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

by

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April 2009

Abstract

In this paper we examine voluntary contributions to a public good when the timing of contributions is endogenously determined by contributors, focusing on the simple quasi-linear setting with two players (Varian, 1994). We show that the move order that is predicted to emerge is sensitive to how commitment opportunities are modeled. We show that a favorable move order is predicted to emerge in Hamilton and Slutsky's (1990) 'observable delay' extended game, but a detrimental move order is predicted to emerge in their 'action commitment' extended game. We then report a laboratory experiment designed to examine whether the predicted move ordering emerges, and how this impacts overall contributions, in these extended games. The results are similar in both extended games. We find that when the detrimental move order is observed, contributions are indeed lower, as predicted. However, this detrimental move order is seldom observed. Instead of committing to low contributions, players tend to avoid making a commitment. These experimental results on timing decisions 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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1. Introduction

When agents voluntarily contribute to a public good the 'free-rider problem' is well-known: agents' contributions are predicted to be inefficiently low. Varian (1994) shows that the free-rider problem gets worse when agents can commit to a contribution: an agent can enjoy a first-mover advantage by committing to free-ride, forcing later contributors to provide the public good on their own. When agents with a high value of the public good move early, commit to contribute nothing and let agents with lower valuations provide the public good, a detrimental outcome results: overall provision is lower than when commitment opportunities are absent. This result suggests that the use of commitment may aggravate the free-rider problem, but a more fundamental question remains unanswered: will agents in fact *choose* to commit if they are given the opportunity to do so? Will the detrimental move ordering emerge when agents can endogenously determine the timing of their contributions? In this paper we address these questions theoretically and empirically by endogenizing the order of moves in a simple two-player version of Varian's (1994) voluntary contributions model. We derive new theoretical results that show that the detrimental move order may emerge as the predicted outcome of an endogenous move game, but that this depends crucially on the nature of commitment opportunities available to agents. We then test these predictions using laboratory experiments.

The importance of understanding how agents select the timing of their actions in strategic contexts has been emphasized in a growing theoretical and experimental literature on endogenous timing in duopoly games. Hamilton and Slutsky (1990), for example, use a theoretical framework where simultaneous or sequential play emerges from an extended duopoly game in which firms can set their quantities in one out of two possible periods. They propose two extended games, the 'extended game with observable delay' and 'the extended game with action commitment', which differ in how commitment opportunities are modeled and in the resulting predicted outcomes. In the extended 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.[1] Observed behavior in controlled laboratory experiments

[1] 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).

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).

As a possible explanation for the gap between predicted and observed timing behavior in duopoly experiments it has been noted that attempts to exploit a first-mover advantage in sequential duopoly games are frequently met by second-movers producing more than their best response (e.g., Huck, Müller and Normann, 2002).[2] While this is costly for the second-mover, it is also costly to first-movers since it results in a higher aggregate quantity and hence a lower price. Because the resulting payoffs in the sequential games are then typically lower than predicted, the underlying incentives to commit to early production decisions are also not aligned to the theoretical ones, and this may prevent play from converging to the predicted equilibria of the endogenous timing games. Experimental evidence suggests that a similar phenomenon may apply in Varian's (1994) model of voluntary contributions. Gächter et al. (2009), using an exogenously imposed move structure based on this model, find that late contributors typically resist being taken advantage of by early low contributors, and first-movers fail to attain a predicted first-mover advantage. Thus, it is unclear which move ordering would emerge in practice in settings where the move structure is determined endogenously, since the resulting move structure will typically reflect how alternative move structures reward participants.[3]

The main aim of this paper is to examine, theoretically and empirically, which move structure emerges in Varian’s (1994) model of voluntary contributions when the timing of

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[2] See also Huck, Müller, and Normann (2001), who study firms’ behavior in exogenous sequential duopoly games.

[3] A related issue arises in linear voluntary contributions game experiments. In this setting it is often found that when players contribute sequentially leadership contributions ‘crowd in’ contributions by followers, but leaders are nevertheless “suckers” and earn typically less than followers (see, e.g., Gächter and Renner, 2003; Güth et al., 2007). While the existence of crowding in can explain why exogenously imposed leaders may have an incentive to make positive contributions (e.g., Cartwright and Patel, 2009), it is open to question whether anyone would ever *volunteer* to lead, given that leading is not profitable. In fact, Arbak and Villeval (2007) find that a significant proportion of subjects volunteer to lead even when it is not profitable to do so. Rivas and Sutter (2008) also examine endogenous leadership in a linear public goods setting and observe very frequent leadership contributions.

contributions to the public good is determined endogenously by individuals' decisions. Our paper focuses on the simplest version of Varian's (1994) model with two players, quasi-linear and asymmetric returns from public good consumption. To study endogenous timing we follow the approach of Hamilton and Slutsky (1990). We embed Varian's (1994) two-player voluntary contributions game into their extended game with observable delay and extended game with action commitment. We show that, theoretically, the two extended games result in different move orderings, suggesting that outcomes are likely to be sensitive to how commitment opportunities are modeled. In the extended game with observable delay both players commit to an early contribution, and so a simultaneous move game arises. The detrimental move ordering is predicted not to arise. In the extended game with action commitment one player commits and the other waits and so a sequential move game arises. In fact the predicted move structure corresponds to the detrimental move ordering with associated lower provision.

We investigate these predictions in a laboratory experiment. For both extended games we find that most timing decisions are out of equilibrium: subjects show a strong tendency to avoid making a commitment to early contributions. Thus, our empirical results contrast with the theoretical results. Importantly, in the extended game with action commitment where the detrimental move ordering is predicted to emerge, this move order is observed in less than 20% of cases. These experimental results on timing decisions suggest that commitment opportunities may be less damaging to public good provision than previously thought. We argue that subjects' tendency to delay contributions reflects an intrinsic preference for waiting, perhaps as a tool to gain confidence about one's decision (Tykocinski and Ruffle, 2003), or to resolve strategic uncertainty about the opponent's action. Importantly, we find the tendency of subjects to delay cannot be exploited by a subject who attempts to commit. As in Gächter et al. (2009), we find that second-movers are willing to punish first-movers who make low contributions. This results in a more even distribution of contributions than predicted and eliminates any first-mover advantage in sequential games. In fact if others delay a subject does better delaying as well.

The remainder of the paper is organized as follows. In the next Section we extend Varian's (1994) model using Hamilton and Slutsky's (1990) action commitment and observable delay extended games. In Section 3 we describe our experiment and the results. Section 4 concludes.

2. Theory

In this paper we focus on Varian's (1994) model of voluntary contributions with quasi-linear payoff functions and two players. 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:

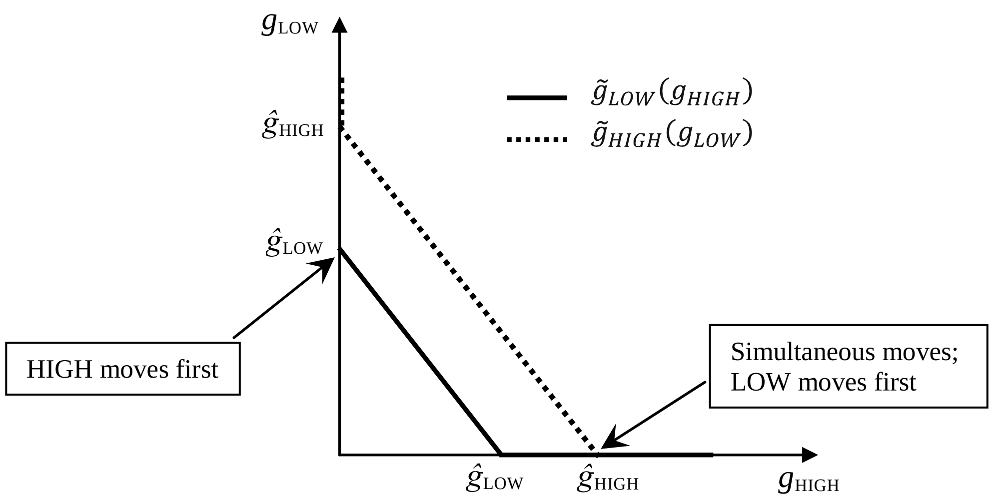
$$\pi_i = e_i - g_i + f_i(G)$$

where individual i's return from the public good, $f_i(G)$, is increasing and strictly concave. As in Varian (1994) we assume that each player has an interior 'stand-alone contribution' $0 < \hat{g}_i < e_i$ where $\hat{g}_{HIGH} > \hat{g}_{LOW}$.[4] Thus, in Varian's terminology, HIGH is the 'player who likes the public good most'. We focus on the case where these stand-alone contributions are not too different, $f_{HIGH}(\hat{g}_{HIGH}) - f_{HIGH}(\hat{g}_{LOW}) < \hat{g}_{HIGH}$, as this is the case where equilibrium contributions depend on the move ordering.

2.1 Equilibrium under exogenous move orderings

Varian (1994) shows that the best-response function of player i is given by $\tilde{g}_i(g_j) = \max\{\hat{g}_i - g_j, 0\}$. Figure 1 shows HIGH and LOW best response functions.

Figure 1. Best-response functions



[4] Player i's stand-alone contribution is the contribution that maximizes her payoff when the other agent contributes zero.

In the unique Nash equilibrium of the simultaneous move game LOW contributes zero and HIGH makes her stand-alone contribution. We denote the resulting equilibrium payoffs as π_{LOW}^{S} and π_{HIGH}^{S}.

Next we consider a sequential move game where *i* moves first and *j* moves second. In the subgame perfect equilibrium *j*'s strategy is given by her best-response function $\tilde{g}_j(g_i)$ and *i*'s strategy maximizes $\pi_i\left(g_i, \tilde{g}_j(g_i)\right)$. When LOW moves first $\pi_{LOW}\left(g_{LOW}, \tilde{g}_{HIGH}(g_{LOW})\right)$ is maximized when $g_{LOW} = 0$ and so the outcome is the same as with simultaneous moves: $g_{LOW} = 0$ and $g_{HIGH} = \hat{g}_{HIGH}$, leading again to the payoffs π_{LOW}^{S} and π_{HIGH}^{S}.

The assumption that stand-alone contributions are not too different implies that when HIGH moves first she will commit to contributing zero and rely on the LOW player to contribute $\hat{g}_{LOW}$. Here, since $\hat{g}_{LOW} < \hat{g}_{HIGH}$, public good provision is lower than with alternative move orderings, and so we refer to this as the detrimental move ordering. The resulting payoffs are $\pi_{HIGH}^{D} > \pi_{HIGH}^{S}$ and $\pi_{LOW}^{D} < \pi_{LOW}^{S}$.[5] Thus, relative to other move orderings, the subgame perfect equilibrium when HIGH moves first features lower public good provision, a higher payoff for HIGH, a lower payoff for LOW, and lower combined payoffs.[6]

2.2 Endogenous moves

To analyze endogenous timing we follow the approach of Hamilton and Slutsky (1990). We apply their extended game with observable delay and extended game with action commitment to the voluntary contributions game. In these extended games each person makes one contribution decision but there are two contribution periods. In the extended game with observable delay players simultaneously announce a contribution period. If the players announce the same period then they play the simultaneous contribution game described in the previous sub-section. If one announces the first period and the other the second period, then they play the relevant sequential contribution game. Note that a player is unable to unilaterally choose a move ordering. By

[5] The first inequality follows from the assumption that stand-alone contributions are not too different. The second inequality follows because LOW enjoys lower private consumption and lower public good provision in the detrimental move ordering.

[6] The condition for maximizing the sum of payoffs is that the marginal returns from the public good sum to unity: $f_{LOW}^{'}(G^*) + f_{HIGH}^{'}(G^*) = 1$. Since in the simultaneous move equilibrium total provision is equal to $\hat{g}_{HIGH}$, $f_{LOW}^{'}(\hat{g}_{HIGH}) + f_{HIGH}^{'}(\hat{g}_{HIGH}) = f_{LOW}^{'}(\hat{g}_{HIGH}) + 1 > 1$. Provision is inefficiently low and the sum of payoffs is not maximized. Since equilibrium provision in the detrimental move ordering is even lower than in the simultaneous move equilibrium strict concavity of f_i implies $\pi_{HIGH}^{D} + \pi_{LOW}^{D} < \pi_{HIGH}^{S} + \pi_{LOW}^{S}$.

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.

In the extended game with action commitment players either make their contribution in the first period or wait until the second period to make their contribution. If neither 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 what the move ordering is. Moreover, when a player commits to contributing early she does so by committing herself to a particular contribution. Thus the games differ in the commitment opportunities available to the players.

2.2.1 The extended game with observable delay

In the extended game with observable delay contributions can occur in one of two possible periods (period 1 or 2). 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.

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

Recalling that $\pi^D_{HIGH} > \pi^S_{HIGH}$ and $\pi^D_{LOW} < \pi^S_{LOW}$, 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.

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. For HIGH any strategy that places positive probability on announcing the second period is weakly dominated by announcing the first period. This refinement thus rules out sequential contributions.

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). At the beginning of period 1 players simultaneously choose whether to make an early contribution decision 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.

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 $s_i \in [0, e_i] \cup \{W\}$. 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, there is an equilibrium in which $s_{LOW} = 0$ and $s_{HIGH} = \hat{g}_{HIGH}$. This corresponds to the simultaneous move equilibrium. Second, there is an equilibrium where $s_{LOW} = 0$ and $s_{HIGH} = W$. This corresponds 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.[7] Thus the extended game has three pure strategy subgame perfect equilibria, reproducing the outcomes of the three exogenous move ordering games.[8] 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. In fact, the first two equilibria above are eliminated since for LOW any strategy $s_{LOW} = g_{LOW} \in [0, e_{LOW}]$ is weakly dominated by $s_{LOW} = W$. To see this, notice first that if $s_{HIGH} = W$, LOW is at least as well off waiting as committing to a contribution: $s_{LOW} = W$ yields a payoff to LOW equal to $\pi_{LOW}(W, W) = \pi_{LOW}^S \geq \pi_{LOW}\left(g_{LOW}, \tilde{g}_{HIGH}(g_{LOW})\right) = \pi_{LOW}(g_{LOW}, W)$. Intuitively, since HIGH waits the resulting equilibrium will correspond to a point on HIGH's best-response function, and by waiting LOW attains her most preferred point on HIGH's best-response function. Next note that for any $s_{HIGH} = g_{HIGH} \in [0, e_{HIGH}]$, LOW is also at least as well off waiting as committing to a contribution: $s_{LOW} = W$ yields a payoff to LOW equal to $\pi_{LOW}(W, g_{HIGH}) = \pi_{LOW}(\tilde{g}_{LOW}(g_{HIGH}), g_{HIGH}) \geq \pi_{LOW}(g_{LOW}, g_{HIGH})$. Intuitively, waiting

[7] Note that $s_{HIGH} = s_{LOW} = W$ is not an equilibrium, as this results in a payoff to HIGH of π^S_{HIGH} and a profitable deviation for HIGH is to choose $s_{HIGH} = 0$ which yields $\pi^D_{HIGH} > \pi^S_{HIGH}$.

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

allows LOW to best-respond, which cannot be worse than choosing some contribution. Thus waiting is at least as good as any other strategy. Finally, note that for $s_{HIGH} = g_{HIGH} \geq \hat{g}_{LOW}$ the previous inequality is strict for $s_{LOW} = g_{LOW} > 0$ and so $s_{LOW} = W$ weakly dominates any $s_{LOW} = g_{LOW} \in (0, e_{LOW}]$, while for $s_{HIGH} = g_{HIGH} < \hat{g}_{LOW}$ the inequality is strict for $s_{LOW} = g_{LOW} = 0$ and so $s_{LOW} = W$ weakly dominates $s_{LOW} = g_{LOW} = 0$.

The third equilibrium has LOW play her weakly dominant strategy, $s_{LOW} = W$, while HIGH chooses $s_{HIGH} = g_{HIGH} = 0$. This strategy for HIGH 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. A further equilibrium refinement used in Hamilton and Slutsky (1990), whereby we restrict attention to equilibria in undominated strategies, predicts that the simultaneous move game where both players contribute in the first period will emerge from the extended game with observable delay, and a detrimental move ordering will emerge from the extended game with action commitment. In the former case LOW will contribute zero and HIGH will make her stand-alone contribution in the first period. In the latter case, the prediction is that in the first period HIGH will commit to contributing zero while LOW waits, and in the second period LOW will make her stand-alone contribution.

3. Experiment

Gächter et al. (2009) show that in the exogenous move game aggregate contributions are lower in the detrimental move ordering. However, will this move ordering emerge in practice? Our experiment includes a treatment based on the extended game with observable delay. This setting is theoretically unfavorable to observing the detrimental move ordering: HIGH would like to move first but LOW wants to avoid being second and so it is unclear how sequential moves will emerge. We contrast this with another treatment based on the extended game with action commitment where the detrimental move ordering is predicted. Nevertheless, since in Gächter et al. (2009) there are some discrepancies between observed and predicted contributions and earnings it is open to question whether the predicted timing decisions will be observed.

3.1 The constituent game

Our experiment is based on the following game. There are two players, 'HIGH' and 'LOW'.[9] Each player is endowed with 17 tokens and must decide 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:

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

where $v_{HIGH} = 1.32$ and $v_{LOW} = 0.89$. The payoff functions imply that the HIGH player enjoys a higher return from the public good than the LOW player: in Varian's terminology the HIGH (LOW) player is thus the player who likes the public good most (least). Earnings were presented to subjects in the form of earnings tables (see Appendix B) which rounded earnings to a multiple of 5 points. The rounding preserved the key predictions outlined in the previous sub-section.

Predictions about total contributions and the distribution of contributions depend on the move order. In particular, 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, in the detrimental move ordering where HIGH moves first, HIGH is predicted to contribute 0 tokens and LOW to contribute 6 tokens.

3.2 The experimental treatments

We study endogenous timing in this constituent 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.

[9] 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.

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: either the move ordering where LOW moves first (LOW-FIRST), or the detrimental move ordering where HIGH moves first (HIGH-FIRST). Predictions about which move ordering will emerge are summarized in Table 1.

Table 1. Predicted Move Orderings, Contributions and Payoffs*

treatment	predicted move ordering(s)	predicted contributions {HIGH, LOW}	predicted payoffs {HIGH, LOW}
AC	SIM-1	{15, 0}	{1150, 1555}
	LOW-FIRST	{15, 0}	{1150, 1555}
	HIGH-FIRST+	{0, 6}+	{1340, 890}+
OD	SIM-1+	{15, 0}+	{1150, 1555}+
	LOW-FIRST	{15, 0}	{1150, 1555}

* Predictions are based on subgame perfect equilibrium. Subgame perfect equilibria in undominated strategies are marked with a plus sign.

In the OD treatment, in a subgame perfect equilibrium LOW contributes in period 1, while HIGH can contribute either in period 1 or in period 2. Thus, two possible move orderings are consistent with subgame perfection: SIM-1 and LOW-FIRST. In either of these LOW contributes zero and HIGH contributes 15 tokens. Only the SIM-1 move ordering can emerge in a subgame perfect equilibrium in undominated strategies. In the AC treatment three move orderings are consistent with subgame perfection: SIM-1, LOW-FIRST and HIGH-FIRST. However, only the latter, detrimental, move ordering can emerge in a subgame perfect equilibrium in undominated strategies. The implications for contributions and payoffs are that, according to subgame perfection, contributions and combined payoffs will be no higher in the AC than OD treatment, since the detrimental move ordering can emerge in the former but not in the latter. According to our sharper prediction, contributions and combined payoffs will be lower in the AC than OD treatment, since the detrimental move ordering will emerge in the former but not in the latter.

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.[10] Four sessions were conducted (two sessions for each treatment) with 16 participants per sessions. The average age was 20.8 years and 55% were male. No subject took part in more than one session and so 64 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 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

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

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.[11] 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 test predictions based on a one-shot model 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.[12] 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 converted into British Pounds at a rate of £0.01 per point. Subject earnings ranged from £8.50 to £17.35, averaging £12.62 (at the time of the experiment £1 ≈ $1.44), and sessions lasted about 70 minutes on average.

3.4 Results

Our initial analysis of data focuses on subjects' timing behavior. We then turn to subjects' contribution decisions. We end our analysis by examining the relation between contribution decisions and timing behavior.

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[11] 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.

[12] Subjects' assessment of their own risk preferences was elicited asking the question suggested by Dohmen et al. (2006). 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 5.91 with a standard deviation of 1.89.

3.4.1 Timing behavior in the AC and OD treatments

Table 2 reports the proportions of period 1 choices in the AC and OD treatments. These proportions are based on 960 timing decisions, evenly divided among treatment and type of player. The relative frequency of period 1 contributions is higher in AC (30%) than in OD (17%), but the difference is just marginally insignificant ($p = 0.114$).[13] 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, but the difference falls short of statistical significance ($p = 0.114$ for HIGH; $p = 0.143$ for LOW).

Table 2. Proportions of Period 1 Contributions

	AC			OD		
	round 1 to 8	round 9 to 15	overall	round 1 to 8	round 9 to 15	overall
HIGH	.34	.20	.27	.27	.11	.19
LOW	.35	.31	.33	.18	.13	.16
overall	.34	.25	.30	.22	.12	.17

These patterns are surprising: our theoretical analysis suggests that a substantial fraction of subjects should commit to a contribution in period 1. In both treatments, all the subgame perfect equilibria of the two extended games have at least one player contributing in period 1. Moreover, in OD the only equilibrium in undominated strategies has both players announcing period 1. Contrary to these theoretical results, in our experiment we observe that the majority of subjects prefer to wait until period 2 to make a contribution decision. This is true for both types of player in both treatments. Moreover, there is no trend towards more frequent period 1 choices in later rounds. Table 2 shows the evolution of the relative frequency of period 1 choices from the first to the second half of the experiment: in both treatments and for both HIGH and LOW the proportions of period 1 choices *decrease* over time.

[13] All p-values are based on two-sided randomization tests, unless otherwise reported. Moir (1998) describes the randomization test and discusses its advantages in the analysis of laboratory generated economic data based on small sample sizes. All the statistical tests reported in the paper are applied to 4 independent observations per treatment. Where ties occur we use a conservative approach and break ties in favor of the null hypothesis, i.e. we report the highest p-value from all possible ways to break ties.

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 3 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), and controls for time effects and individual characteristics.[14]

Table 3. Regression Analysis of the Probability of Contributing in Period 1

	coefficient	marginal effect
1 if AC	.402* (.210)	.120
1 if LOW	.068 (.127)	.020
1 if Female	-.427** (.196)	-.125
Willingness to Take Risks	.032** (.015)	.009
Round	-.045*** (.007)	-.014
Constant	-.625*** (.155)	-
N.	*960*	
Prob >χ^2	*.000*	
Pseudo-R^2	*.060*	

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 contributing in period 1 is about 12% higher if a subject participated in the AC treatment and the effect is marginally significant at the 10% level. This result should nevertheless be taken with caution: recall that using the non-parametric randomization test we found that the difference in relative frequencies of period 1 across treatments is marginally insignificant (p = 0.114).[15] The subject's role in the experiment (LOW or HIGH) also does not significantly affect timing behavior: LOW subjects are slightly more likely to choose period 1 but the effect is far from significant (p = 0.589). The regression

[14] 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.

[15] On the one hand the non-parametric test may be preferred because inferences do not rely on auxiliary modeling assumptions, while on the other hand the non-parametric test uses less of the information in the sample and may lack power.

also confirms that the likelihood of committing to a contribution level in period 1 does not increase, but actually decreases over time: the coefficient of the variable Round is negative and highly significant.

Subjects' timing behaviour seems better explained by their personal characteristics: for example, female participants are significantly less likely (about 12%) to make a contribution decision in period 1 than male subjects. This result is consistent with the findings by Arbak and Villeval (2007), who in a related experiment on endogenous leadership in a linear voluntary contributions game find that female participants are significantly less likely to make a leadership contribution than male participants. As commitment 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 want to 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.

Figure 1 and Table 4 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 68% in OD and 49% in AC. Moreover, in both treatments the probability of observing both players contributing simultaneously in period 2 tends to increase substantially in the second half of the experiment (by about 15 percentage points in OD and by 10 percentage points in AC). For our OD treatment our sharp theoretical prediction is that SIM-1 will emerge, but in fact this is quite rare – its probability is 3% and decreases over time. Similarly our sharp prediction for the AC treatment is that the detrimental move ordering will emerge, and again the prediction fails – the probability of HIGH-FIRST is 18% and decreases over time.

Figure 1. Probability of Alternative Move Orderings across Rounds

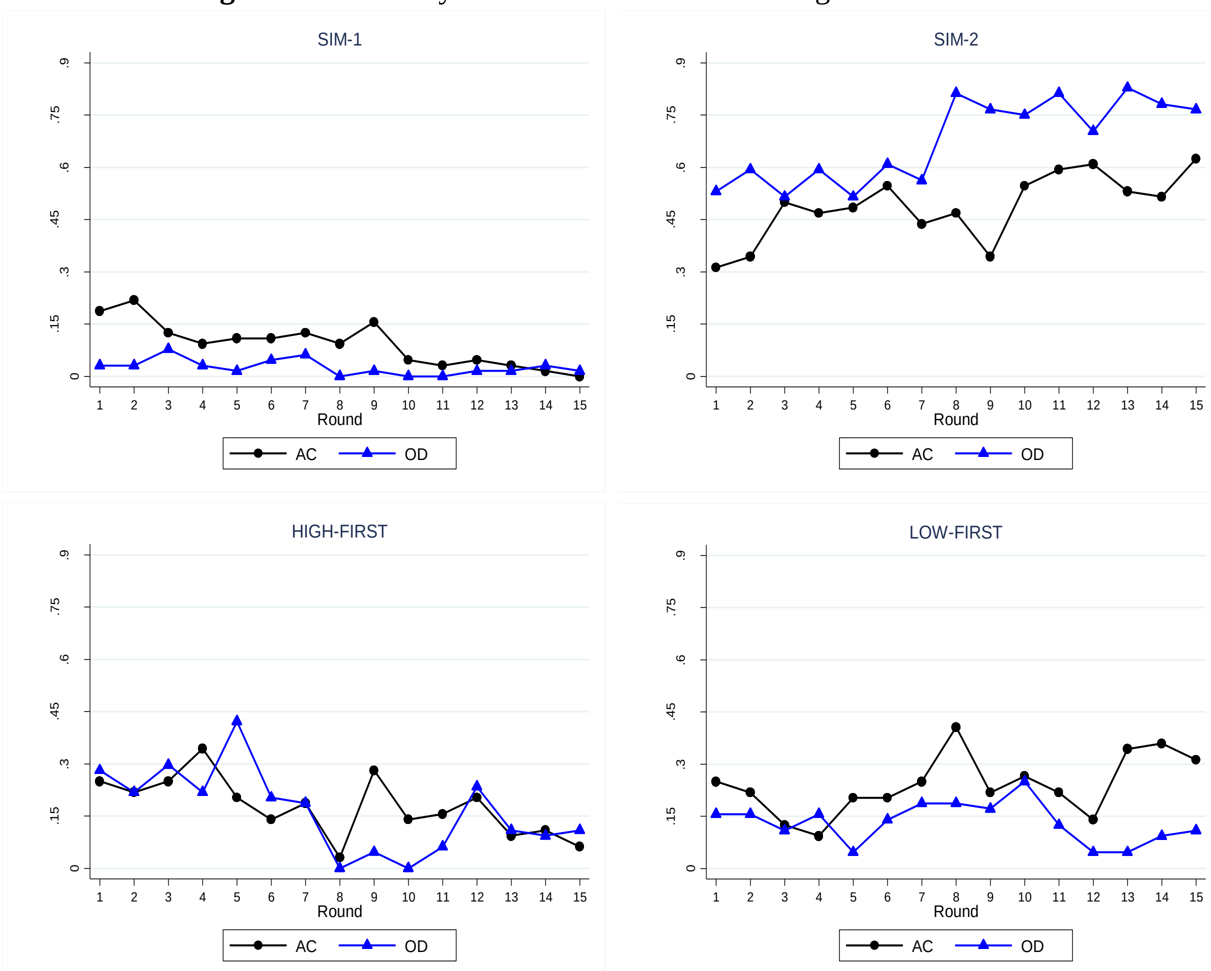


Table 4. Probability of Alternative Move Orderings *

	AC			OD		
		round			Round	
move ordering	overall	1 to 8	9 to 15	overall	1 to 8	9 to 15
SIM-1	.09 *(.06)*	.13 *(.09)*	.05 *(.04)*	.03 *(.01)*	.04 *(.02)*	.01 *(.01)*
SIM-2	.49 *(.16)*	.44 *(.20)*	.54 *(.13)*	.68 *(.05)*	.59 *(.05)*	.77 *(.09)*
HIGH-FIRST	.18 *(.04)*	.20 *(.09)*	.15 *(.12)*	.17 *(.04)*	.23 *(.09)*	.09 *(.03)*
LOW-FIRST	.24 *(.12)*	.22 *(.08)*	.27 *(.19)*	.13 *(.07)*	.14 *(.09)*	.12 *(.07)*

* 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.

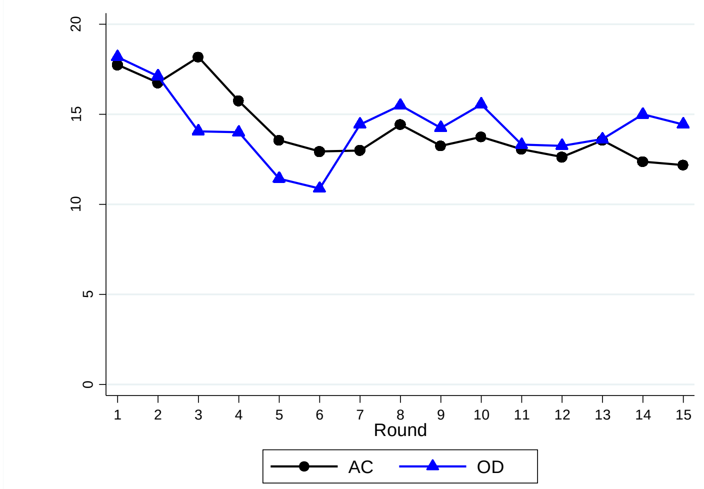
We summarize our main findings about the timing behavior observed in the experiment in our first result:

> **RESULT 1:** Both LOW and HIGH subjects show 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, by far the most likely move ordering in our experiment is SIM-2, where neither player commits to a contribution decision in period 1. This result contrasts with theoretical predictions: in theory all the subgame perfect equilibria of our two extended games have at least one player contributing in period 1.

3.4.2 Contribution behavior in the AC and OD treatments

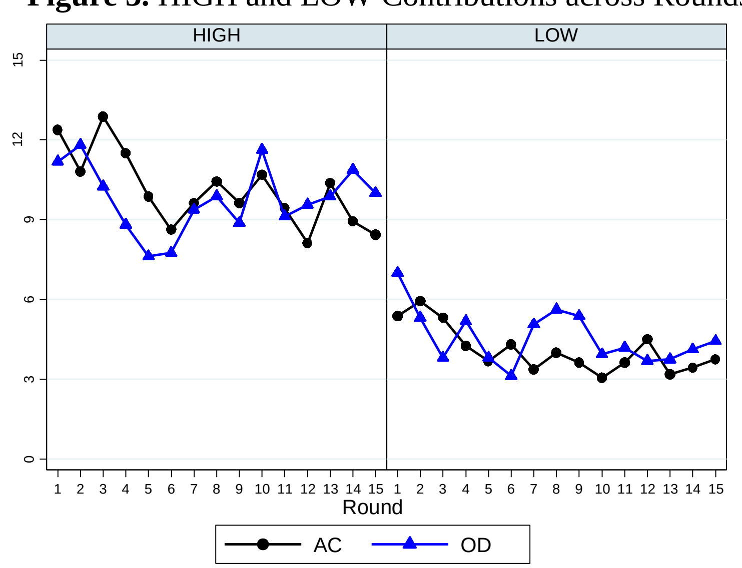
To begin our analysis of contribution behavior we start by looking at aggregate contributions to the public good made by pairs of subjects in each treatment, simply pooling across different move orderings. Figure 2 shows the development of average aggregate contributions across the 15 rounds of the experiment. Contributions are somewhat higher in the very first rounds and then stabilize to a lower level. The pattern is common to both treatments and aggregate contributions across the whole 15 rounds are in fact very similar, averaging 14.3 tokens in OD and 14.2 tokens in AC ($p = 0.943$).

Figure 2. Aggregate Contributions across Rounds



The distribution of contributions across HIGH and LOW subjects is also very similar across the two treatments. Figure 3 shows how average contributions by type of player develop across rounds. In both treatments HIGH subjects contribute on average more tokens to the public good than LOW subjects: HIGH subjects contribute on average 9.8 tokens in OD and 10.1 tokens in AC ($p = 0.543$), and LOW subjects' contributions across the whole 15 rounds average 4.6 in OD and 4.1 in AC ($p = 0.743$).

Figure 3. HIGH and LOW Contributions across Rounds



These patterns partly reflect our findings about subjects' timing behavior. As discussed in the previous sub-section, both in AC and in OD a large fraction of subjects choose to delay their contribution decisions until period 2. As a consequence, by far the most common move ordering observed in the two treatments of our experiment was SIM-2, where predicted aggregate contributions equal 15 tokens and the distribution of contributions across type of player is one where HIGH contributions exceed LOW contributions (see Table 1 above). Moreover, HIGH-FIRST is the only move ordering where predicted aggregate contributions differ from 15 tokens and the predicted distribution of contributions has LOW contribute more than HIGH, and this move ordering was observed in only one-sixth of the games played within each treatment.

Table 5 shows how aggregate contributions break out across the four possible move orderings of our extended games. In line with theory predictions, contributions are lower in HIGH-FIRST than in the other move orderings. Aggregate contributions in HIGH-FIRST average 12.2 in AC and 11.2 in OD, about double the predicted level, although in both treatments contributions converge to lower values in the games played in the second part of the experiment. Aggregate contributions in the most common move ordering (SIM-2) are the most aligned with theoretical predictions: in both treatments contributions average about 14 tokens and this outcome appears stable across rounds.

Table 5. Aggregate Contributions per Treatment and Move Ordering [*]

treatment	move ordering	predicted	overall	round 1 to 8	round 9 to 15
AC	SIM-1	*15*	19.0 *(8.46) (n =25)*	19.8 *(7.62) (n =20)*	16.0 *(11.79) (n =5)*
	SIM-2	*15*	14.3 *(6.29) (n =120)*	14.2 *(6.97)(n =60)*	14.4 *(5.58) (n =60)*
	HIGH-FIRST	*6*	12.2 *(6.98) (n =40)*	14.3 *(6.43)(n =23)*	9.4 *(6.89) (n =17)*
	LOW-FIRST	*15*	13.2 *(6.66) (n =55)*	15.2 *(6.53)(n =25)*	11.5 *(6.40) (n =30)*
OD	SIM-1	*15*	15.3 *(4.68) (n =7)*	14.8 *(5.36) (n =5)*	16.5 *(3.53) (n =2)*
	SIM-2	*15*	14.5 *(6.23) (n =163)*	14.8 *(6.33)(n =76)*	14.1 *(6.16) (n =87)*
	HIGH-FIRST	*6*	11.2 *(6.24) (n =39)*	11.6 *(6.19)(n =29)*	10.0 *(6.55) (n =10)*
	LOW-FIRST	*15*	17.4 *(7.04) (n =31)*	17.3 *(7.13)(n =18)*	17.6 *(7.19) (n =13)*

[*] 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 6 shows how contributions vary by type of player as well as by treatment and move ordering. We notice that HIGH and LOW contributions tend to differ substantially from the point predictions made by theory in all cases. In most of the cases where HIGH is predicted to contribute 15 and LOW is predicted to contribute zero, HIGH contributes on average between 9 and 11 tokens, and LOW between 4 and 7 tokens. In HIGH-FIRST, where HIGH is predicted to contribute zero and LOW 6 tokens, HIGH (LOW) contributions are clearly higher (lower) than the predicted level. In fact, contrary to theoretical predictions, HIGH contribution behavior does not seem to differ much across the different move orderings and LOW contributions are actually lowest in HIGH-FIRST. As a result, the distribution of contributions is more even than predicted.

Table 6. Individual Contributions by Type of Player*

Treatment	Move ordering	HIGH		LOW	
		predicted	observed	predicted	observed
AC	SIM-1 *(n =25)*	*15*	11.4 *(4.74)*	*0*	7.7 *(4.75)*
	SIM-2 *(n =120)*	*15*	10.3 *(4.75)*	*0*	4.0 *(4.21)*
	HIGH-FIRST *(n =40)*	*0*	10.0 *(5.61)*	*6*	2.2 *(3.57)*
	LOW-FIRST *(n =55)*	*15*	9.2 *(5.06)*	*0*	4.0 *(4.48)*
OD	SIM-1 *(n =7)*	*15*	9.0 *(4.76)*	*0*	6.3 *(3.35)*
	SIM-2 *(n =163)*	*15*	10.2 *(4.93)*	*0*	4.3 *(3.70)*
	HIGH-FIRST *(n =39)*	*0*	8.3 *(5.82)*	*6*	2.8 *(4.04)*
	LOW-FIRST *(n =31)*	*15*	9.5 *(4.88)*	*0*	7.9 *(4.21)*

*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. (2009), 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 7 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). The similarity between the data indicates that subjects' behavior in subgames is not affected by whether these have been reached endogenously or not. Note that Gächter et al. (2009) also find that the distribution of contributions across type of player is more even than predicted. As in our HIGH-FIRST and LOW-FIRST move orderings, in their sequential treatments first-movers contribute substantially more than predicted and second-movers contribute less than predicted. Gächter et al. (2009) find that this can be explained by a tendency of second-movers to punish first-movers for excessively low contributions by systematically contributing less than their best-response. Although we have too few observations on second-mover behavior to conduct the same analysis as Gächter et al. (2009), our data suggest a similar phenomenon in our endogenously determined sequential subgames. For example pooling data from our two treatments, we note that when HIGH contributes 0 as a first-mover LOW contributes 3.64 tokens on average (n=11), and when LOW contributes 0 as a first-mover HIGH contributes 8.68 tokens on average (n=28). Note that by contributing one less token than the 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 best response, whereas the punishee's earnings function is strictly increasing in the punisher's contribution.

Table 7. Contributions under Exogenous 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 = 170)	14.5 *(6.16)*	10.1 *(4.91)*	4.3 *(3.70)*
HIGH-FIRST	Exogenous (n = 240)	10.2 *(5.39)*	7.7 *(5.42)*	2.5 *(3.16)*
	Endogenous (n = 39)	11.2 *(6.24)*	8.3 *(5.82)*	2.8 *(4.04)*
LOW-FIRST	Exogenous (n = 240)	13.3 *(6.04)*	9.4 *(4.86)*	3.9 *(3.90)*
	Endogenous (n = 31)	17.4 *(7.04)*	9.5 *(4.88)*	7.9 *(4.21)*

*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 T89 treatments of Gächter et al. (2009). The endogenous move orderings data are from our OD treatment, pooling the data from SIM-1 and SIM-2 move orderings.

Since the observed distribution of contributions across types of player differs substantially from theoretical point predictions, it is not surprising that average earnings made by HIGH and LOW subjects in the different move orderings are not in line with the predicted earnings. In particular, in theory both HIGH and LOW should prefer the move ordering where they move first, commit to zero initial contributions, and force the other player to provide the public good: thus, theory predicts that a first-mover advantage and a second-mover disadvantage exists in the two extended games. Our data cannot confirm this prediction. Table 8 shows the observed average earnings made by HIGH and LOW subjects in the two sequential move orderings in AC and OD. We find no evidence that HIGH and LOW subjects are better off when they move first than when they move second. In fact, in both treatments HIGH subjects are worse off in HIGH-FIRST, where they move first, than in LOW-FIRST, where they move second, and vice versa for LOW subjects. This result also replicates the findings by Gächter et al. (2009).

Table 8. Earnings by Type of Player*

treatment	move ordering	HIGH		LOW	
		predicted	observed	predicted	observed
AC	HIGH-FIRST *(n = 40)*	*1340*	1182 *(168.3)*	*890*	1307 *(226.6)*
	LOW-FIRST *(n = 55)*	*1150*	1283 *(237.8)*	*1555*	1258 *(209.7)*
OD	HIGH-FIRST *(n = 39)*	*1340*	1220 *(253.3)*	*890*	1240 *(264.3)*
	LOW-FIRST *(n = 31)*	*1150*	1468 *(234.3)*	*1555*	1198 *(176.7)*

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

We summarize our main findings about the contribution behavior observed in the experiment in the following result:

RESULT 2: In both treatments of our experiment, aggregate contributions are lowest when the HIGH player moves first. The distribution of contributions across types of player is more even than predicted. One consequence is that, contrary to theoretical predictions, we fail to observe a first-mover advantage in either treatment.

3.4.3 Can contribution behavior explain timing behavior?

The absence of a first-mover advantage in both treatments of our experiment could constitute a plausible explanation for the observed low frequencies of period 1 choices by both LOW and HIGH subjects. Since contributing first is less profitable than contributing second, it seems reasonable that subjects preferred contributing in period 2 to contributing in period 1.

Table 9 reports the average payoff that subjects earned by contributing in period 1 and in period 2, conditional on the period choice of their opponent. In both AC and OD LOW subjects' average earnings are higher when they wait to contribute until period 2 irrespective of the opponent's timing decision. For AC it is complicated to draw a parallel between the empirical payoffs shown in Table 9 and the theoretical payoffs in the reduced game with action commitment since the empirical payoffs are averaged over a variety of contribution decisions. Nevertheless, Table 9 suggests that LOW is better off waiting than committing to a contribution in period 1; given this HIGH does better by waiting also. For OD, while the theoretical analysis of the reduced game with observable delay shows that both LOW and HIGH have a weakly dominant strategy to announce the period 1, based on the empirically observed payoffs both have a strictly dominant strategy to announce period 2. Thus, the unique equilibrium of the reduced game with observable delay computed using empirical rather than subgame perfect payoffs has both players announcing period 2.

Table 9. Earnings by Type of Player*

AC treatment	LOW	
HIGH	*g in* t_{LOW}=1	*WAIT*
g in t_{HIGH}=1	1418,1236	1182, 1307
WAIT	1283,1258	1296,1298
OD treatment	LOW	
HIGH	t_{LOW}=1	t_{LOW}=2
t_{HIGH}=1	1435,1236	1220, 1240
t_{HIGH}=2	1468, 1198	1308, 1292

* The table shows subjects' average earnings in points, $(\pi_{HIGH}; \pi_{LOW})$, conditional on their timing choice and their opponent's timing choice.

A problem with this explanation is that subjects did not observe the data shown in Table 9: each subject was only informed of her own and her opponent's payoff at the end of each round. Moreover, some subjects did not experience all possible move orderings, and others had only very limited experience with some move orderings. For example, about 20% of our subjects *never* made a contribution decision in period 1 and only half of our subjects made an early contribution in more than three rounds of the experiment. Thus it is not clear how subjects could become aware of the absence of a first-mover advantage. For this reason we examine in more detail the payoffs observed by subjects and how these influence timing decisions by performing a regression analysis of the probability of making a contribution in period 1 on the experienced earnings differentials between period 1 and period 2 play.

For each subject we compute the average earnings, measured in hundreds of points, that she made by contributing in period 1 and in period 2 in the first 8 rounds of the experiment. We then compute the difference between average period 1 earnings and average period 2 earnings and record the value in the variable $\Delta EARN_i$. This variable is positive if the subject observed that period 1 play yielded her higher average earnings than period 2 play in the first 8 rounds of the experiment, and negative otherwise. For subjects who always contributed in period 1 or always contributed in period 2 we set $\Delta EARN_i$ to zero. We then augment our earlier regression model (see Table 3) with the variable $\Delta EARN_i$ and estimate the model using data from the last 7 rounds of the experiment. If prior success with choosing period 2 relative to period 1 explains the predominance of period 2 choices we would expect the $\Delta EARN_i$ variable to be significantly positive. Table 10 reports the probit estimates of the regression model.

Consistent with the suggested explanation for timing behavior, the coefficient of the variable $\Delta EARN_i$ is positive. However, the marginal effect is small: a 100 point difference between period 1 and period 2 earnings would increase the probability of choosing period 1 by less than ½ %. Moreover, we cannot reject the hypothesis that the coefficient on $\Delta EARN_i$ is equal to zero ($p = 0.899$). The pattern of results for the other variables included in the model resembles the one already observed in Table 3: subjects who participated in the AC treatment are marginally more likely to contribute in period 1, and men are more likely to contribute early than women. The Round variable is no longer significant. This may indicate that timing behaviour is stable in the last 7 rounds of the experiment, or it may reflect the smaller sample size underlying the augmented regression results. Similarly, the Willingness to Take Risks variable is no longer significant.

Table 10. Regression Analysis of the Probability of Contributing in Period 1

	coefficient	marginal effect
$\Delta EARN_i$	.015 *(.121)*	.004
1 if AC	.465* *(.241)*	.116
1 if LOW	.302 *(.227)*	.075
1 if Female	-.554** *(.259)*	-.135
Willingness to Take Risks	.057 *(.077)*	.014
Round	-.046 *(.035)*	-.011
Constant	-.885** *(.441)*	-
N.	*448*	
Prob >χ^2	*.000*	
Pseudo-R^2	*.084*	

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

Overall, these findings cast some doubt on the proposed explanation for the propensity to contribute in period 2. An alternative explanation for the observed tendency to delay one's contributions until the second period could be that subjects have an intrinsic preference for waiting. For example, delaying contribution decisions until the second period may be valued as a way to gain confidence about one's decision by some subjects. This explanation would be consistent with the findings by Tykocinski and Ruffle (2003), who show that the decision to delay one's decision in individual decision-making tasks appeals most to those who are less resolute about their decision. In strategic contexts an additional reason why individuals may prefer to wait is that by waiting they 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.[16] Free-form comments left by subjects in the post-experimental questionnaire about the motivations underlying their choices in the course of the experiment support this interpretation.[17]

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 more fundamental 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. (2009), we do find that aggregate contributions are 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 usually *avoid* committing to an early contribution. This holds true irrespective of agents’ valuation of the public good, and irrespective of how commitment opportunities are modeled. Following Hamilton and Slutsky (1990) we embody commitment opportunities within extended games. In one treatment the detrimental move ordering is not predicted, nor is it often observed. Interestingly, while in theory both players should choose to contribute early, resulting in a

[16] Fonseca, Müller, and Normann (2006) also offer this preference-based explanation as an alternative account for the timing behavior observed in their experiment on endogenous timing in duopoly games.

[17] 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”.

simultaneous move game in the first period, in actuality players tend to delay and play a simultaneous move game in the second period. In a second treatment the detrimental move ordering is predicted but in our data it is rarely observed. Theory predicts that the player with a low valuation of the public good waits, and the player with the high valuation exploits this by immediately committing to contributing zero. In our experiment, by far the most common outcome is for both players to wait.

We argue that this tendency to avoid commitment reflects an intrinsic preference for delaying one's decisions as a way to resolve strategic uncertainty about the opponent's actions, and more generally to gain confidence about one's choices. We also notice that the contribution behavior observed in our experiment leaves little room for a subject to exploit other subjects who follow this "waiting strategy". 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.

Overall, these 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.

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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