribution levels during the first game we find that while average group contributions are different in the presence of feedback (using a t-test $p = 0.054$) in contrast to the theory round one group contributions in the first game do not depend on the presence of feedback (using a t-test $p = 0.264$).

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 $G_{-i}(t-1) = 0$. As a further check of the feedback effect we compare contribution frequencies with and without feedback. 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, $p = 0.486$; 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 6.3 showed that dynamic play does not play 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, we conclude that the 'small-price-of-trust' hypothesis does not appear to be driving the increase in contributions we observe when moving from a static to a dynamic voluntary contribution game.

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 |

### 6.5 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. Here we suggest two alternative possibilities.

The first, 'trembles hypothesis' is that contributions are greater in the dynamic than in the static game because when there are more opportunities to give there are more opportunities for trembles or mistakes. Of course, trembles may take many forms and may depend both on the game and stakes, however some trembles can cause contributions to be larger in the dynamic game. 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. Since there are 4 rounds per game in the dynamic treatment and only 1 round per game in the static treatment, there are 4 times as many opportunities to contribute in the dynamic setting, and perhaps, *due to trembles alone*, the number of chips in the group accounts will be higher in the dynamic than in the static setting.

A second, 'expectations hypothesis' is that players have belief-dependent motivations as in the theory of psychological games (Geanakopolos, Pearce and Stachetti (1989), Battigalli and Dufwenberg (2005)). Suppose a player's benefit from the game depends both on the monetary payoff and on her ability to fulfill the perceived expectations of others in her group. In particular, suppose players suffer subjective payoff losses if they fail to satisfy their beliefs regarding the expectations of other group members as to how much each should contribute to the public good, e.g., a player reasons that contributing too little might cause her to be resented by the other group members and she wants to minimize such resentment. If players want to fulfill such expectations, they may choose to contribute to the public good even in the absence of feedback, and with more opportunities to give in the dynamic game, they will give more in the aggregate than in the static game.[22]

Particularly supportive of the trembles hypothesis are the contributions that occur when $G_{-i} = 0$. Looking at the conditional frequencies reported in Tables 4, 7 and 9, it appears that, independent of the treatment, when $G_{-i} = 0$, an average of around 10–15% of subjects contribute something in every round, though in the feedback treatments (Tables 4 and 7) there is a slight decrease in this frequency over the course of a game. This decrease may suggest that trembles decline with feedback or perhaps that the expectations of others become more refined. Further study (and a very different experimental design) would be required to sort out which of these two hypotheses, if any, has the greater validity.

## 7 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. Yet most theoretical and empirical work on voluntary contribution games has ignored the implications of this dynamic game environment. 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

[22] Players might also fear frustrating the expectations of the experimenter by not contributing something in each period of the dynamic game. While our design makes it difficult to avoid experimenter "demand effects," the fact that very few groups achieved the completion equilibrium could be taken as evidence that we were not too demanding!

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.

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 may be what is driving the larger contributions in the dynamic games. However, the data are not consistent with the prediction that first round contribution levels in the dynamic $b = 0$ treatment without feedback are smaller than those observed in the dynamic $b = 0$ treatment with feedback. While overall contribution in the dynamic treatment without feedback does not differ from the dynamic treatment with feedback, they are significantly larger than the contribution frequencies in the static, $b = 0$ game. Thus, in contrast to the individual contribution frequencies, the average contribution data suggests 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 might 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 the larger aggregate contributions in the dynamic game with its multiple periods of giving as compared with the static game. We speculate that such behavior may be due to trembles or belief-dependent motivations on the part of players. As our experiment was not designed to consider these possibilities, we leave an exploration of these possibilities 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?

## References


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