SYMPOSIUM

Jan Potters · Martin Sefton · Lise Vesterlund

Leading-by-example and signaling in voluntary contribution games: an experimental study

Abstract We report experimental results on the effect of leadership in a voluntary contribution game. Consistent with recent theories we find that leading-by-example increases contributions and earnings in an environment where a leader has private information about the returns from contributing (Hermalin in Am Econ Rev 88:1188–1206, 1998; Vesterlund in J Public Econ 87:627–657, 2003). In contrast the ability to lead-by-example has no effect on total contributions and earnings when such returns are commonly known. In our environment the success of leadership therefore appears to be driven by signaling rather than by nonpecuniary factors such as reciprocity.

J. Potters
Tilburg University, Tilburg, The Netherlands

M. Sefton
University of Nottingham, Nottingham, UK

L. Vesterlund (✉)
University of Pittsburgh, Pittsburgh, PA 15620, USA
E-mail: vester@pitt.edu

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1 Introduction

In many naturally-occurring voluntary-contribution environments a leader can choose her actions before others. For example, the leader of a work team can choose her effort prior to other workers; a community leader may volunteer before others; individuals may contribute to a charity before other potential donors; or a nation may be first to commit to participation in an international environmental agreement. Field experiments suggest that contributions may increase when a sequential mechanism is employed.[1] The objective of the present paper is to examine why the ability to "lead-by-example" may increase contributions.

One possible reason is that the leader's action conveys relevant information to followers. In particular a leader's contribution may signal to followers that it is in their interest to contribute as well. For example, in the case of team production some workers may be better informed of the value of team output than others, and likewise, in the case of charities, some donors may be better informed than others of the value of their donations. Theoretical work has shown how, in the presence of asymmetric information, leading-by-example can improve group performance and enhance efficiency (Hermalin 1998; Vesterlund 2003).

In an environment where there is uncertainty about the quality of a public good Potters et al. (2005) find that contributions to the public good are larger when players move sequentially. While this result matches the signaling prediction, it is also consistent with alternative explanations. In particular the outcome may be the same when followers are reciprocal and mimic leader contributions. If a leader anticipates such behavior, then even a self-interested leader may decide to contribute although, in a simultaneous-move environment, she would not. Thus reciprocity may cause larger contributions in the sequential- than simultaneous-move game. Motives such as inequality aversion, prestige, or status may have similar effects, as these too can cause followers to have upward sloping response functions (Romano and Yildirim 2001).[2] While signaling only can influence the ability to lead-by-example when there is asymmetric information, reciprocity may render leading-by-example effective in both an asymmetric- and full-information environment. Since Potters et al. only examine an asymmetric-information setting it is not possible to determine whether the substantial effect of leading-by-example is caused by signaling or reciprocity.

Recent studies present mixed results on whether reciprocity causes leading-by-example to be effective in full-information settings. In a public-bad setting Moxnes and Van der Heijden (2003) show that the presence of a leader improves the overall outcome, as the average extraction rates are significantly lower with sequential than simultaneous moves. Meidinger and Villeval (2002) also conclude that rec-

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[1] Silverman et al. (1984) examine a national telethon and show that announcing the names of individuals pledging money and the amount of money pledged resulted in greater contributions. List and Lucking-Reiley (2002) demonstrate that larger initial contributions increase subsequent donations. Shang and Croson (2003) find that contributions increase with the size of the previously announced contribution. Soetevent (2005) finds that offerings for charitable purposes are significantly higher when open rather than closed church collection baskets are used.

[2] Kumru and Vesterlund (2004) investigate the effect of status on sequential giving.

iprocity causes leading-by-example to be effective. In contrast, sequential moves have not been found to increase contributions in a quasi-linear public good environment (Andreoni et al. 2002) nor in a linear public good environment (Gaechter and Renner 2003).

Using laboratory experiments we examine the effect of leading-by-example in both an asymmetric- and full-information environment. If leading-by-example is found to be equally effective under the two information treatments, then it is likely that nonpecuniary factors such as reciprocity can account for the increase in contributions. If on the other hand sequential moves do not increase contributions in the full-information case then signaling is the more suitable explanation for the success of leadership in the asymmetric-information case. By comparing the sequential- and simultaneous-contribution games in both full- and asymmetric-information environments we can identify the joint impact of asymmetric information and sequential play.

We describe our basic model in the next section, our experimental design in Sect. 3, and our results in Sect. 4. Section 5 concludes.

2 A simple model of leading-by-example

Our experiment is based on a simple voluntary contribution game. There are two players, Leader (L) and Follower (F). Each player decides whether to contribute ($x_i = 1$), or not ($x_i = 0$) to a group activity. The payoff functions are

$$\pi_i = 1 - x_i + m(x_L + x_F), \quad i \in \{L, F\},$$

where m is the private return (and $2m$ is the social return) from a contribution. The value of m is drawn by Nature, and is equally likely to be either 0, 0.75, or 1.5. A fully efficient outcome, in the sense of joint-payoff maximization, requires that neither player contributes if $m = 0$ and both players contribute if $m = 0.75$ or $m = 1.5$. To illustrate how the ability to lead-by-example affects contributions we examine the equilibria that arise when the leader's choice is or is not observed by the follower.

Suppose both players observe m before making their choices, and that this is common knowledge. In this *full-information* environment, regardless of whether the leader's choice is observed, there is a unique Nash equilibrium in which no player contributes if $m = 0$ or $m = 0.75$, and both players contribute if $m = 1.5$. Thus, when $m = 0.75$ contributions are inefficiently low.

Now consider an *asymmetric-information* environment where the leader observes m prior to making her choice, but the follower only knows the distribution of m, and that this is common knowledge. When players choose simultaneously the follower makes his decision based solely on the distribution of m. With an expected value of m of 0.75 a risk-neutral follower will choose not to contribute. The leader, however, can condition her choice on the realization of m, and will contribute if and only if $m = 1.5$. In this case, compared with the full-information environment, there is an additional inefficiency because followers fail to contribute when $m = 1.5$. Consider instead the sequential case where the leader chooses first, and then, after observing her choice, the follower makes his choice. This structure enables the follower to draw inferences about m from the leader's decision, and

Table 1 Equilibrium and efficient choices

	$m = 0$	$m = 0.75$	$m = 1.5$
Full-info. equilibrium			
Simultaneous	$x_L = x_F = 0$	$x_L = x_F = 0$	$x_L = x_F = 1$
Sequential	$x_L = x_F = 0$	$x_L = x_F = 0$	$x_L = x_F = 1$
Asymmetric-info. equilibrium			
Simultaneous	$x_L = x_F = 0$	$x_L = x_F = 0$	$x_L = 1, x_F = 0$
Sequential	$x_L = x_F = 0$	$x_L = x_F = 1$	$x_L = x_F = 1$
Efficient choices	$x_L = x_F = 0$	$x_L = x_F = 1$	$x_L = x_F = 1$

the leader will adjust her contribution decision in anticipation of these inferences. In the unique perfect Bayesian equilibrium of this signaling game the leader contributes if and only if it is efficient to do so ($m = 0.75$ or $m = 1.5$), and the follower copies her action. Thus in the case of asymmetric information the ability to lead-by-example increases both follower and leader contributions and a fully efficient outcome is attained for every value of m. Table 1 summarizes the efficient and equilibrium outcomes.

The dynamics of our model is similar to that of Hermalin (1998) and Vesterlund (2003).[3] Using perfectly revealing signals these models focus on the gain achieved from revealing the signal to the follower (i.e., securing contributions when $m = 1.5$). By restricting the available signals the efficiency gain in our model is even greater as we also secure contributions when $m = 0.75$. Thus the equilibrium may be more efficient with asymmetric rather than full information.[4]

Now we illustrate that sequential moves also may increase contributions when individuals are motivated by nonpecuniary factors such as reciprocity or inequality aversion. If the follower is motivated by reciprocity then he may interpret a decision by the leader to contribute as a kind act and a decision not to contribute as an unkind act, and he may reciprocate this (un)kindness. If the leader anticipates such a reciprocal response then the final outcome could be identical to that of the signaling equilibrium.

A similar prediction arises if participants have inequality-averse preferences as in Fehr and Schmidt (1999).[5] We assume for simplicity that preferences are common knowledge and that individuals only are averse to advantageous inequality, i.e., a player's utility is $U_i = \pi_i - \beta_i \max\{\pi_i - \pi_j, 0\}$. To rule out signaling we assume that both players observe m before making their choices, and we focus on the case $m = 0.75$. Absent signaling, this corresponds to the follower's expected value of contributing in the asymmetric information case.

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[3] While Hermalin studies a team production model, Vesterlund examines a model of charitable giving. Although both models show that sequential moves may improve efficiency in an asymmetric information setting, there are a number of differences. Perhaps most important is that Hermalin does not allow for the possibility that contributions crowd out giving by others. While there is no such negative correlation in our model it is present in a more general model of public good provision. Indeed if one extends Hermalin's model to such an environment then sequential moves will often result in smaller contributions.

[4] Komai (2005) examines a similar model.

[5] A similar analysis could be performed using the social preference model of Bolton and Ockenfels (2000). See Bolton and Ockenfels (2005) for a comparison of social preference models based on relative payoffs considerations and those based on (inferred) intentions.

When both players are sufficiently averse to advantageous inequality it may be an equilibrium for both to contribute even when they move simultaneously. To see this, suppose that the follower expects the leader to contribute. By contributing as well he will get utility $2m = 1.5$; by not contributing he will get utility $1 + m - \beta_F(1 + m - m) = 1.75 - \beta_F$. Contributing is optimal if $\beta_F \geq 0.25$. Hence, a necessary condition for both players contributing to be an equilibrium in the simultaneous game is that $\beta_F \geq 0.25$ and $\beta_L \geq 0.25$. This is not the only equilibrium, however. Irrespective of the values of β it is always an equilibrium for both players not to contribute.

The case for efficiency is considerably more favorable when players move sequentially. First, the follower will mimic the leader's decision to contribute when $\beta_F \geq 0.25$. If the leader anticipates this, she will contribute irrespective of her level of inequality aversion. Thus, only the follower's degree of inequality aversion matters in the sequential game. Second, unlike the simultaneous game, the equilibrium in which both players contribute is the unique equilibrium in the sequential game when $\beta_F \geq 0.25$.

3 Experiment

We examined two-person simultaneous and sequential contribution games under both asymmmetric and full information conditions. Thus the experiment consisted of four different treatments. For each treatment we ran four sessions, with 12 subjects in each session, for a total of 192 subjects. Subjects were undergraduate students at the University of Nottingham and randomly assigned to a treatment. No subject participated in more than one session of the experiment.

All sessions used an identical protocol. Upon arrival, subjects were randomly assigned a computer terminal and given a role as Leader or Follower, which they retained throughout the session.[6] This allocation of roles was described in a set of written instructions that the experimenter read aloud.[7] As part of the instructional phase, subjects completed a quiz on how to calculate the payoffs of the game, and the experimenter checked that all subjects had completed the quiz correctly before continuing with the instructions. Subjects were allowed to ask questions by raising their hand and speaking to the experimenter in private. Subjects were not allowed to communicate with one another throughout the session, except via the decisions they entered on their terminal.

To provide subjects an opportunity to learn while capturing the one-shot nature of the theory, the decision-making phase of the session consisted of 18 rounds in which leaders were randomly and anonymously paired with followers. The random pairing was done under the stipulation that no one played another subject twice in a row, and that no pair of subjects would be matched more than three times.[8] Subjects' identities were never revealed to anyone.

In each round the subjects were given the choice between two actions: A or B. Choosing A gave the individual a certain private return of 40 pence. Choosing B

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[6] The roles were labeled "first-mover" and "second-mover" in the instructions and software.

[7] Reading the instructions aloud caused the information and move structure to become public knowledge. A copy of the instructions can be found at http://www.pitt.edu/~vester/.

[8] The same randomly generated matching scheme was used in all sessions.

gave both subjects a return of 0, 30, or 60 pence, where subjects were told each value was equally likely. In terms of the model in Sect. 2, choosing A corresponds to not contributing ($x_i = 0$) and B corresponds to contributing ($x_i = 1$). Subject i's payoff, in pence, was $\pi_i = 40(1 - x_i + m(x_i + x_j))$, where $m = 0, 0.75$, or 1.5, which corresponds to the payoff function of Sect. 2 after appropriate normalization.

In all treatments, at the beginning of each round leaders were informed of the return from B and were prompted to choose A or B. When all leaders had chosen, followers were either informed of the return from B (full-information treatments) or told that each of the three values was equally likely (asymmetric-information treatments). Similarly the follower was either informed of the leader's choice (sequential treatments) or not informed (simultaneous treatments). The follower then chose between A or B. [9] At the end of each round, subjects were informed of choices and payoffs in their game, as well as the actual return from B, and they recorded these on a record sheet.

For each session of the experiment a total of 108 joint decisions were made (6 pairs × 18 rounds). The corresponding sequence of 108 values of m was randomly drawn prior to the experiment, with $m = 0$ being observed 34 times, $m = 0.75$ a total of 39 times, and $m = 1.5$ a total of 35 times. This same sequence provided the values of the return from B for all sessions.

At the end of the experiment subjects were paid their earnings from all 18 rounds in private. All sessions lasted less than an hour and subjects earned an average of £ 11.52 (with a minimum of £ 6.90 and a maximum of £ 13.80). [10]

4 Results

In our analysis of the results we report on the effect of leadership first in the asymmetric information environment and then in the full-information one. [11]

4.1 Asymmetric information

The evidence from the asymmetric-information treatments strongly supports the prediction that revealing the leader's choice increases contributions. In the sequential treatment total contributions are 50% larger than those observed in the simultaneous treatment. [12] This increase in contributions is significant whether we look at all rounds or just the first nine or last nine rounds. [13]

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[9] Note that all sessions have sequential moves in the sense of priority in time.

[10] At the time of the experiment the exchange rate was approximately £1 = \$1.45.

[11] Part of the data from the asymmetric-information condition is also presented in Potters et al. (2005). While the purpose of that study was to determine whether sequential moves arise endogenously, a comparison of behavior between the endogenously-generated and exogenously-imposed games was included to determine how sensitive behavior is to the pre-play signals involved in the endogenously-generated games. Here we focus exclusively on exogenous games and provide a more detailed analysis of differences between the sequential and simultaneous move treatments.

[12] Average group contributions per session are 117.25 in the sequential treatment, and 76.75 in the simultaneous treatment. The maximum feasible contribution is 216, and the efficient contribution is 148.

[13] In all three cases $p = 0.0143$. All of our results are unchanged whether we base the analysis on first nine, last nine, or all rounds, and so in the rest of the paper we only refer to analysis based on all rounds. Unless otherwise noted all reported test statistics refer to Wilcoxon rank-sum
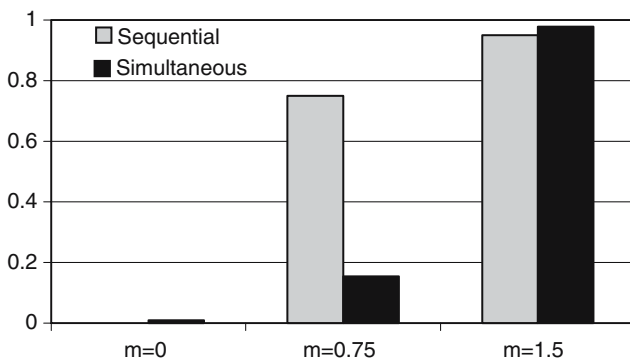
Fig. 1 Leader contribution rates under asymmetric information

What causes contributions to increase? The answer is twofold. First, in the sequential treatment the follower is very likely to mimic the decision of the leader. Second, the leader appears to correctly anticipate this response.

In the sequential treatment followers mimic a contribution by the leader 80.6% of the time, and they mimic the leader's decision not to contribute in 92.2% of the cases. Using a binomial test we find that followers are significantly more likely to contribute when leaders contribute.[14] Although followers mimic leaders' decisions less than the 100% predicted by equilibrium, it is still sufficient to make contributions at $m = 0.75$ the expected payoff-maximizing strategy for the leader. Given a return of $m = 0.75$ a payoff-maximizing leader should contribute if she believes that doing so will increase the probability that the follower contributes by at least 33.3%-points. Since in our data a leadership contribution increases the follower's contribution rate by 72.8%, it is in the leader's best interest to contribute.

The leaders' behavior suggests that the vast majority correctly anticipate the follower's response. Figure 1 displays leader-contribution rates when faced with a given value of m. For both the sequential and simultaneous treatments leaders almost never contribute when $m = 0$, and they almost always contribute when $m = 1.5$. As predicted the noticeable difference between the two treatments occurs when $m = 0.75$. When $m = 0.75$ we see a signifciant increase in leader contribution rates from 15% with simultaneous moves to 75% with sequential moves (exact one-sided p-value equals 0.0143). Thus, in the asymmetric-information environment leaders are more likely to make efficient decisions when their decisions are observed by followers.

Does observing the leader's contribution cause followers' decisions to be more efficient? Figure 2 displays follower–contribution rates conditional on m. For comparison, the contribution rates for the simultaneous treatment are also shown. In the sequential treatment, where leaders contribute more often when the return is high, the uninformed followers can, by mimicking the leader, limit their inefficient contributions ($m = 0$), and increase their efficient contributions ($m = 0.75$

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tests applied to session level data (i.e., aggregating data within a session and treating it as one independent observation). See Siegel and Castellan (1988) for a discussion of this test.

[14] In all four sessions of the sequential treatment there is a (strong) positive correlation between leader and follower choices. Thus, the test rejects the null hypothesis that followers are not influenced by the leaders' decisions in favor of the (one-sided) alternative that followers' contributions increase with leaders' ($p = 0.0625$). See Siegel and Castellan (1988) for a discussion of this test.
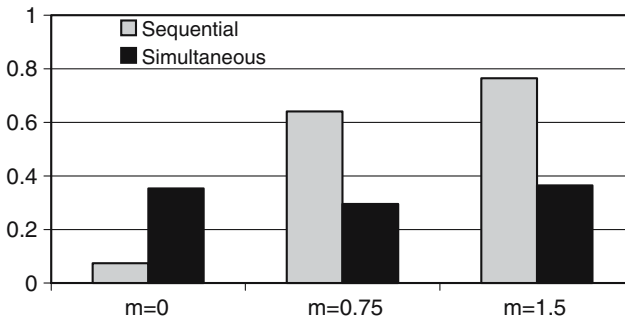
Fig. 2 Follower contribution rates under asymmetric information

or $m = 1.5$).[15] Thus, as with leaders, followers' contributions are more efficient under the sequential mechanism. It is not only efficient for followers to mimic the leader, it is also in their best interest to do so. When the leader contributes, followers on average earn 91.0 pence when contributing as well, and 85.9 pence when not contributing. When the leader does not contribute, followers earn 40 pence when mimicking the leader, but only 12.9 pence when contributing.[16]

Combining the leader and follower decisions we see that the sequential mechanism improves group welfare.[17] This is because combined contributions are significantly higher when $m = 0.75$ or 1.5, and significantly lower when $m = 0$.[18] Table 2 summarizes earnings in the two treatments. Observed earnings are 91% of the predicted efficient level in the sequential treatment. The primary reason earnings fall short of the efficient level is that followers occasionally fail to contribute when $m = 0.75$ or 1.5. In the simultaneous treatment followers earn close to what is predicted, while leaders earn more than predicted. The discrepancy in the simultaneous treatment is caused by followers contributing about one third of the time. While each unpredicted follower contribution decreases the follower's earnings by 10 pence, it increases that of the leader by 30 pence.

Though joint payoffs are higher than predicted in the simultaneous treatment and lower than predicted in the sequential treatment, our results are still consistent with the comparative static prediction that both players enjoy higher earnings when the leaders' choices are observed.

The results from the asymmetric-information treatments demonstrate that in the sequential mechanism leader contributions induce followers to contribute too. This gives leaders an incentive to contribute when they otherwise would not (i.e.,

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[15] Relative to the simultaneous sessions, contribution rates in the sequential sessions are always lower when $m = 0$ and higher when $m = 0.75$ or $m = 1.5$. Thus, follower decisions are in all three cases significantly more efficient in the sequential game (one sided p-value $= 0.0143$).

[16] In equilibrium a leader's contibution indicates that the public good's value equals either 30 or 60 pence, thus in equilibrium the gain from mimicking a leader's contribution is $\frac{1}{2}(30+60)-40 = 5$ pence. If the leader instead does not contribute it indicates that the value of the public good is 0, and thus the follower may gain 40 pence by not contributing.

[17] Leader-earnings are significantly higher in the sequential treatment, as are follower-earnings, and combined earnings. In all three cases the one-sided p-values are 0.0143.

[18] In all three cases the one-sided p-values are 0.0143.

Table 2 Average earnings (£) per subject

	Leaders	Followers	Efficiency[a]
Sequential			
Predicted	13.2	13.2	100
Observed	11.7	12.3	91
Simultaneous			
Predicted	8.4	10.7	72
Observed	10.1	10.4	78

[a]Efficiency is defined as joint earnings as a percent of maximum possible earnings

when $m = 0.75$). Consequently, both leaders and followers are better off, and leading-by-example improves group performance.

4.2 Full information

Signaling is one explanation for the difference between the sequential and simultaneous treatments with asymmetric information. As illustrated above there are however alternative explanations. If the follower is sufficiently motivated by social preferences then he may mimic a contribution by the leader, and this provides the leader with an incentive to give. To assess whether social preferences drive the results in the asymmetric-information treatment, we examine the effect of sequential moves in an environment with full information.

Consider first behavior when $m = 0$ and $m = 1.5$, where we do not expect social preferences to have much impact. Independent of the sequence of moves no participant should contribute when $m = 0$, and indeed of the 272 such decisions only five deviate in the simultaneous games and just one in the sequential games. When $m = 1.5$ payoff maximization and efficiency dictates that both subjects contribute, and of the 140 games there are only six deviations in the simultaneous games and ten in the sequential games. [19] Independent of the sequence of moves behavior in the full-information treatment at $m = 0$ and $m = 1.5$ is consistent with the equilibrium prediction.

As argued in Sect. 2, to investigate the effect social preferences may have on the ability to lead-by-example, we need to focus on the case where $m = 0.75$. First, absent signaling this corresponds to the follower's expected value of contributing in the asymmetric-information case, second, this is the situation where social preferences may cause sequential moves to increase contributions and efficiency in the full-information game.

There is strong evidence of reciprocal behavior in the sequential game. Conditional on the leader contributing, the follower contributes in 33.3% of the cases, whereas the follower never contributes when the leader does not contribute.[20] In

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[19] Every one of the ten sequential deviations is characterized by the leader not contributing. Absent a leader contribution a payoff-maximizing follower should still contribute, however that did not happen in four of the ten cases. While these cases are rare, it is noteworthy that followers only deviate from payoff maximization when the leader fails to contribute. An aversion to (disadvantageous) inequality may explain why some followers prefer an outcome where each player earns 40 pence to one where the leader earns 100 pence and the follower earns 60 pence.

[20] The degree of reciprocity is consistent with that of previous studies. When $m = 0.75$ the sequential full-information game reduces to a sequential prisoners dilemma. Examining such a
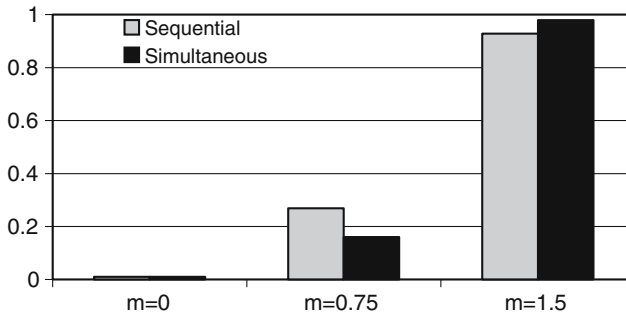
Fig. 3 Leader contributions rate under full information

fact, leader and follower choices are positively correlated in all four sessions of the sequential full-information treatment, and so a Binomial test rejects the null hypothesis that followers are not influenced by leaders' decisions in favor of the (one-sided) alternative that followers' contributions increase with leaders' ($p = 0.0625$).

Whether the amount of reciprocation is large or small is a matter of interpretation. The crucial consideration in our game is whether the leader in contributing triggers a sufficient follower response to make it profitable for her to contribute. With the leader's contribution increasing the chance a follower contributes by a third, this precisely outweighs the cost of contributing, and a risk-neutral leader will be indifferent between contributing and not.

This raises the question of whether the leader is affected by her contribution being observed. Figure 3 shows the leaders' contribution rates conditional on m and the sequence of moves. As noted earlier, independent of the sequence of moves leaders generally contribute when $m = 1.5$ and don't contribute when $m = 0$. In the case where $m = 0.75$ leader contributions are significantly larger in the sequential (27%) than simultaneous treatment (16%).[21]

Although, sequential moves increase the leader's contribution when $m = 0.75$, the increase in leader contributions is much smaller than in the asymmetric-information treatments where contributions increased from 15 to 75%.

Sequential moves cause an insignificant increase in the leader's overall contribution rate from 38 to 40% (one-sided $p = 0.1714$), and the effect on efficiency of the leader's choice is also limited: in the sequential treatment 71% of leaders' choices correspond to the efficient choice, compared with 69% in the simultaneous treatment. In contrast sequential moves increase the leader contribution rates from 38 to 58% in the asymmetric treatment, and the efficient leader choices increases from 69% (simultaneous) to 89% (sequential).

The leader's behavior greatly influences the likelihood by which the follower chooses the socially optimal outcome. Since leaders contribute 27% of the time when $m = 0.75$, and followers mimic the leader's contribution one-third of the

game when $m = 0.8$, Clark and Sefton (2001) find that followers are more likely to contribute when the leader contributes (37%) than when she does not (3%). In spite of procedural differences between our studies, the degree of reciprocity is nonetheless very similar.

[21] The one-sided p-value is either 0.0571 or 0.0286, depending on how one breaks a tie between one of the sequential sessions and one of the simultaneous sessions in which leaders contribute in exactly 7 of 39 cases.
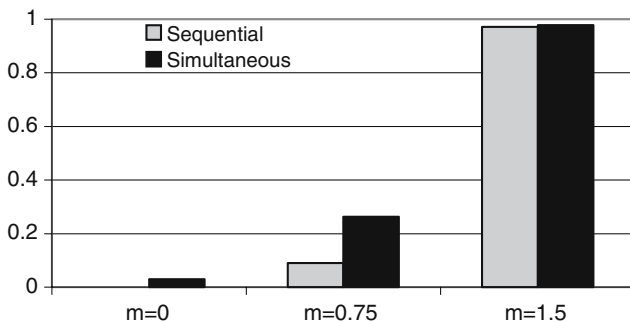
Fig. 4 Follower contribution rates under full information

time, the follower's contribution rate at $m = 0.75$ is reduced to 9% in the sequential treatment.[22] In contrast followers contribute 27% of the time in the simultaneous treatment (see Fig. 4). Thus, when there is full information and $m = 0.75$ the ability to lead-by-example causes a decrease in follower contributions and an increase in leader contributions.[23] This differs substantially from the asymmetric information case where, when $m = 0.75$, sequential moves cause follower–contribution rates to increase from 29 to 64%. Independent of m in the full-information case sequential moves significantly decrease follower contribution rates from 42 to 35% (one-sided $p = 0.0571$). The follower's percentage of efficient choices also decreases, while 72% were efficient in the simultaneous treatment, that only holds for 66% of the sequential ones. This is in sharp contrast to the asymmetric information case where sequential moves increase follower contribution rates from 34 to 50%, and improve the efficiency of the followers' choices (43% simultaneous vs. 77% sequential).

The net result is that with full information neither total contributions nor earnings are significantly different under sequential and simultaneous mechanisms. Average total contributions per session are lower in the sequential treatment (80.75) than simultaneous treatment (86.50), however this difference is not significant.[24] Similarly we see that while sequential moves cause a small decrease in leader earnings and a minor increase in follower earnings, neither of these differences are significant (two-sided p-values are 0.1143 and 0.3429, respectively). The net result is a minor and insignificant decrease in combined earnings (two-sided $p = 0.6857$). Thus, in the full-information environment, the ability to lead-by-example does not improve group outcomes.

An interesting prediction of our model is that given sequential moves the imperfectly revealing signals cause efficiency to be greater in the asymmetric- than

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[22] In comparison in a sequential prisoners dilemma game where $m = 0.8$ Clark and Sefton find that leaders contribute 32% of the time, and followers 14% of the time.

[23] The follower's mimicking of the leader's decision helps explain both of these changes. On one hand the follower's mimicking causes the leader's incentive to give to be greater in the sequential than simultaneous move game. On the other hand, with leaders contributing 27% of the time and followers conditioning their contribution on that of the leaders, follower contributions are smaller in the sequential game. Van der Heijden et al. (2001) find a similar effect in a gift exchange experiment.

[24] Depending on how one splits the ties the two-sided p-value ranges from 0.4857 to 0.8857.

full-information environment. While the earnings differential is consistent with this prediction the difference is not significant (two-sided $p = 0.6857$).

In summary, we observe evidence of reciprocation. However, our data also show that sequential moves are nevertheless ineffective in increasing overall contributions and earnings when both players know the value of contributing. This suggests that it is unlikely that social preferences drive the leading-by-example effect evident in our asymmetric-information treatment.

5 Conclusion

Our experiment strongly supports the theoretical prediction that leading-by-example improves group performance in the presence of asymmetric information. When an uninformed follower cannot observe the choice of an informed leader, the follower rarely contributes, and the leader only contributes when it is privately optimal for her to do so. In contrast, when an uninformed follower can observe the choice of an informed leader, he tends to copy the leader's decision, and the leader tends to contribute when it is collectively optimal to do so.

Relative to previous signaling experiments it is striking how well subject behavior accords to the equilibrium predictions. For example, in the entry limit pricing game of Cooper et al. (1997) play consistently starts off with the first mover choosing her myopic maximum, i.e., the choice that maximizes her payoffs if she ignores the effect her choice has on that of the second mover. Similarly the second mover typically starts off at the myopic maximum, ignoring the information that is contained in the first mover's choice. Only with sufficient repetition does play converge to equilibrium in their experiment.

In our asymmetric-information sequential treatment strategic behavior develops almost immediately and is stable. If the leader anticipates that the follower mimics her choice she should contribute when the return is 0.75, but if she ignores this response she should not contribute (not contributing is the myopic maximum). In the first round leaders already contribute at a rate of 75% when they are confronted with a return of $m = 0.75$. Similarly, the myopic maximum for the follower is not to contribute. We find, however, that conditional on the leader contributing followers contribute at a rate of 69% in the first round.[25]

One reason why equilibrium play develops rapidly in our experiment may be that the equilibrium of the game is unique (see also Cadsby et al. 1990). Note however that uniqueness does not generally secure rapid convergence to equilibrium. For example, the lemons market experiments with cheap talk in Forsythe et al. (1999) are also characterized by a unique (pooling) equilibrium, yet play shows only a very weak tendency to converge toward the equilibrium. Cason and Reynolds (2005) also find that a unique perfect Bayesian Equilibrium lacks predictive power

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[25] A reasonable conjecture is that equilibrium play for the case $m = 0.75$ develops so well in the present game because leaders experience the response of the follower relatively easily. After all, leaders have a dominant strategy to contribute when $m = 1.5$ (irrespective of whether they understand equilibrium play) and by doing so they automatically experience the followers response to a contribution. We find little support for this conjecture, however. The first time a leader is confronted with $m = 0.75$ they contribute at a rate of 62.5% when they have already experienced that the follower contributes after a contribution, and contribute at a rate of 75.0% if they do not yet have that experience.

in a multi-round pricing game with asymmetric information. Another reason signaling works so well in our experiment may be that the equilibrium is efficient, implying that at equilibrium there is no conflict between individual rationality and efficiency. Finally, a reason may be that in equilibrium, earnings are equally distributed between the two players. These characteristics are likely to enhance the behavioral attraction of the equilibrium of our game.

These three factors, uniqueness, efficiency, and equity, may explain why the Perfect Bayesian Equilibrium concept performs well in our experiment, whereas it does not in the experiment of Meidinger and Villeval (2002) (their signaling game is more complicated than ours and has multiple equilibria, none of which are efficient, and none of which imply equal payoffs to the leader and follower).[26] In our view, the two experimental designs cover different aspects of leading-by-example. Whereas their richer game is arguably closer to situations where repeated interaction is commonplace, our simpler game with a random-matching protocol makes it closer to the one-shot theoretical model.

Our results lend support to the theoretical contributions of Hermalin (1998) and Vesterlund (2003) in that they empirically demonstrate that signaling can play a crucial role in the success of leading-by-example. Our results also provide some broad implications for theory beyond the literature on sequential voluntary contributions, to the extent that they identify conditions under which the Perfect Bayesian Equilibrium concept has good predictive power. Further research that systematically varies the factors identified above may provide important stress tests for locating the boundaries of the applicability of this equilibrium concept.

While the observed behavior is consistent with the signaling hypothesis, followers who are motivated by social preferences may behave in a similar manner. In our full-information sequential treatment we observe evidence of reciprocity, consistent with numerous previous studies. However, the degree of reciprocity does not lead to an increase in contributions over those observed in our simultaneous treatment. The opportunity to lead-by-example fails to raise overall contributions or earnings because when the opportunity is not taken, as is usually the case, follower–contribution rates are even lower than in the simultaneous-move game. Our finding that the move structure has no effect on overall contributions and efficiency in the full-information environment suggests that signaling plays an important role in explaining the success of leadership in the asymmetric-information environment.

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[26] Moreover, their repeated game protocol is likely to give more scope to reciprocity than our random-matching protocol.

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