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Daniele Nosenzo
and
Martin Sefton
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Karina Terry
Centre for Decision Research and Experimental Economics
School of Economics
University of Nottingham
University Park
Nottingham
NG7 2RD
Tel: +44 (0) 115 95 15620
Fax: +44 (0) 115 95 14159
karina.terry@nottingham.ac.uk

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ENDOGENOUS MOVE STRUCTURE AND VOLUNTARY PROVISION OF PUBLIC GOODS: THEORY AND EXPERIMENT

by

Daniele Nosenzo and Martin Sefton*

University of Nottingham

13 August 2010

Abstract

In this paper we examine voluntary contributions to a public good, embedding Varian (1994)'s voluntary contribution game in extended games that allow players to choose the timing of their contributions. We show that predicted outcomes are sensitive to the structure of the extended game, and also to the extent to which players care about payoff inequalities. We then report a laboratory experiment based on these extended games. We find that behavior is similar in the two extended games: subjects avoid the detrimental move order of Varian's model, where a person with a high value of the public good commits to a low contribution, and instead players tend to delay contributions. These results suggest that commitment opportunities may be less damaging to public good provision than previously thought.

Keywords: Public Goods, Voluntary Contributions, Sequential Contributions, Endogenous Timing, Action Commitment, Observable Delay, Experiment

JEL Classifications: H41, C72, C92

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* Corresponding author. School of Economics, University of Nottingham, University Park, Nottingham NG7 2RD, United Kingdom (e-mail: martin.sefton@nottingham.ac.uk).

1. Introduction

This paper studies, theoretically and experimentally, voluntary contributions to a public good when the timing of contributions is endogenously determined by contributors. We focus on a simple setting with two players, quasi-linear returns from private/public good consumption and complete information about returns from public/private good consumption (Varian, 1994). Varian (1994) has shown that commitment opportunities may aggravate the free-rider problem in this environment: under appropriate assumptions, players can enjoy a first-mover advantage by committing to free-ride, forcing second-movers to provide the public good on their own. When players with a high value of the public good move first, commit to free-ride and let players with lower valuations provide the public good, a detrimental outcome results: overall provision is lower than when players contribute simultaneously. Gächter et al. (2010) present experimental evidence consistent with the Varian model prediction: when the player with the higher valuation moves first contributions are significantly lower than with alternative move orders. However, they also note several departures from the model predictions. In particular, they find that first-movers who commit to free-ride trigger systematic punishment on the part of second-movers.[1] Also, while overall provision of the public good is lower when the high value player moves first, the high value player typically fails to attain her predicted first-mover advantage. Because there is no advantage in committing to be a free-rider, it is unclear whether individuals will actually *choose* to commit if they are given the opportunity to do so, and thus whether the detrimental move ordering will emerge in practice.

Our paper studies endogenous timing following the approach of Hamilton and Slutsky (1990).[2] We embed Varian's (1994) voluntary contributions game into their 'extended game with observable delay' and 'extended game with action commitment'; these differ in how commitment opportunities are modeled. In Section 2 we describe these games in detail and analyze their theoretical properties, both under standard assumptions, i.e. where players maximize own material payoffs, and assuming inequality averse preferences (Fehr and Schmidt,

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[1] Andreoni, Brown and Vesterlund (2002) also examine Varian's model and find similar departures from model predictions. For the parameters they study, however, aggregate contributions are predicted to be quite similar across move orderings, and in fact are quite similar in the experiment.

[2] Other important theoretical contributions to the literature on endogenous timing games include Saloner (1987), Robson (1990), Mailath (1993), Ellingsen (1995), van Damme and Hurkens (1999), Matsumura (1999), Normann (2002), van Damme and Hurkens (2004) and Santos-Pinto (2008).

1999). We show that sequential move orderings that result in reduced public good provision cannot arise in the extended game with observable delay under either set of assumptions. In the extended game with action commitment a detrimental move ordering emerges under the standard assumption, and can also emerge if players are inequality averse. Moreover, inequality aversion introduces a rich set of theoretical outcomes in both games, depending on the precise preference parameters. For example, inequality aversion also introduces the possibility that both players delay their contribution in both extended games.

In Section 3 we describe a laboratory experiment that implements these extended games. For both extended games we find that subjects show a strong tendency to avoid making a commitment to early contributions. Importantly, less than 20% of the extended games result in the detrimental move ordering, and even in the extended game with action commitment where the detrimental move ordering is predicted to emerge according to standard theory, this move order is observed less than 20% of the time. This tendency to delay decisions until the last period may be consistent with inequality aversion. In fact, other patterns in the data are also consistent with concerns for earnings equality. For example, as in Andreoni, Brown, and Vesterlund (2002) and Gächter et al. (2010), we find that second-movers are willing to punish first-movers who make low contributions and this results in a more even distribution of contributions than predicted by standard theory, and reduces the benefits of commitment. However, we find that inequality aversion can only partially explain the tendency to delay. In Section 4 we conclude.

2. Theory

We begin by summarizing Varian's (1994) model. Player i, $i \in$ {HIGH, LOW}, is endowed with wealth e_i and contributes an amount $0 \leq g_i \leq e_i$ to a public good. The remainder is allocated to private good consumption. The total amount of the public good provided is $G = g_{HIGH} + g_{LOW}$. Player i's payoff is given by:

$$\pi_i = e_i - g_i + f_i(G)$$

where individual i's return from the public good, $f_i(G)$, is increasing and strictly concave. Each player has an interior 'stand-alone contribution' $0 < \hat{g}_i < e_i$ where $\hat{g}_{HIGH} > \hat{g}_{LOW}$.[3] We focus on the case where these stand-alone contributions are not too different, $f_{HIGH}(\hat{g}_{HIGH}) -$

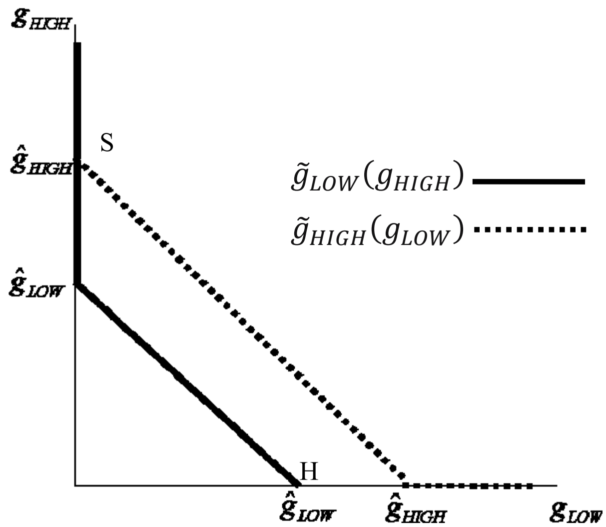
[3] Player i's stand-alone contribution is the contribution that maximizes her payoff when j contributes zero. In Varian's terminology, HIGH is the 'player who likes the public good most'

$f_{HIGH}(\hat{g}_{LOW}) < \hat{g}_{HIGH}$, as this is the case where equilibrium contributions depend on the move ordering.

2.1 Equilibrium under exogenous move orderings

The players' best-response functions are given by $\tilde{g}_i(g_j) = \max\{\hat{g}_i - g_j, 0\}$and are displayed in Figure 1.

Figure 1. Best-response functions



The unique Nash equilibrium of the simultaneous move game is at point S, where LOW contributes zero and HIGH makes her stand-alone contribution. We denote the resulting equilibrium payoffs as π^S_{LOW} and π^S_{HIGH}. In a sequential move game where LOW moves first HIGH's subgame perfect equilibrium strategy is given by her best-response function $\tilde{g}_{HIGH}(g_{LOW})$, shown as a dotted line in the Figure. LOW's subgame perfect equilibrium strategy is her most preferred point on this best response function, which is at S where she contributes nothing. Thus the subgame perfect equilibrium outcome of the sequential game is also at point S. In a sequential game where HIGH moves first LOW's subgame perfect equilibrium strategy is given by $\tilde{g}_{LOW}(g_{HIGH})$. The assumption that stand-alone contributions are not too different implies that HIGH's most preferred point on LOW's best response function is at H, where she contributes nothing and LOW contributes $\hat{g}_{LOW}$. Hence the subgame perfect equilibrium outcome is at point H with resulting payoffs π^H_{LOW} and π^H_{HIGH}. Note that $\pi^H_{HIGH} > \pi^S_{HIGH}$ (since HIGH prefers point H to S) and $\pi^H_{LOW} < \pi^S_{LOW}$ (since LOW consumes less of the private good *and* less of the public good at H, compared to S). Also, public good provision (and the sum of payoffs) is lower at H than S; hence we refer to the sequential game where HIGH moves first as the detrimental move ordering.[4] In summary, relative to other move orderings, the sequential game where HIGH moves first features a higher payoff for HIGH, a lower payoff for LOW, lower public good provision, and lower combined payoffs.

2.2 Endogenous moves

We analyze endogenous timing following the approach of Hamilton and Slutsky (1990). We embed Varian's voluntary contributions game within extended games in which players can choose the timing of their contributions, and examine the equilibria of these extended games.

2.2.1 The extended game with observable delay

In the extended game with observable delay each person makes one contribution decision but there are two contribution periods. At the beginning of the game players simultaneously announce in which period they will make their contribution decisions and are committed to their choice of contribution period. Players then observe the profile of announcements and make their contribution decisions according to the resulting move ordering. Thus, if the players announce the same period then they play the simultaneous contribution game described in the previous sub-section, while if one announces the first period and the other the second period they play the relevant sequential contribution game. Note that a player is unable to unilaterally choose a move ordering. By committing to contributing in the first period a player ensures that she does not move second, but cannot rule out the possibility that players move sequentially. Likewise, by committing to contributing in the second period a player ensures that she does not move first in a sequential game, but it is still possible that she ends up making simultaneous contributions. Note also that when a player commits to a contribution period she does not commit to how much she contributes.

A pure strategy for player *i* specifies a choice of a contribution period $t_i \in \{1,2\}$, a contribution decision if $t_i = t_j = 1$, a contribution decision if $t_i = t_j = 2$, a contribution decision if $t_i = 1$ and $t_j = 2$, and a contribution function mapping the set of possible

[4] The sum of payoffs can be written $\pi_{LOW} + \pi_{HIGH} = e_{LOW} + e_{HIGH} - \mathrm{G} + f_{LOW}(G) + f_{HIGH}(G)$, which is concave in *G*. The sum of payoffs is maximized at G^* where $f'_{LOW}(G^*) + f'_{HIGH}(G^*) = 1$. When total provision is less than G^* the sum of marginal returns from the public good exceed unity and combined payoffs increase with *G*. At point S total provision is equal to $\hat{g}_{HIGH}$, and the sum of marginal returns is $f'_{LOW}(\hat{g}_{HIGH}) + f'_{HIGH}(\hat{g}_{HIGH}) = f'_{LOW}(\hat{g}_{HIGH}) + 1 > 1$. Thus, at S total contributions are lower than G^* and combined payoffs increase with *G*.

contribution decisions of player j, [0, e_j], onto the set of possible contribution decisions of player i, [0, e_i], if $t_i = 2$ and $t_j = 1$.

The subgames following the announcement stage are proper subgames with unique subgame perfect equilibria, as discussed in the previous sub-section. We analyze the reduced game that results when these subgames are replaced by their subgame perfect equilibrium values. The payoff matrix for the reduced game is shown below:

HIGH	LOW	
	$t_{LOW} = 1$	$t_{LOW} = 2$
$t_{HIGH} = 1$	$\pi^S_{HIGH}, \pi^S_{LOW}$	$\pi^H_{HIGH}, \pi^H_{LOW}$
$t_{HIGH} = 2$	$\pi^S_{HIGH}, \pi^S_{LOW}$	$\pi^S_{HIGH}, \pi^S_{LOW}$

Recalling that $\pi^H_{HIGH} > \pi^S_{HIGH}$ and $\pi^H_{LOW} < \pi^S_{LOW}$, the reduced game has multiple equilibria. In all of them LOW chooses $t_{LOW} = 1$, while HIGH chooses $t_{HIGH} = 1$ with any probability p $\in$ [0, 1]. Thus in a subgame perfect equilibrium of the extended game the detrimental move ordering cannot arise.

As an equilibrium refinement Hamilton and Slutsky (1990) select equilibria that do not involve the use of a weakly dominated strategy in the reduced game. This refinement gives a sharp prediction in our game. For HIGH, announcing period 1 weakly dominates any strategy placing positive probability on announcing period 2. This refinement thus selects the equilibrium in which both players announce to contribute in period 1.

2.2.2 The extended game with action commitment

In the extended game with action commitment players can contribute in exactly one of two periods (period 1 or 2). In period 1 each player simultaneously chooses either a contribution or to wait (*W*). If player *i* chooses to wait in period 1, she must then make a contribution decision $g_i \in [0, e_i]$ in period 2, after being informed of player *j*'s action (either g_j or *W*) in period 1. If neither player waits no decisions are made in the second period and the game ends. If both wait then the players play the simultaneous contribution game in the second period. If one contributes in the first period and the other waits the player that waits observes the other player's contribution before making a contribution decision in the second period. As in the game with observable delay, the actual move ordering depends on the profile of decisions. However, unlike in the game with observable delay, when a player makes an early contribution decision she does not know whether the other player is also making an early decision or is waiting.

A pure strategy for player *i*, specifies a choice in the first period, either $g_i \in [0, e_i]$ or W, a contribution in the second period if both players wait in period 1, and a contribution function mapping player *j*'s possible contribution decisions, [0, e_j], onto her own possible contribution decisions, [0, e_i], if *i* chose to wait in period 1 and *j* chose to contribute in period 1.

Again, this game has proper subgames with unique subgame perfect equilibria at the beginning of period 2 and we analyze the reduced game that results when these subgames are replaced by their subgame perfect equilibrium values. Formally, in the reduced game player *i* chooses a strategy $s_i \in$ [0, e_i] ∪ {W}. Player's *i* payoff function is given by:

$$\pi_i(s_i, s_j) = \begin{cases} \pi_i(g_i, g_j) & if\ s_i = g_i \in [0, e_i]\ and\ s_j = g_j \in [0, e_j] \\ \pi_i\left(g_i, \tilde{g}_j(g_i)\right) & if\ s_i = g_i \in [0, e_i]\ and\ s_j = W \\ \pi_i(\tilde{g}_i(g_j), g_j) & if\ s_i = W\ and\ s_j = g_j \in [0, e_j] \\ \pi_i^S & if\ s_i = s_j = W \end{cases}$$

where $\tilde{g}_i(g_j)$ denotes player *i*'s best-response function.

In the reduced game there are three pure strategy equilibria. First, $s_{LOW} = 0$ and $s_{HIGH} = \hat{g}_{HIGH}$ is an equilibrium, corresponding to the simultaneous move equilibrium. Second, $s_{LOW} = 0$ and $s_{HIGH} = W$ is an equilibrium, corresponding to the sequential move equilibrium where LOW moves first. Third, and finally, there is an equilibrium in which $s_{HIGH} = 0$ and $s_{LOW} = W$, corresponding to the equilibrium with the detrimental move ordering.[5] Thus the extended game has three pure strategy subgame perfect equilibria, reproducing the outcomes of the three exogenous move ordering games.[6] Note that the detrimental move ordering may arise in a subgame perfect equilibrium of the extended game with action commitment.

Again, if we restrict attention to equilibria that do not involve the use of a weakly dominated strategy in the reduced game we obtain a sharper prediction. The first two equilibria

[5] Note that it is not an equilibrium for both players to wait. This results in a payoff to HIGH of π_{HIGH}^S and a profitable deviation for HIGH is to choose $s_{HIGH} = 0$ which yields $\pi_{HIGH}^H > \pi_{HIGH}^S$.

[6] This point was previously noted by Romano and Yildirim (2001).

above are eliminated since for LOW any strategy $s_{LOW} = g_{LOW} \in [0, e_{LOW}]$ is weakly dominated by $s_{LOW} = W$.[7] The third equilibrium has LOW play her weakly dominant strategy, $s_{LOW} = W$, while HIGH chooses $s_{HIGH} = g_{HIGH} = 0$. HIGH's strategy is not weakly dominated: it is a strict best response to $s_{LOW} = W$. Thus the third equilibrium survives the refinement.

In summary, theoretical analysis suggests that different forms of commitment opportunity will lead to different endogenous move orderings. Subgame perfection predicts that the detrimental move ordering will not emerge from the extended game with observable delay, while it can emerge from the extended game with action commitment. Restricting attention to equilibria in undominated strategies yields sharper predictions. The extended game with observable delay results in a simultaneous move game in the first period, with LOW contributing zero and HIGH making her stand-alone contribution. The extended game with action commitment results in the detrimental mover ordering: HIGH commits to contributing zero while LOW waits, and in the second period LOW makes her stand-alone contribution.

2.3 Inequality averse players

The preceding analysis is based on the assumption that players maximize own-payoffs. However, Andreoni, Brown, and Vesterlund (2002) and Gächter et al. (2010) find that subjects are willing to deviate from own-payoff maximizing responses in order to punish low contributors, and earnings are more equitable than predicted. These, and numerous other findings from laboratory experiments, are consistent with models in which players are concerned about payoff inequalities as well as own payoff. In this sub-section we examine how inequality aversion affects these theoretical results.

We restrict ourselves to an analysis of Fehr and Schmidt's (1999) specification of inequality aversion, where agent i's utility is given by

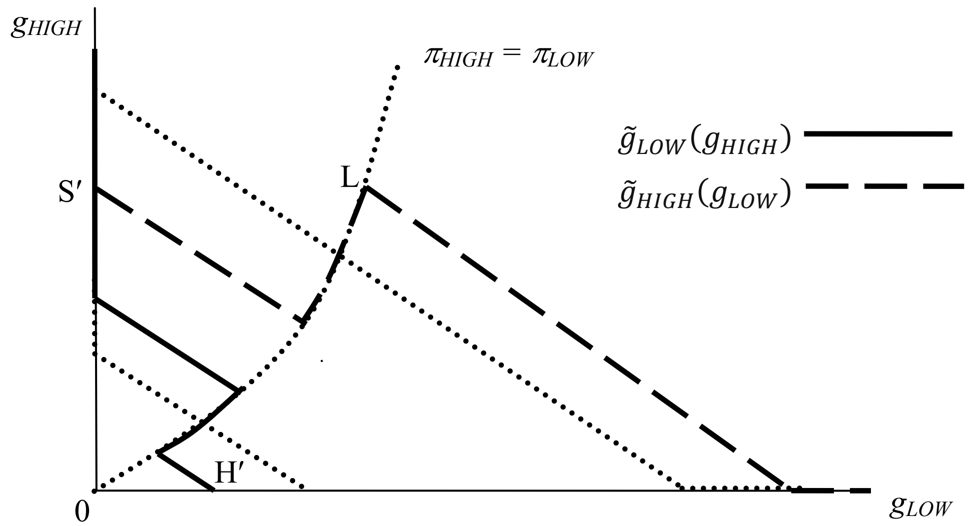
$$U_i = \pi_i - \alpha * max\{\pi_j - \pi_i, 0\} - \beta * max\{\pi_i - \pi_j, 0\}$$

[7] To see this, first note that if HIGH waits LOW can attain π_{LOW}^{S} by also waiting, or by immediately contributing nothing; any other strategy results in a lower payoff. Next, if HIGH commits to contributing nothing LOW can attain π_{LOW}^{H} by waiting (and then contributing $\hat{g}_{LOW}$ in period 2), or by contributing $\hat{g}_{LOW}$ immediately; any other strategy yields a lower payoff. Finally, if HIGH commits to any other contribution in period 1 LOW maximizes her payoff by waiting (and then best responding in period 2), or by best responding immediately; any other strategy results in a lower payoff.

with $\alpha \geq \beta$ and $1 > \beta \geq 0$. We assume both agents have the same inequality aversion parameters, and this is common knowledge. We also restrict attention to the case where $f_{HIGH} = k\, f_{LOW}$ with $1 < k < 1 + 1/f'_{\text{LOW}}(0)$.[8]

In Figure 2 the best responses for the case $\alpha = \beta = 0$ are shown as downward sloping dotted lines, and the locus of points where payoffs are equalized is shown as an upward sloping dotted line.[9] Inequality aversion alters the best response functions as shown in the Figure: players contribute less than their selfish best response when they are behind and more than their selfish best response when they are ahead.[10] For mild degrees of inequality aversion the best response functions intersect at a single point S′ where LOW contributes nothing and HIGH supplies the public good on her own, as shown in Figure 2.[11] The equilibrium outcome of the simultaneous move game is at S′.

Figure 2. Mildly Inequality Averse Best Response Functions



[8] This is the case for the function used as the basis for subjects' earnings in the experiment. We describe the experimental earnings functions in Section 3.
[9] The restriction that $k < 1 + 1/f'_{\text{LOW}}(0)$ ensures that the equal-earnings locus is upward sloping.
[10] Figure 2 shows the best responses of players with $\alpha \geq \beta > 0$. When $\alpha = 0$ or $\beta = 0$ the corresponding part of a player's best response coincides with his or her material best response.
[11] By "mild inequality aversion" we thus mean a degree of inequality aversion whereby players' best responses are perturbed but still intersect at a single point. When behind, HIGH's best response brings total contributions up to G_1, where $f'_{HIGH}(G_1) = (1+\alpha)/(1+\alpha-\alpha/k)$. When ahead LOW's best response brings total contributions up to G_2, where $f'_{LOW}(G_2) = (1-\beta)/(1-\beta+\beta k)$, or $f'_{\text{HIGH}}(G_2) = k(1-\beta)/(1-\beta+\beta k)$. For the best response functions to intersect at a single point we must have $G_1 > G_2$, or $f'_{HIGH}(G_1) < f'_{HIGH}(G_2)$. Thus, for "mild inequality aversion" the parameters must satisfy the condition $(1+\alpha)/(1+\alpha-\alpha/k) < (1-\beta)/(1-\beta+\beta k)$.

If the inequality aversion parameters are sufficiently close to $\alpha = \beta = 0$ then LOW's most preferred point on HIGH's best response function is also at S′, while HIGH's most preferred point on LOW's best response function is at H′. In this case the implications for timing are the same as in the previous sub-section. Each extended game has a unique equilibrium in undominated strategies: in the OD game both players make contribution decisions in period 1, resulting in the outcome S′, while in the AC game LOW waits and HIGH commits to contributing nothing, resulting in outcome H′.

However, depending on parameter values there is a rich set of potential outcomes. First, HIGH's utility from committing to contributing nothing decreases as α increases (because LOW's best response to zero decreases as α increases) and in fact HIGH's incentive to commit may disappear entirely. For example, if $\alpha = 1/8$ and $\beta = 0$, then for our experimental earnings functions the equilibrium outcome is at S′ for any move ordering. In this case any timing decisions constitute an equilibrium of the OD game. In the AC game, the only equilibrium in undominated strategies has both players wait and then coordinate on S′ in period 2. Thus inequality aversion introduces the theoretical possibility that both players delay contributions.

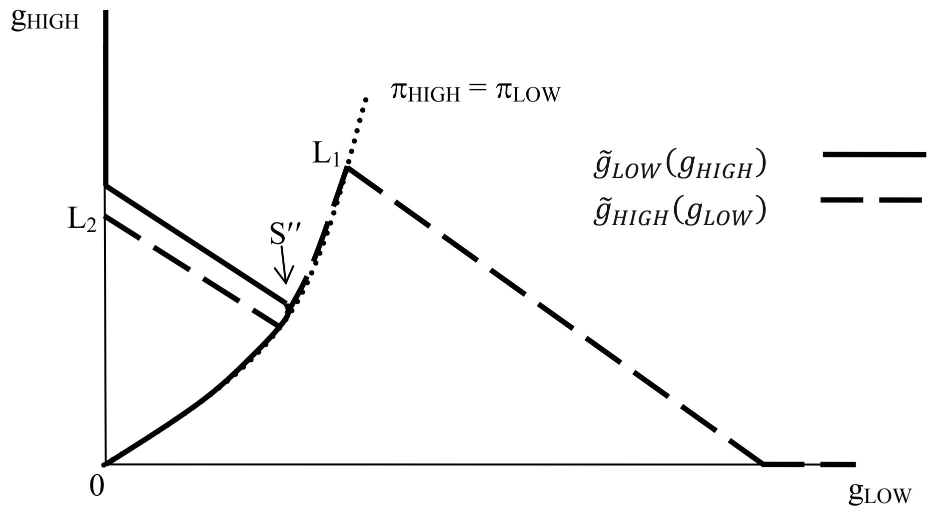
Next consider the point L, at the top of the upward sloping part of HIGH's best response function. It can be shown that HIGH prefers L to S′ for any parameter values. There are also parameter values where LOW prefers L to S′ (for example, for our experimental earnings function this is the case if $\alpha = 2/3$ and $\beta = 0$). In this case the subgame perfect equilibrium outcome of the game where LOW moves first is at L. In the AC game there is an equilibrium in undominated strategies where HIGH waits and LOW commits, resulting in point L, and similarly the sequential game in which LOW moves first, resulting in point L, emerges as an equilibrium in undominated strategies of the OD game. Thus, inequality aversion introduces the possibility that *beneficial* sequential move orderings emerge.

The situation for moderate degrees of inequality aversion is shown in Figure 3.[12] The simultaneous move game has multiple equilibria and in order to analyze the extended game we

[12] By "moderate inequality aversion" we simply mean that the best responses overlap, for which the formal condition is $(1+\alpha)/(1+\alpha-\alpha/k) > (1-\beta)/(1-\beta+\beta k)$, but that the highest point on the upward sloping part of LOW's best response is below the highest point on the upward sloping part of HIGH's best response, which requires $\beta < 1/2$. For our experimental earnings functions moderate inequality aversion implies that LOW's best response to zero is zero as shown in the Figure.

assume that players coordinate on the Pareto-dominant equilibrium, denoted S″. This is also HIGH's most preferred point on LOW's best response function, and thus the subgame perfect equilibrium outcome of the game when HIGH moves first. There are two possibilities for the subgame perfect equilibrium outcome of the game where LOW moves first, denoted by the points L_1 and L_2.

Figure 3. Moderately Inequality Averse Best Response Functions

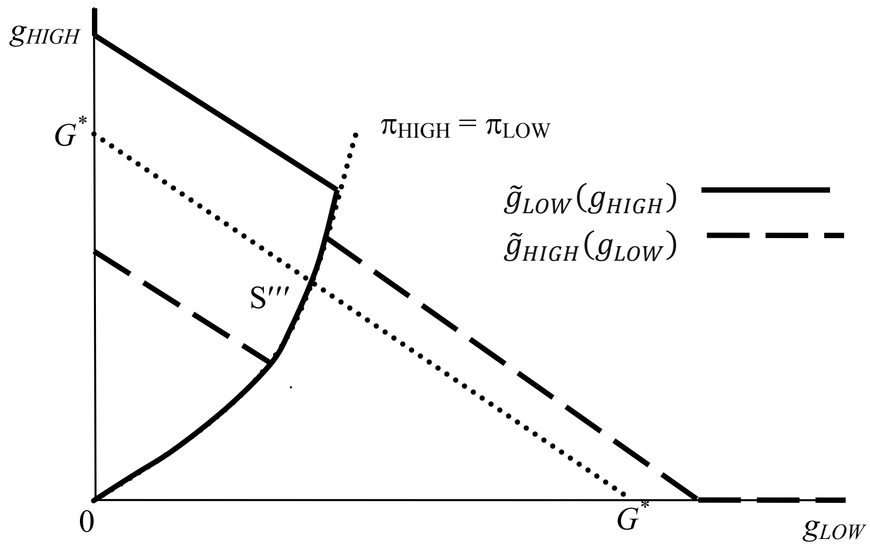


Suppose the subgame perfect equilibrium of the game where LOW moves first is at L_1 (for example, this is the equilibrium for our experimental earnings functions when $\alpha = 1$ and $\beta = 0$). In this case the unique equilibrium in undominated strategies of the OD game is for LOW to announce period 1 and HIGH to announce period 2, resulting in L_1. Similarly the unique equilibrium of the AC game is for HIGH to wait and LOW to choose L_1. Again, inequality aversion results in a beneficial sequential move game.

The second possibility is that the subgame perfect equilibrium of the game where LOW moves first is at L_2 (for example, this is the equilibrium for our experimental earnings functions when $\alpha = \beta = 0.2$). Then the unique equilibrium in undominated strategies of the OD game is for both players to announce period 1, resulting in S″. On the other hand, in the unique equilibrium in undominated strategies of the AC game HIGH waits and LOW commits to L_2. Thus the AC game results in a detrimental move ordering in which *LOW* commits.

Finally, if players are 'strongly inequality averse' their best response functions are as shown in Figure 4 so that the upward sloping portion of LOW's best response function encompasses the upward sloping portion of HIGH's best response function.[13]

Figure 4. Strongly Inequality Averse Best Response Functions



In this case, when ahead, each player best responds by bringing total contributions up to a level beyond G^* as shown in the Figure.[14] The equilibrium outcome of all move orderings (assuming that the simultaneous move game results in the Pareto-dominant equilibrium) is the same, at S‴. This results in equal earnings and the efficient level of public good provision. Any move ordering can result from the equilibrium of the extended OD game, while the unique equilibrium in undominated strategies for the AC game has both players to wait and then coordinate on S‴ in period 2.

Naturally, these results rely on the simplifying assumptions that the players have the same inequality aversion parameters, and that these are common knowledge. Yet the analysis of this simple case suffices to show that inequality aversion expands considerably the set of timing outcomes consistent with equilibrium. Interestingly, a general point that emerges is that

[13] Strong inequality aversion requires requires $\beta > 1/2$.

[14] As already noted in footnote 11, when ahead LOW's best response brings total contributions up to G_2 where $f'_{\text{HIGH}}(G_2) = k(1-\beta)/(1-\beta+\beta k)$. Note also that when ahead HIGH's best response brings total contributions up to G_3 where $f'_{\text{HIGH}}(G_3) = (1-\beta)/(1-\beta+\beta k)$. Finally note that from the assumption that $f_{\text{HIGH}} = kf_{\text{LOW}}$ and the definition of G^* it follows that $f'_{\text{HIGH}}(G^*) = k/(k+1)$. Using these expressions it can be shown that $\beta < 1/2$ implies $G_2 < G_3 < G^*$ and $\beta > 1/2$ implies $G_2 > G_3 > G^*$.

detrimental sequential move orderings can be consistent with equilibrium in the AC game, but not the OD game.

3. Experiment

3.1 The basic game

Our experiment is based on the discrete version of Varian's game used in Gächter et al. (2010). There are two players, 'HIGH' and 'LOW'. [15] Each player is endowed with 17 tokens and decides how many to place in a Shared Account and how many to retain in a Private Account. We denote the number of tokens player *i* places in the Shared Account by $g_i \in \{0, \ldots, 17\}$. A player's earnings from the game are the sum of her earnings from her Private Account and the Shared Account, where a player receives 50 points for each token in her Private Account and an additional amount of points for any token placed in the Shared Account. Thus placing a token in the Shared Account is akin to contributing to a public good. The earnings were derived from a quadratic payoff function:

$$\pi_i = 50 \cdot (17 - g_i) + v_i \cdot \left[68 \cdot (g_i + g_j) - (g_i + g_j)^2\right]$$

where $v_{HIGH} = 1.32$ and $v_{LOW} = 0.89$. Earnings were presented to subjects in the form of earnings tables (see Appendix B) which rounded earnings to a multiple of 5 points.

Predictions about total contributions and the distribution of contributions depend on the move order. In particular, under the assumption that players maximize own earnings, if HIGH and LOW make simultaneous contributions to the public good, or if LOW moves first, the equilibrium involves HIGH contributing 15 tokens and LOW contributing 0 tokens. However, if HIGH moves first, HIGH is predicted to contribute 0 tokens and LOW to contribute 6 tokens. Thus, under standard assumptions, when HIGH moves first a detrimental outcome results.

3.2 The experimental treatments

We study endogenous timing in this game using two different experimental treatments. In both treatments subjects know that they can make contributions in one out of two periods: they can either choose to commit to an early contribution, by contributing in period 1, or they can choose to contribute late in period 2.

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[15] During the experiment we used the labels 'RED' and 'BLUE' rather than 'HIGH' and 'LOW' when referring to the two types of player. See the experimental instructions, reproduced in Appendix A, for further details.

Our OD treatment uses Hamilton and Slutsky's (1990) extended game with observable delay. Prior to making contribution decisions, subjects simultaneously decide whether to contribute in period 1 or in period 2. After both subjects have committed to a contribution period, a computer screen announces the resulting move ordering, and subjects then make their contributions accordingly. In our AC treatment we use Hamilton and Slutsky's extended game with action commitment. In period 1 subjects can either choose to make a contribution decision immediately by typing in a number of tokens to place in the Shared Account, or they can choose to wait until period 2. In period 2 each subject is informed of any decisions made in period 1 and then, if the subject chose to wait in period 1, he or she must also make a contribution decision.

Note that in both treatments four possible move orderings can occur: if both subjects make a contribution decision in the same period, then a simultaneous move ordering emerges, either in period 1 (SIM-1), or in period 2 (SIM-2). If subjects make contribution decisions in different periods, then a sequential move ordering emerges where either LOW moves first (LOW-FIRST), or HIGH moves first (HIGH-FIRST). Under the standard assumption that subjects maximize own earnings the equilibria in undominated strategies of the extended games result in SIM-1 (OD treatment) or HIGH-FIRST (AC treatment). However, as we have seen in the previous section, these results are sensitive to concerns for inequality.

3.3 Experimental procedures

The experiment was conducted at the University of Nottingham using subjects recruited from a university-wide pool of students who had previously indicated their willingness to be paid volunteers in decision-making experiments.[16] Four sessions (two sessions for each treatment) were initially conducted in spring 2009 using 16 participants per session. The experiment was repeated in spring 2010 (again two sessions per treatment with 16 participants per session). Overall, the average age of participants in the eight sessions was 20.6 years and 48% were male. No subject took part in more than one session and so 128 subjects participated in total.

All sessions used an identical protocol. Upon arrival, subjects were welcomed and randomly seated at visually separated computer terminals. Subjects were then given a written set of instructions that the experimenter read aloud. The instructions included a set of control

[16] Subjects were recruited through the online recruitment system ORSEE (Greiner, 2004). The experiment was programmed and conducted with the software z-Tree (Fischbacher, 2007).

questions about how choices translated into earnings. Subjects had to answer all the questions correctly before the experiment could continue.

The decision-making phase of the session consisted of 15 rounds of one of the extended games described above, where in each round subjects were randomly matched with another participant. Neither during nor after the experiment were subjects informed about the identity of the other people in the room they were matched with. The matching procedure worked as follows. At the beginning of each session the participants were randomly allocated to one of two eight-person matching groups. The computer then randomly allocated the role of HIGH to four subjects and the role of LOW to the other four subjects in each matching group. Subjects were informed of their role at the beginning of the first round and kept this role throughout the 15 rounds. At the beginning of each round the computer randomly formed pairs consisting of one HIGH and one LOW participant within each matching group. To ensure comparability among sessions and treatments, we randomly formed pairings within each matching group prior to the first session and used the same pairings for all sessions.[17] Because no information passed across the two matching groups, we treat data from each matching group as independent. Thus our design generates two independent observations for each session, or four independent observations per treatment. Repetition of the task was used because we expected that subjects might learn from experience. However, our desire to examine a one-shot game led us to use the random re-matching design in order to reduce repeated game effects.

Subjects were paid based on their choices in one randomly-determined round. At the end of round fifteen a poker chip was drawn from a bag containing chips numbered from 1 to 15. The number on the chip determined the round that was used for determining all participants' cash earnings. At the end of the experiment subjects were asked to complete a short questionnaire asking for basic demographic and attitudinal information, including a self-assessment of their own risk attitudes.[18] Subjects were then privately paid according to their point earnings in the round which had been randomly selected at the end of round fifteen. Point earnings were

[17] Subjects were informed that they would be randomly matched with another person in the room in each round (see Appendix A), although the details of the matching procedure were not specified.

[18] Subjects' assessment of their own risk preferences was elicited asking the question suggested by Dohmen et al. (*forthcoming*). The question reads: "Are you generally a person who is fully prepared to take risks or do you try to avoid taking risks? Please tick a box on the scale, where the value 1 means: 'unwilling to take risks' and the value 10 means: 'fully prepared to take risk' ". The average response was 6.05 with a standard deviation of 1.89.

converted into British Pounds at a rate of £0.01 per point. Subject earnings ranged from £8.50 to £18.10, averaging £12.85, and sessions lasted about 74 minutes on average.

3.4 Results

In the following analysis of data we pool the experimental data collected in spring 2009 and spring 2010: before pooling the data we checked for differences in timing and contribution behavior across the two blocks of sessions and found none.

3.4.1 Timing behavior in the AC and OD treatments

Table 1 reports the proportions of period 1 choices in the AC and OD treatments. These proportions are based on 1920 timing decisions, evenly divided among treatment and type of player. The relative frequency of period 1 contributions is higher in AC (29%) than in OD (22%), but the difference is statistically insignificant (p = 0.237).[19] This result holds for both HIGH and LOW subjects: the relative frequency of period 1 contributions is somewhat higher in AC than in OD for both types. The treatment effect is marginally significant for LOW (p = 0.088), but not significant for HIGH (p = 0.677).

Table 1. Proportions of Period 1 Contributions

	AC			OD		
	round			Round		
	1 to 8	9 to 15	Overall	1 to 8	9 to 15	Overall
HIGH	.33	.20	.27	.33	.14	.24
LOW	.32	.31	.31	.22	.16	.19
overall	.32	.25	.29	.27	.15	.22

Overall in both treatments of our experiment the majority of subjects prefer to wait until period 2 to make a contribution decision. Moreover, there is no trend towards more frequent period 1 choices in later rounds: in both treatments and for both HIGH and LOW the proportions of period 1 choices *decrease* from the first to the second half of the experiment. [20]

[19] Unless otherwise noted p-values are based on two-sided randomization tests, taking as the unit of observation the independent matching group, and computed using the STATA command tsrtest. Moir (1998) describes the randomization test and discusses its advantages.
[20] This contrasts with Poulsen and Roos (2010) who find an increasing tendency to commit, as predicted by standard theory, in a bargaining game with endogenous timing and observable delay.

Regression analysis of timing decisions confirms that the treatment and type of player have little explanatory power for the observed frequency of period 1 contributions. Table 2 reports the coefficients and marginal effects from a probit model where the explanatory variables are a treatment dummy (AC = 1, OD = 0), a dummy for type of player (LOW = 1, HIGH = 0), an interaction term between the treatment dummy and the type of player dummy, and controls for time effects and individual characteristics.[21]

Table 2. Regression Analysis of the Probability of Contributing in Period 1

	Coefficient	marginal effect
Treatment (1 if AC)	.066 *(.235)*	.021
Type (1 if LOW)	-.164 *(.101)*	-.051
Treatment * Type	.343* *(.203)*	.104
Gender (1 if Female)	-.423*** *(.114)*	-.132
Willingness to Take Risks	.052*** *(.018)*	.016
Round	-.045*** *(.010)*	-.014
Constant	-.468** *(.191)*	-
N.	*1920*	
Prob >χ^2	*.000*	
Pseudo-R^2	*.052*	

Probit regression. Dependent variable equals 1 if subject made a contribution in period 1 and 0 otherwise. Robust standard errors in parenthesis adjusted for intragroup correlation (matching-groups are used as independent clustering units). * $.05 \le p \le .10$; ** $.01 \le p < .05$; *** $p < .01$.

Holding all other variables constant, the probability of HIGH contributing in period 1 is higher in the AC treatment than in the OD treatment, but the effect is statistically insignificant. For LOW subjects the effect is instead significant at the 10% level (Wald test: $\chi^2(1) = 2.90, p = 0.089$). These findings are consistent with the non-parametric results reported earlier. LOW subjects seem to be somewhat less likely to contribute in period 1 in the OD treatment than HIGH subjects, but the effect is statistically insignificant, and is reversed for the AC treatment. The regression also confirms that the likelihood of committing to a contribution level in period 1 decreases over time: the coefficient of the variable Round is negative and highly significant.

[21] The marginal effects are calculated holding all variables at their means. The marginal effects for the dummy variables are for discrete changes of the variable from 0 to 1. The marginal effect for the interaction term has been computed using the Stata command inteff (see Norton et al., 2004. Also see Ai and Norton, 2003).

Subjects' timing behavior is better explained by their personal characteristics: for example, female participants are significantly less likely (about 13%) to make a contribution decision in period 1 than male subjects. This result is consistent with the findings by Arbak and Villeval (2007), who find that female participants are significantly less likely to make a leadership contribution than male participants in a related experiment on endogenous leadership in a linear voluntary contributions game. As committing to a contribution in period 1 may be seen as a risky decision (e.g. because there is a chance that period 2-movers deviate from their best-response contribution to punish low period 1 contributions), we may expect that higher sensitivity to risks may also induce subjects to delay their contribution decision until period 2. Indeed, we find that subjects who self-report a lower willingness to take risks are significantly less likely to contribute in period 1.

Next we examine the frequency with which different move orderings emerge. Since observed move orderings in our experiment reflect subject decisions *and* the matching scheme imposed by the experimenter, we remove the impact of the particular matching scheme used by computing expected relative frequencies of different move orderings given subjects' timing decisions. For each matching-group we compute the expected relative frequency of a given move ordering $(t_{HIGH},\ t_{LOW})$, $t_{HIGH}, t_{LOW} \in \{1; 2\}$, in a given round of the experiment as:

$$Prob(t_{HIGH},\ t_{LOW}\ ) = \frac{T_{HIGH} \cdot T_{LOW}}{16}$$

where T_{HIGH} is the number of HIGH players (out of four) within the matching group that choose to contribute in period t_{HIGH} and T_{LOW} is the number of LOW players (out of four) within the matching group that choose to contribute in period t_{LOW}. For example, to compute the probability of observing the detrimental move ordering HIGH-FIRST, i.e. $(t_{HIGH} = 1,\ t_{LOW} = 2)$, in a given matching group in a given round of the experiment we count the number of HIGH and LOW players within the matching group who in that round choose to move in period 1 and 2 respectively and apply the formula above.

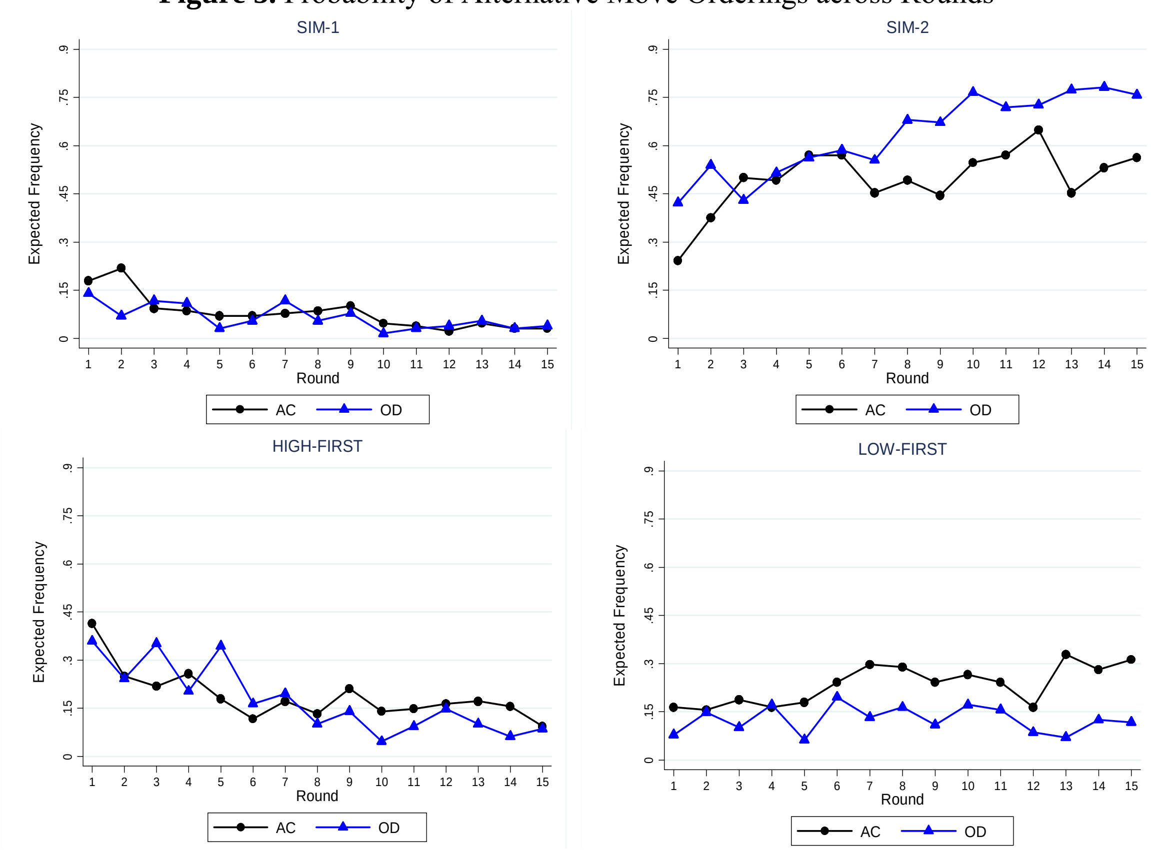
Table 3 and Figure 5 show, separately for each treatment, how the probability of a move ordering evolves across the 15 rounds of the experiment. Averaging across rounds and matching-groups, the move ordering that is most likely to emerge in our experiment is by far SIM-2: its probability is 63% in OD and 50% in AC. Moreover, in both treatments the probability of observing both players contributing simultaneously in period 2 increases in the second half of the experiment (by about 20 percentage points in OD and by 8 percentage points in AC). The probability of observing a sequential move ordering is low in both treatments: in particular, the probability of HIGH-FIRST, that is predicted to lead to lower public good provision under standard assumptions, is less than 20% and decreases over time both in OD and AC.

Table 3. Probability of Alternative Move Orderings *

	AC			OD		
		round			round	
move ordering	Overall	1 to 8	9 to 15	overall	1 to 8	9 to 15
SIM-1	.08 *(.05)*	.11 *(.07)*	.05 *(.03)*	.07 *(.09)*	.09 *(.10)*	.04 *(.09)*
SIM-2	.50 *(.13)*	.46 *(.14)*	.54 *(.12)*	.63 *(20)*	.54 *(.17)*	.74 *(.24)*
HIGH-FIRST	.19 *(.10)*	.22 *(.09)*	.15 *(.16)*	.18 *(.07)*	.24 *(.08)*	.10 *(.09)*
LOW-FIRST	.23 *(.10)*	.21 *(.08)*	.26 *(.16)*	.13 *(.08)*	.13 *(.07)*	.12 *(.10)*

* The table shows the expected relative frequency of a move ordering based on individual timing decisions, averaged across rounds and matching-groups, with standard deviations in parentheses. Standard deviations are computed using matching-group-level averages across the 15 rounds as observation units.

Figure 5. Probability of Alternative Move Orderings across Rounds

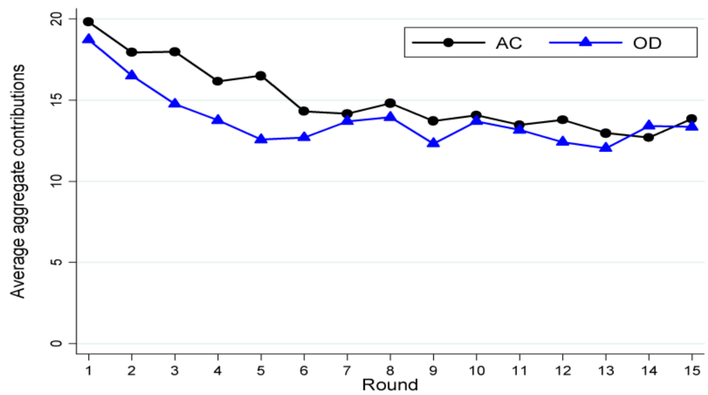


In summary, our experiment shows that both LOW and HIGH subjects have a strong tendency to wait to make a contribution decision until period 2. This tendency is common to both treatments and increases over time. As a result, sequential move orderings are rarely observed in the experiment, and by far the most likely move ordering is SIM-2, where both players delay.

3.4.2 Contribution behavior in the AC and OD treatments

Figure 6 shows how the average contribution per pair, pooling across different move orderings, develops over the experiment. In both treatments contributions decrease initially, and then stabilize at a lower level. Contributions per pair across all rounds average 13.8 tokens in OD and 15.1 tokens in AC (p = 0.290).

Figure 6. Aggregate Contributions across Rounds



The distribution of contributions across HIGH and LOW subjects is also very similar in the two treatments as shown in Figure 7. HIGH subjects contribute more than LOW subjects: HIGH subjects contribute on average 10.3 tokens in OD and 10.7 tokens in AC (p = 0.668), and LOW subjects' contributions across the whole 15 rounds average 3.5 in OD and 4.3 in AC (p = 0.345).

Figure 7. HIGH and LOW Contributions across Rounds

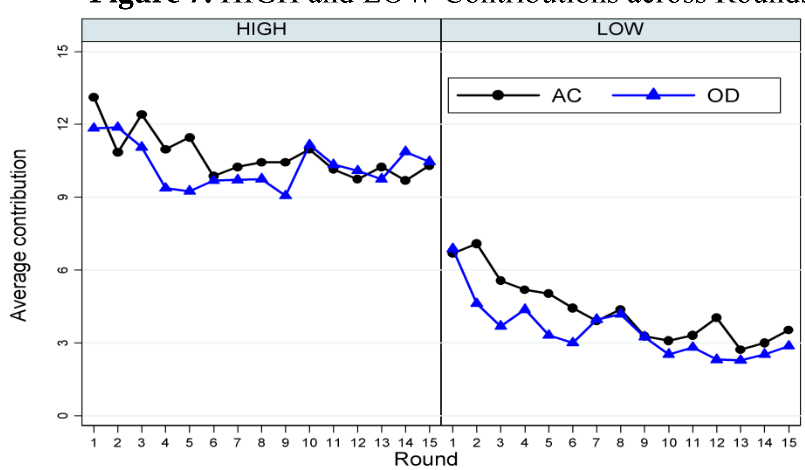


Table 4 shows how aggregate contributions break out across the four possible move orderings of our extended games. In the most common move ordering, SIM-2, the subgames played in the OD and AC treatments are comparable: both subjects know that they are contributing simultaneously in period 2. The outcomes are similar across the two treatments, with pairs contributing on average 14.9 tokens in AC and 13.4 tokens in OD. In OD aggregate contributions are lowest in HIGH-FIRST: this result is in line with Varian's model predictions and with previous findings from Gächter et al (2010), who also found that public good provision was lowest in the sequential game where the player with the highest valuation of the public good moves first. In AC although aggregate contributions averaged across all rounds are lowest in the other sequential game, LOW-FIRST, in the second half of the experiment contributions are lowest in HIGH-FIRST.

Table 4. Aggregate Contributions per Treatment and Move Ordering*

Treatment	Move Ordering	Overall	Round 1 to 8	Round 9 to 15
AC	SIM-1	19.7 *(9.32) (n =45)*	21.9 *(7.90)(n =35)*	12.1 *(10.28) (n =10)*
	SIM-2	14.9 *(6.17) (n =245)*	15.3 *(6.73)(n =125)*	14.4 *(5.51) (n =120)*
	HIGH-FIRST	14.5 *(7.44) (n =84)*	16.3 *(7.57)(n =49)*	12.0 *(6.53) (n =35)*
	LOW-FIRST	14.0 *(6.68) (n =106)*	15.5 *(7.80)(n =47)*	12.8 *(5.41) (n =59)*
OD	SIM-1	14.8 *(5.95) (n =33)*	16.6 *(5.83) (n =21)*	11.7 *(4.97) (n =12)*
	SIM-2	13.4 *(6.19) (n =305)*	14.1 *(6.58)(n =136)*	12.8 *(5.81) (n =169)*
	HIGH-FIRST	13.0 *(6.24) (n =83)*	13.9 *(6.32)(n =64)*	10.0 *(5.00) (n =19)*
	LOW-FIRST	16.5 *(6.05) (n =59)*	16.5 *(6.41)(n =35)*	16.4 *(5.61) (n =24)*

* The table shows aggregate contributions per game, with standard deviations and underlying number of games in parentheses. Standard deviations are computed using games as observation units.

Table 5 shows how contributions vary by type of player as well as by treatment and move ordering. In most of the cases HIGH contributes on average between 9 and 12 tokens, and LOW between 4 and 8 tokens. In HIGH-FIRST, where according to standard theory HIGH should commit to free ride and let LOW contribute 6 tokens, HIGH (LOW) contributions are clearly higher (lower) than the predicted level. In fact, HIGH contribution behavior does not seem to differ much across the different move orderings and LOW contributions in HIGH-FIRST are actually lower than in alternative move orderings. As a result, the distribution of contributions is more even than is predicted under the standard assumption that players maximize own material payoffs.

Table 5. Individual Contributions by Type of Player*

Treatment	Move ordering	HIGH	LOW
AC	SIM-1 *(n =45)*	11.6 *(5.26)*	8.1 *(5.79)*
	SIM-2 (*n =245)*	10.8 *(4.75)*	4.0 *(4.25)*
	HIGH-FIRST *(n =84)*	11.2 *(5.60)*	3.3 *(4.65)*
	LOW-FIRST *(n =106)*	9.7 *(5.18)*	4.3 *(4.71)*
OD	SIM-1 *(n =33)*	10.4 *(4.34)*	4.4 *(4.90)*
	SIM-2 *(n =305)*	10.3 *(5.10)*	3.1 *(3.42)*
	HIGH-FIRST *(n =83)*	9.8 *(5.30)*	3.2 *(4.00)*
	LOW-FIRST *(n =59)*	10.8 *(4.84)*	5.6 *(4.62)*

*The table shows contribution per game, with standard deviations in parentheses. Standard deviations are computed using games as observation units.

It is interesting to compare these contributions with those observed in Gächter et al. (2010), who run an experimental test of the Varian's (1994) model under exogenously imposed move structures using the same parameterization that we used for the current experiment. The cleanest comparison is with our OD treatment, because in this treatment subjects always know the move ordering when they make their contributions. Table 6 compares contributions from the exogenous and endogenous move orderings (for the purposes of this comparison we pool the data from SIM-1 and SIM-2 move orderings).

Table 6. Contributions under Endogenous and Exogenous Move Orderings*

		AGGREGATE	HIGH	LOW
SIM	Exogenous (n = 240)	14.3 *(5.98)*	10.5 *(4.96)*	3.8 *(3.32)*
	Endogenous (n = 338)	13.5 *(6.17)*	10.3 *(5.03)*	3.2 *(3.60)*
HIGH-FIRST	Exogenous (n = 240)	10.2 *(5.39)*	7.7 *(5.42)*	2.5 *(3.16)*
	Endogenous (n = 83)	13.0 *(6.24)*	9.8 *(5.30)*	3.2 *(4.00)*
LOW-FIRST	Exogenous (n = 240)	13.3 *(6.04)*	9.4 *(4.86)*	3.9 *(3.90)*
	Endogenous (n = 59)	16.5 *(6.05)*	10.8 *(4.84)*	5.6 *(4.62)*

*The table shows aggregate and individual contributions per game, with standard deviations in parentheses. Standard deviations are computed using games as observation units. The exogenous move orderings data are from the FMA treatments of Gächter et al. (2010). The endogenous move orderings data are from our OD treatment, pooling the data from SIM-1 and SIM-2 move orderings.

One reason contributions may differ in the endogenously determined move orderings is that subjects may behave more cooperatively in settings where they can influence the way they interact with each other, compared to settings where the structure of the interactions is imposed exogenously, as suggested by recent studies (e.g., Dal Bó et al., *forthcoming*; Sutter et al., *forthcoming*). However, we find little evidence for this in our data. Although we observe higher contribution levels when subgames with sequential move orderings are reached endogenously rather than exogenously, none of these differences are significant at conventional levels (all p-values > 0.145). For the simultaneous move ordering, contributions in the exogenous games exceed those in the endogenous games, though the difference is again insignificant (all p-values > 0.575).[22]

Another interesting similarity between our study and Gächter et al. (2010) is that in both studies the distribution of contributions across type of player is more even than predicted by standard theory, irrespective of move ordering. Gächter et al. (2010) find that this compression of contributions in sequential games can be explained by a tendency of second-movers to punish first-movers for excessively low contributions by systematically contributing less than their material best-response. Although we have too few observations on second-mover behavior to conduct the same analysis as Gächter et al. (2010), our data suggest a similar phenomenon in our endogenously determined sequential subgames. For example pooling data from our two treatments,

[22] For these comparisons we apply randomization tests to 8 independent observations from our OD treatment and 4 independent observations from the Gächter et al. (2010) data.

we note that when HIGH contributes 0 as a first-mover LOW contributes 3.62 tokens on average (n=16), compared with a material best response of 6 tokens, and when LOW contributes 0 as a first-mover HIGH contributes 10.79 tokens on average (n=58), compared with a material best response of 15 tokens. Note that by contributing one less token than the material best response the punisher incurs a small cost (her earnings are reduced by 5 points) relative to the cost incurred by the punishee (e.g. HIGH's earnings in HIGH-FIRST are reduced by 75 points if LOW contributes 5 rather than 6 tokens). This is because the punisher's earnings function is relatively flat in the neighborhood of her material best response, whereas the punishee's earnings function is strictly increasing in the punisher's contribution.

3.4.3 Explaining timing behavior

Given that committing to low contributions in period 1 induces punishment by second-movers, one possible reason why subjects in our experiment refrain from making early contributions may be that this is less profitable than contributing in period 2.[23] Table 7 examines this possibility by showing the average payoff that subjects earned by contributing in period 1 and in period 2, conditional on the period choice of their opponent.

Table 7 suggests that, for AC, LOW is better off waiting than committing to a contribution in period 1, irrespective of HIGH's timing decision. Given this HIGH does better by waiting also. Overall, averaging across opponents' timing decisions, both type of player are better off waiting than committing. However, it is complicated to draw a parallel between the empirical payoffs shown in Table 7 and the theoretical payoffs in the AC game since the empirical payoffs are averaged over a variety of contribution decisions. In fact, for both types of player there are some contribution levels in period 1 that yield a higher payoff than waiting. For the OD treatment, it is even less clear that waiting is a profitable strategy. Overall HIGH is better off choosing period 1, and given this LOW is better off choosing period 1 as well.

[23] Note, however, that in linear public goods game experiments leaders typically end up earning less than followers (e.g., Gächter and Renner, 2003; Güth et al., 2007), but nevertheless Arbak and Villeval (2007) and Rivas and Sutter (2009) find that a significant proportion of subjects *volunteer* to lead. While the existence of followers who contribute more if leaders contribute can explain why strategic leaders may have an incentive to make positive contributions once they are appointed (e.g., Cartwright and Patel, 2010), it remains an open question why a strategist would volunteer to lead given that it is not profitable to do so. Arbak and Villeval (2007) suggest voluntary leaders may be motivated by social concerns.

Table 7. Earnings by Type of Player*

AC treatment		HIGH earnings when HIGH chooses:		LOW earnings when LOW chooses:	
		g in t_{HIGH}=1	*WAIT*	*g in* t_{LOW}=1	*WAIT*
Opponent chooses:	*g in* t_j=1	1409	1303	1219	1329
	WAIT	1239	1298	1269	1318
	Total	1298	1299	1254	1320

OD treatment		HIGH earnings when HIGH chooses:		LOW earnings when LOW chooses:	
		t_{HIGH}=1	t_{HIGH}=2	t_{LOW}=1	t_{LOW}=2
Opponent chooses:	t_j=1	1322	1377	1301	1293
	t_j=2	1251	1247	1291	1313
	Total	1271	1268	1295	1309

* The table shows subjects' average point earnings conditional on their timing choice and their opponent's choice.

As discussed in Section 2, inequality aversion provides another reason why subjects might delay, and as already noted, there are patterns in contribution behavior that are consistent with concerns for earnings equality. The theoretical analysis in Section 2 shows that the frequently observed SIM-2 move order can emerge when players are inequality averse, but only in two cases. One of these occurs when players are mildly inequality averse and equilibrium contributions do not depend on move structure. In this case, in the equilibria of the AC and OD games in which both players delay, LOW contributes nothing. However, of the 550 games with the SIM-2 move structure observed in the experiment, in only 199 (36%) did LOW free ride. The second case occurs when players are strongly inequality averse. In this case, in the equilibria of the AC and OD games where both players delay, the players provide the socially efficient level of the public good. However, socially efficient provision is attained in only 27 out of 550 games (5%) with the SIM-2 move structure. Thus the vast majority of SIM-2 games feature contributions that are inconsistent with the simple model of inequality aversion.

Finally, as noted by Fonseca, Müller, and Normann (2006) an alternative reason for delaying decisions in a strategic context is that by doing so individuals may be able to resolve the strategic uncertainty about the opponent's action, giving them an opportunity to observe and hence respond to their period 1 contribution decisions. Free-form comments left by subjects in the post-experimental questionnaire about the motivations underlying their choices in the course of the experiment lend some support to this interpretation.[24] We also notice that the contribution behavior observed in our experiment leaves little room for a subject to exploit other subjects who delay. The rare attempts by subjects with high valuations to jump in and contribute zero in the first period usually backfire, as opponents tend to react by contributing less than their best response. Thus, the waiting strategy is sustained by the willingness of subjects to punish others who attempt to exploit them. Interestingly, it takes only a small willingness to punish to eliminate exploitation.

4. Conclusions

In an important theoretical contribution to the literature on the voluntary provision of public goods Varian (1994, p. 165) shows that "the ability to commit to a contribution exacerbates the free-rider problem": a first mover exploits a first-mover advantage by committing to an early, low contribution, relying on other late contributors to provide the public good on their own. If an agent with a high value of the public good commits to free riding overall provision of the public good is lower.

Previous theoretical studies have raised questions about the applicability of this result. Vesterlund (2003) and Romano and Yildirim (2005) point out that Varian's (1994) result relies crucially on the assumption that agents can commit to contribute exactly once. They show that when multiple contributions are feasible leaders are unable to commit to not increasing their contributions later, and allowing agents to contribute sequentially does not undermine public good provision. Our paper raises a different question: we explicitly allow commitment and examine whether the ability to commit exacerbates free-riding.

In our experiment, and in line with the results reported in Gächter et al. (2010), we do find that aggregate contributions are generally lower in the detrimental move ordering where the agent with the highest value of the public good moves first. However, we also find that subjects

[24] Examples of comments made by subjects about their timing decisions are: "*People don't like to take risks. Rather play it safe and with full knowledge*". Another person explained that (s)he had chosen to move second most of the time in order to " *observe what people have done*". Someone explained that (s)he "*always went in stage 2 so there was a chance to see other player's decision*".

usually *avoid* committing to an early contribution. Following Hamilton and Slutsky (1990) we embody commitment opportunities within extended games with observable delay and with action commitment. In the extended game with observable delay the detrimental move ordering should not, theoretically, arise, nor is it often observed in the experiment. In the extended game with action commitment the detrimental move ordering is predicted under standard theoretical assumptions, but in our data it is rarely observed. In our experiment, by far the most common outcome is for both players delay and contribute in the last period.

Our results are reminiscent of the findings from the theoretical and experimental literature that uses Hamilton and Slutsky's (1990) extended games to study endogenous timing in duopoly games. In the extended duopoly game with action commitment, under appropriate assumptions, a sequential move ordering is predicted to emerge where a firm leads by producing in the first period and the other follows and produces in the second period after having observed the leader's quantity choice. However, observed behavior in controlled laboratory experiments systematically contradicts this theoretical result (Huck, Müller, and Normann, 2002; Fonseca, Huck, and Normann, 2005). The predicted Stackelberg leader-follower outcomes are rarely observed, both because simultaneous play occurs more frequently than sequential play, and because the chosen quantities in the duopoly games are typically more in line with Cournot than with Stackelberg levels. Moreover, a notable tendency to delay production decisions until the second period is often observed. Indeed, firms appear reluctant to commit to early production even in an extended game with observable delay which has a unique, symmetric subgame perfect equilibrium where both firms produce in the first period (Fonseca, Müller, and Normann, 2006). [25]

Overall, our results suggest that the existence of commitment opportunities may not necessarily result in an exacerbation of the free-rider problem. While in theory there exists a sequential move ordering where aggregate contributions and joint earnings are lower than in a simultaneous move orderings, this detrimental move ordering rarely emerges when agents can choose the timing of their contributions.

[25] Datta Mago and Dechenaux (2009) study price leadership in an endogenous game with observable delay and asymmetric firms where the unique subgame perfect equilibrium has one firm setting the price in period 1 and the other firm setting the price in period 2. In their experiment they find strong tendency to wait from both firms, although equilibrium predictions find more support in the data when firm size asymmetry is high.

Appendix A: Experimental Instructions

Instructions

General

Welcome! You are about to take part in an experiment in the economics of decision making. You will be paid in private and in cash at the end of the experiment. The amount you earn will depend on your decisions, so please follow the instructions carefully. It is important that you do not talk to any of the other participants until the experiment is over. If you have a question at any time, raise your hand and a monitor will come to your desk to answer it.

The experiment will consist of fifteen rounds. There are sixteen participants in this room. Before the first round begins the computer will randomly assign the role of “RED” to eight participants and the role of “BLUE” to eight participants. You will be informed of your role, either RED or BLUE, at the beginning of round one and you will keep this role throughout the fifteen rounds. In each round the computer will randomly form eight pairs consisting of one RED and one BLUE participant. Thus, you will be randomly matched with another person in this room in each round, but this may be a different person from round to round. You will not learn who is matched with you in any round, neither during nor after today’s session.

Each round is identical. In each round you and the person you are matched with will make choices and earn points. The point earnings will depend on the choices as we will explain below. At the end of the experiment one of the fifteen rounds will be selected at random. Your earnings from the experiment will depend on your point earnings in this randomly selected round. These point earnings will be converted into cash at a rate of 1p per point.

How You Earn Points

At the beginning of the round you will be given an endowment of 17 tokens. You have to decide how many of these tokens to place in a Private Account and how many to place in a Shared Account.

For each token you place in your Private Account you will earn 50 points, as shown in Table 1.

For each token placed in the Shared Account you will earn an additional amount, regardless of whether the token was placed by you or the person you are matched with. Likewise, for each token placed in the Shared Account the person you are matched with will earn an additional amount, regardless of whether the token was placed by you or them. Earnings from the Shared Account are shown in Table 2.

Your point earnings for the round will be the sum of your earnings from your Private Account and your earnings from the Shared Account.

So that everyone understands how choices translate into point earnings we will give an example and a test. Please note that the allocations of tokens used for the example and test are simply for illustrative purposes. In the experiment the allocations will depend on the actual choices of the participants.

Example: Suppose RED places 9 tokens in his Private Account and 8 tokens in the Shared Account, and BLUE places 10 tokens in his Private Account and 7 tokens in the Shared Account. In this example there are a total of 15 tokens in the Shared Account. RED will earn 450 points from his Private Account, plus 1050 points from the Shared Account, for a total of 1500 points. BLUE will earn 500 points from his Private Account, plus 705 points from the Shared Account, for a total of 1205 points.

Test: Before we continue with the instructions we want to make sure that everyone understands how their earnings are determined. Please answer the questions below. Raise your hand if you have a question. After a few minutes a monitor will check your answers. When everyone has answered the questions correctly we will continue with the instructions.

Suppose RED allocates 11 tokens to his Private Account and 6 tokens to the Shared Account, and BLUE allocates 5 tokens to his Private Account and 12 tokens to the Shared Account.

1. What will be RED's point earnings from his private account? __________
2. What will be RED's point earnings from the shared account? __________
3. What will be RED's point earnings for the round? __________
4. What will be BLUE's point earnings from his private account? __________
5. What will be BLUE's point earnings from the shared account? __________
6. What will be BLUE's point earnings for the round? __________

How You Make Decisions

[AC treatment:

In each round you must allocate your endowment by typing in a number of tokens to place in the Shared Account. You can enter any whole number between 0 and 17 inclusive. The computer will then automatically place the remainder of your endowment in your Private Account. Each round consists of two stages. In stage one you can either allocate your endowment immediately by typing in a number of tokens to place in the Shared Account, or wait until stage two to allocate your endowment. You do this by typing in the letter "W", for "WAIT".

At the same time, the person with whom you are matched will be either allocating their endowment or deciding to wait.

After you and the person you are matched with have both made stage one decisions the computer will show an information screen to both of you displaying whether each person made an allocation decision in stage one, or decided to wait until stage two.

Four possible situations may occur:

1) If both you and the other person made allocation decisions in stage one: in this situation no decisions are made in stage two and the round ends immediately.
2) If both you and the other person decided to wait until stage two to make allocation decisions: both of you must make allocation decisions at the same time in stage two. You must type in a number of tokens to place in the Shared Account. At the same time, the other person will be deciding how many tokens to place in the Shared Account.
3) If you made your allocation decision in stage one and the other person decided to wait until stage two: the other person must make an allocation decision in stage two. In stage two the computer will inform the other person of your allocation decision. After seeing how many tokens you allocated to the Shared Account, the other person will make an allocation decision by typing in a number of tokens to place in the Shared Account.
4) If the other person made an allocation decision in stage one and you decided to wait until stage two: you must make your allocation decision in stage two. In stage two the computer will inform you of the other person's allocation decision. After seeing how many tokens the other person allocated to the Shared Account, you will make your allocation decision by typing in a number of tokens to place in the Shared Account.**]**

[OD treatment:

In each round you must allocate your endowment by typing in a number of tokens to place in the Shared Account. You can enter any whole number between 0 and 17 inclusive. The computer will then automatically place the remainder of your endowment in your Private Account. Each round consists of two stages. At the beginning of the round you must decide whether to make your allocation decision in stage one or in stage two.

At the same time, the person with whom you are matched will be deciding whether to make their allocation decision in stage one or in stage two.

After you and the person you are matched with have both decided in which stage to make allocation decisions the computer will show an information screen to both of you displaying in which stage each person will make an allocation decision.

Four possible situations may occur:

1) If both you and the other person decided to make allocation decisions in stage one: both of you must make allocation decisions at the same time in stage one. You must type in a number of tokens to place

in the Shared Account. At the same time, the other person will be deciding how many tokens to place in the Shared Account. In this situation no decisions are made in stage two.

2) If both you and the other person decided to make allocation decisions in stage two: both of you must make allocation decisions at the same time in stage two. You must type in a number of tokens to place in the Shared Account. At the same time, the other person will be deciding how many tokens to place in the Shared Account. In this situation no decisions are made in stage one.

3) If you decided to make your allocation decision in stage one and the other person decided to make an allocation decision in stage two: in stage one you must decide how many tokens to place in the Shared Account. In stage two the computer will inform the other person of your allocation decision. After seeing how many tokens you allocated to the Shared Account, the other person will make an allocation decision by typing in a number of tokens to place in the Shared Account.

4) If the other person decided to make an allocation decision in stage one and you decided to make your allocation decision in stage two: in stage one the other person must decide how many tokens to place in the Shared Account. In stage two the computer will inform you of the other person's allocation decision. After seeing how many tokens the other person allocated to the Shared Account, you will make your allocation decision by typing in a number of tokens to place in the Shared Account.**]**

At the end of stage two the computer will show an information screen to you and the person you are matched with. This screen will display the total number of tokens placed in the Shared Account and the earnings of each person for that round. After you have read the information screen, you must click on the continue button to go on to the next round.

Notice that each round consists of TWO stages, but in each round you will make only ONE allocation decision. Once you have made an allocation decision it cannot be changed. However, you can choose whether to make your allocation decision in stage one or in stage two.

How Your Cash Earnings Are Determined

At the end of round fifteen there will be a random draw to select the round for which you will be paid. A poker chip will be drawn from a bag containing chips numbered from 1 to 15. The number on the chip will determine the round that is used for determining all participants' cash earnings. Your point earnings in this randomly selected round will be converted into cash at a rate of 1p per point. You will be paid in private and in cash.

Beginning the Experiment

Now, please look at your computer screen and begin making your decisions. If you have a question at any time please raise your hand and a monitor will come to your desk to answer it.

Appendix B. Earnings Tables

EARNINGS TABLES

Table 1. Earnings from Your Private Account

TOKENS IN YOUR PRIVATE ACCOUNT	YOUR POINT EARNINGS FROM THE PRIVATE ACCOUNT
0	0
1	50
2	100
3	150
4	200
5	250
6	300
7	350
8	400
9	450
10	500
11	550
12	600
13	650
14	700
15	750
16	800
17	850

Table 2. Earnings from the Shared Account

TOKENS IN THE SHARED ACCOUNT	RED'S POINT EARNINGS FROM THE SHARED ACCOUNT	BLUE'S POINT EARNINGS FROM THE SHARED ACCOUNT
0	0	0
1	90	60
2	180	120
3	260	175
4	340	230
5	415	285
6	490	340
7	565	385
8	635	430
9	700	475
10	765	520
11	825	560
12	885	600
13	940	635
14	995	670
15	1050	705
16	1095	740
17	1140	770
18	1180	800
19	1220	830
20	1260	855
21	1295	880
22	1330	900
23	1360	920
24	1385	940
25	1410	960
26	1435	975
27	1455	990
28	1470	1000
29	1485	1010
30	1500	1020
31	1510	1025
32	1515	1030
33	1520	1035
34	1525	1040

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