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Delegation and Public Pressure in a Threshold Public Goods Game: Theory and Experimental Evidence

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Abstract

The provision of global public goods, such as climate change mitigation and managing fisheries to avoid overharvesting, requires the coordination of national contributions. The contributions are managed by elected governments who, in turn, are subject to public pressure on the matter. In an experimental setting, we randomly assign subjects into four teams, and ask them to elect a delegate by a secret vote. The elected delegates repeatedly play a one shot public goods game in which the aim is to avoid losses that can ensue if the sum of their contributions falls short of a threshold. Earnings are split evenly among the team members, including the delegate. We find that delegation causes a small reduction in the group contributions. Public pressure, in the form of teammates' messages to their delegate, has a significant negative effect on contributions, even though the messages are designed to be payoff-inconsequential (i.e., cheap talk). The reason for the latter finding is that delegates tend to focus on the least ambitious suggestion. In other words, they focus on the lower of the two public good contributions preferred by their teammates. This finding is consistent with the prediction of our model.

Keywords: delegation; cooperation; threshold public goods game; climate experiment

JEL codes: C72; C92; D81; H4; Q54

I. Introduction

Much of human activity entails delegation, both at the inter-personal level and at the societal level. Furthermore, while we may have preferences for certain options, we often lack the ability or power to be the decision makers. In addition, given the difficulty of optimal preference aggregation, delegation has the potential to ease decision-making. Hence, in many situations, we rely on an "expert," such as a family member or a politician, depending on the scale of the decision task. At the same time, we express preferences with varying degrees of formality (ranging from voting on candidates or referendum topics in democracies to letting someone choose where to have dinner).

Many group decisions involving the provision of a public good rely on voluntary contributions, which are beneficial for the group, but costly for individuals. Here, we focus on discrete provision, where the public good only has value if enough has been contributed, either because the scale of the project requires a minimum investment, or because of its non-scalability. Examples include the construction of a dam or a bridge, national defense investments, and efforts to mitigate dangerous CO_2 concentration levels. Since delegates often make these decisions, we look at the interplay between threshold public goods provision and delegation. Does this institution improve upon single-actor decisions, or are delegates more prone to pursuing self-interest at the expense of the group?[1] In addition, what role does preference signaling by the constituency play in steering delegates' choices?

Commons end in tragedy when institutions fail to control free-riding behavior (Tavoni and Levin, 2014). Field observations and experiments suggest that commons can be managed successfully, even in the absence of governmental regulations or property rights, provided that effective coordination mechanisms, such as communication, are in place (Ostrom et al., 1994; Dietz et al., 2003). However, even in the presence of a known threshold with the potential to trigger a catastrophe, coordination can be difficult, especially when the parties have different stakes in the game (Tavoni et al., 2011). If instead of financing a standard public good, we are dealing with an uncertain common loss arising from crossing a tipping point, such as a fishery collapse triggered by overharvesting or catastrophic climate change from excessive carbon concentrations, sustaining cooperation is even more problematic. Uncertainty on the location of the tipping point aggravates the coordination task, increasing the tendency to slip into inaction (Barrett and Dannenberg, 2012; Dannenberg et al., 2014).

[1] Throughout this paper, we use a "group" to mean a society that consists of "teams." Each team has a "delegate."

Delegates are responsible to different constituencies and are under different degrees of public pressure. In light of the above concerns, we investigate whether delegates can reach a collective target when missing the target may trigger severe losses.

Much research has been done on what facilitates cooperation in experimental settings, notably utilizing the metaphor offered by public goods games and resource dilemmas to capture the conflicting strategic motives behind self- and group-interest. The implications are particularly important for current problems, such as climate change, that require the collaboration of a diversity of actors on a global scale to avoid dangerous consequences. While elements such as communication or group size have been studied extensively, the issues of delegation in the face of strategic uncertainty have yet to be studied in combination, to the best of our knowledge. In section II, we briefly review recent research on leadership and delegation in a number of different experiments, and on uncertainty in threshold public goods games and resource dilemmas. Sections III–V examine the theory, the design, and the results from our experiment, respectively, followed by a brief discussion. All proofs and tables concerning the empirical analysis appear in the Appendix.

II. Related literature

A. Leadership in experiments

Both the appointment of a leader to facilitate decision-making and the delegation of decision power to an agent can have important implications for the behavior of individuals within a group. In particular, leadership and delegation can potentially enhance (or undermine) socially optimal behavior by affecting the level of cooperation of group members. Several studies have looked at leadership and delegation in an experimental setting. Predominantly, leadership has been found to have a positive effect in terms of motivating socially optimal behavior.

Contribution suggestions from a leader, whether elected or a volunteer, increase cooperation in public goods games (e.g., Levy et al., 2011). Hamman, Weber, and Woon (2011) find that electoral delegation results in full provision of the public good, given that group members elect pro-social leaders. Then, Brandts, Cooper, and Weber (2014) find that elected leaders improve group outcomes in cooperation games. Güth et al. (2007) find that when a leader volunteers to take that role, contributions to the public good increase, particularly if the leader has exclusion power. Rivas and Sutter (2009) also find that leadership increases contributions when the leader has the possibility to reward or punish group members. Similarly, Moxnes and Van der Heijden (2003) find that contributions to a "public bad" decrease with leadership. In a voluntary contribution fundraising exercise, Kumru and Vesterlund (2010) find that donations from individuals with higher social rank increase subsequent contributions. Then, Nash et al. (2012) find that delegating the coalition payoffs distribution to an elected agent increases the efficiency and the equality of payoffs in a coalition formation game.

An important channel through which leadership seems to decrease free riding is information provision. In public goods games, the centralization of information by the leader improves efficiency, as compared to a regime of information dispersal (Komai, Grossman, and Deters, 2011). Similarly, the opportunity to imitate first-movers who are well informed increases contributions (Potters, Sefton, and Vesterlund, 2005). A comparable result occurs in a weak-link game with manager-employee interactions (Brandts and Cooper, 2007) and in a stag-hunt type game where the concentration of information and the communication of a recommendation are positive for cooperation (Chaudhuri and Paichayontvijit, 2010).

Leading by example, rather than by words, appears to be more effective in motivating cooperation in public goods games (Czap and Czap, 2011). Leading by example also yields greater effort in coordination games. Here, leadership can be considered a "social good for the group," even though it is costly to the leader (Gillet, Cartwright, and Van Vugt, 2011). Potters, Sefton, and Vesterlund (2007) find that leading by example is beneficial when the leader has private information about the returns and her behavior acts as a signal to followers.[2] Leadership becomes less effective as the group size increases (Komai and Grossman, 2009), as well as when participants ignore the distribution of endowments within the group (Levati, Sutter, and Van der Heijden, 2007).

B. Delegation in experiments

Delegation in experimental games typically involves assigning a decision right to an interested party, a third party, or a non-human device. Delegation appears to be associated with more generosity in gift exchange games, where the delegation of wage choice leads to higher levels of employee effort, both when the decision is randomly delegated to an external

[2] For more on signaling and leadership, see Meidinger and Villeval (2002).

body (Charness, 2000) and when it is delegated to the employee herself (Charness et al., 2012).[3]

In contrast, the delegation of a decision right in dictator and ultimatum games seems to be associated with less socially optimal behavior. In dictator games, the delegation of the decision right to the dictator decreases sharing (Hamman, Loewenstein, and Weber, 2010) and allows for responsibility attribution (and punishment) to be effectively shifted (Bartling and Fischbacher, 2012). The delegation of the decision right by proposers in ultimatum games is associated with an increased payoff for themselves (Fershtman and Gneezy, 2001) and with a higher rate of acceptance of unfair offers if intermediated by a random device (Blount, 1995).

Relatedly, the use of majority and unanimity voting rules seems to increases cooperation in experimental games. Walker et al. (2000) find greater levels of cooperation in a commons dilemma when voting rules are introduced. Then, Kroll, Cherry, and Shogren (2007) find that voting with or without endogenous punishment is associated with higher contributions in a public goods game.

Finally, experiments in social psychology (Insko et al., 1987) and economics (Charness and Jackson, 2007 and 2009; Charness et al., 2007; Song, 2008) show that team membership (in-group bias) and responsibility for others may affect behavior when all team members have common payoffs and the audience passively observes the game played and receives feedback of the outcomes in various games. The aforementioned works show that behavior in the prisoner's dilemma, stag hunt, and trust games becomes more aggressive and less cooperative with delegation.[4]

C. Uncertainty in threshold public goods games and common resource pool dilemmas

The introduction of uncertainty in public goods games and common pool resource dilemmas is relevant to understanding cooperation in environmental dilemmas such as climate change. The experiments described below illustrate the use of threshold public goods and resource dilemmas to study the effect of several variables, particularly uncertainty, on cooperation. The dominant strategy in linear public goods games and common pool resource dilemmas is to act selfishly (the Nash equilibrium is to free ride). However, there are features, such as a threshold, that can lead to a Pareto-superior equilibrium, thus transforming the

[3] See Falk and Kosfeld (2006) and Huck, Müller, and Normann (2004) for additional results on delegation in contracts.

[4] However, Charness, Rigotti, and Rustichini (2007) find higher cooperation in a battle of the sexes game with delegation.

game into one of coordination between the non-provision equilibrium and the socially optimum provision equilibrium.

Threshold public goods games utilizing a specific climate frame have been employed to better understand climate change cooperation. Milinski et al. (2008) find that high risk of loss in the form of dangerous climate change is positive for cooperation, as long as the risk is higher than the average contribution needed. On the issue of equity, Tavoni et al. (2011) find that inequality in initial endowments hinders cooperation. Importantly, these studies simplify the task of selecting the Pareto-superior provision equilibrium by assuming perfect information over the location of the threshold and the costs incurred when it is crossed. A number of climate change experiments have incorporated uncertainty as an important variable in an effort to coordinate a global response to this issue. For instance, Barrett and Dannenberg (2012) find that uncertainty over threshold location hinders collective action, while uncertainty over the impact of crossing the threshold has no negative effect on cooperation. Hasson, Löfgren, and Visser (2012) find that the decision to mitigate is not sensitive to the introduction of uncertainty over the occurrence of climate change. On the issue of intermediate targets, Freytag et al. (2014) find that the use of milestones representing mitigation goals, together with uncertainty over the impact of not reaching the target, is positive for efficiency "when there is no efficiency benchmark and free-riding 'disincentives' are low."

Uncertainty over the location of the provision point is detrimental to cooperation in threshold public goods games under the following conditions: when the level of uncertainty is high (Wit and Wilke, 1998); when players ignore the value or the probability distribution of the threshold (Dannenberg et al., 2014); or when signals regarding the threshold are private (Fischbacher, Güth, & Levati, 2011). On the other hand, uncertainty over the provision point can result in higher levels of cooperation when individuals have information about other players' estimates (Gustafsson, Biel, and Gärling, 2000). Van Dijk et al. (1999) find that the effect of uncertainty varies according to the type of dilemma, type of asymmetry, and type of uncertainty. Uncertainty over the impact of crossing the threshold and over the threshold location can result in lower levels of provision of the public good (McBride, 2010), for instance, owing to the fear of wasting one's contribution. That is, conditional cooperators may shy away from contributing in order to avoid being the "sucker" in a group (Au, 2004; Fischbacher and Gaechter, 2010; Suleiman, Budescu, and Rapoport, 2001).

III. Theory

A. Basic model

There are N teams and each has k members. Each member has initial endowment e and, thus, each team collectively has an endowment of $E = ke$. Each team i decides simultaneously how much to contribute as a team, C_i, to reach a threshold T, and no team can reach the threshold on its own: $E < T$. If the sum of all teams' contributions exceeds the threshold, $\sum_i C_i \geq T$, then they successfully avoid the potential loss, and each team i enjoys the remaining amount, $E - C_i$. Otherwise, each team is left with $q \in [0, 1)$ of the remaining amount with probability p (so that with probability $1 - p$ it still enjoys the entirety of $E - C_i$). There is no rebate.

There are two symmetric pure strategy Nash equilibria, namely no contribution (NC) and a symmetric provision contribution (SPC) (i.e., contributing T/N as a team). The second equilibrium exists only if

$$E - T/N \geq pqE + (1 - p)\, E \Leftrightarrow pE(1 - q) \geq T/N. \qquad (1)$$

In this section, we restrict attention to the comparison of these two symmetric equilibria, since they are likely to be focal relative to the many asymmetric equilibria in this game (Cadsby and Maynes, 1999, Dannenberg et al., 2014). Thus, teams' choices are expected to coalesce around those points.

We experimentally study this discrete public goods game both in the presence of a certain threshold T, and when the threshold is a random variable $\tilde{T}$. Under uncertainty about the location of the threshold, one of two equally likely thresholds T_1 and T_2 is selected randomly, with mean equal to T (i.e., $E(\tilde{T}) = 0.5T_1 + 0.5T_2 = T$, with $T_1 < T_2$). There are three symmetric pure strategy Nash equilibria with threshold uncertainty: no contribution (NC, as for the certain threshold), and symmetric provisions aiming to reach either T_1 (SPC1) or T_2 (SPC2). In the latter two, each team contributes T_1/N and T_2/N, respectively. The expected payoffs of SPC1 and SPC2 are, respectively:

$$\frac{1}{2}pq\left(E - \frac{T_1}{N}\right) + \frac{1}{2}\left(E - \frac{T_1}{N}\right) \text{ and } E - \frac{T_2}{N}. \qquad (2)$$

Our first treatment, as in previous experiments with similar design (Milinski et al. 2008; Tavoni et al., 2011), shows that a fraction of subjects contribute close to zero, even for relatively high values of p. Next, we discuss the main reasons for this result. Then, we examine how delegation and public pressure may affect contributions to the public good.

No contribution is the unique equilibrium in a standard public goods game because of free-riding incentives. By introducing the threshold, the public goods game becomes a coordination game between NC and SPC, and decision makers face the well-known problem of coordination. Coordination failure deepens with the threshold uncertainty. Condition (1) can be modified to accommodate subjective beliefs, as follows:

$$u(T/N) \geq u(0) \Leftrightarrow$$

$$\pi_i\left(E-\frac{T}{N}\right)+(1-\pi_i)\left(pq\left(E-\frac{T}{N}\right)+(1-p)\left(E-\frac{T}{N}\right)\right)\geq pqE+(1-p)\,E \qquad (3)$$

$$\Leftrightarrow \pi_i \geq \frac{T\big(1-p(1-q)\big)}{(EN-T)p(1-q)},$$

where $u(.)$ is team i's linear subjective (expected) utility, and π_i captures the subjective beliefs of team i about reaching the threshold when targeting the SPC (contributing T/N), given the uncertainty about whether total contributions, including those by other teams, will suffice to reach the threshold. The threshold will be met provided that $\sum_{j\neq i}^{N} C_j \geq \frac{T(N-1)}{N}$. However, team i places probability $(1-\pi_i)$ on the event that $\sum_{j\neq i}^{N} C_j < \frac{T(N-1)}{N}$. This subjective probability lowers the symmetric provision equilibrium payoff, since coordination is no longer guaranteed. That is, even though team i contributes T/N, the group might still not reach the threshold, in which case the contributions will be wasted.

Note that uncertainty is involved in both symmetric equilibria when π_i is included: risk is captured by p and subjective beliefs by π_i. While the expected payoff under no contribution depends only on p, the expected payoff under the symmetric provision equilibrium depends on both p and π_i. Thus, in choosing between the two strategies, teams will be more likely to gravitate towards contributing zero.[5]

B. Impact of delegation and teammates' messages

We assume that the delegate and his or her teammates have the same objective function and information, thus, there is no strategic interaction between them. Under any model assuming rationality, such as the standard model described above, delegate behavior would be the same as the individual behavior, irrespective of whether communication within

[5] A status quo bias would also favor non-provision. Since each team is endowed with E in the beginning, NC might be perceived as the status quo, and teams might be reluctant to contribute positive amounts. By contributing positive amounts, teams risk becoming the "sucker" of the group, which increases the tendency towards inaction.

teams is allowed.[6] However, we expect that delegate behavior would not be identical under these scenarios, and experimentally test the impact of delegation and preference communication between teammates and the elected delegate. Specifically, we expect to observe less cooperative behavior from a delegate relative to a single player, in accordance with the reviewed experimental literature (Insko et al., 1987; Charness and Jackson, 2007 and 2009; Charness, Rigotti, and Rustichini, 2007; Song, 2008).

To model the effect of the teammates' messages on the delegate's decision, we employ the widely used reference-dependent preferences utilized, among others, in prospect theory (Kahneman and Tversky, 1979), regret theory (Loomes and Sugden, 1982), and by Köszegi and Rabin (2006). In these models, subjects not only care about the outcome, but also about how it changes relative to a reference level. In the same spirit, we hypothesize that teammates' suggested contributions (or the final earnings the suggested contributions may lead to) serve as reference levels for the delegate. Specifically, in our model, the delegate experiences regret (or rejoice) by not following a teammate's contribution suggestion if the suggested contribution would have secured a higher (lower) payoff. The utility function then depends on both the contributions and the messages from the delegate's teammates. We refer to this as *regret augmented utility*, and express it as follows:

$$V(C_d|m) \equiv u(C_d) + \eta(C_d|m), \qquad (4)$$

where C_d is the delegate's contribution decision and $m \equiv (m_1, \ldots, m_{k-1})$ is the vector of teammates' messages to the delegate suggesting contributions, ranging from the lower bound m_l to the higher bound m_h. The first term $u(C_d)$ is the *standard expected utility* appearing in (3), which we assume to be continuous. The second term is the *regret utility*, which is the sum of the delegate's regrets and/or rejoices experienced by not following teammate j's message under possible states of the world $s \in S$:

$$\eta(C_d|m) \equiv \sum_{j=1}^{k-1} \sum_{s \in S} \mathbb{P}_s \, R\left(f_s(C_d) - f_s(m_j)\right). \qquad (5)$$

Following Loomes and Sugden (1982), the delegate believes that each state $s \in S$ occurs with probability $\mathbb{P}_s$. Then, $f_s: [0, E] \to \mathfrak{R}$, a linear choiceless utility function, evaluates the consequences of either the delegate's chosen contribution or a teammate's message at a particular state $s \in S$. In our setup, there are three states that occur, with the following

[6] Similarly, any between-team communication without a commitment mechanism, such as the delegates' pledges about intended contributions that we investigate here, are cheap talk, and should not affect the decisions.

probabilities: reaching the threshold and avoiding the potential loss (RT);[7] not reaching the threshold and the loss happens (NTL) and $\mathbb{P}_{NTL} = p(1 - \mathbb{P}_{RT})$; and not reaching the threshold, but the loss does not happen ($NTNL$) and $\mathbb{P}_{NTNL} = (1-p)(1 - \mathbb{P}_{RT})$. When negative, the function $R(\cdot)$ captures the delegate's regret for not having followed the teammates' messages. Conversely, a positive value of $R(\cdot)$ indicates rejoice. We further assume that $R(\cdot)$ is continuous, strictly increasing with $R(0) = 0$, and three times differentiable.

To understand the implications of the teammates' messages for the delegate, we focus on the scenario in which team i's delegate receives messages $m^* = (m_h = T/N, m_l = 0)$ from two teammates. This setup allows us to examine how a delegate with reference-dependent preferences may perceive high (m_h) and low (m_l) messages asymmetrically. A delegate who receives m^* and contributes zero will experience non-negative regret utility $\eta(C_d = 0|m^*) \geq 0$ if the following holds:

$$\pi_i R\left(\underbrace{f_{RT}(0) - f_{RT}(m_h)}_{Regret:\, pqE+(1-p)E-\left(E-\frac{T}{N}\right)<0}\right) + p(1-\pi_i) R\left(\underbrace{f_{NTL}(0) - f_{NTL}(m_h)}_{Rejoice:\, qE-q\left(E-\frac{T}{N}\right)>0}\right) +$$

$$+(1-p)(1-\pi_i) R\left(\underbrace{f_{NTNL}(0) - f_{NTNL}(m_h)}_{Rejoice:\, E-\left(E-\frac{T}{N}\right)>0}\right) \geq 0. \qquad (6)$$

The first term shows that the delegate feels regret by contributing 0 in the scenario in which the threshold would have been reached if s/he contributed T/N. In this case, each team would have received a higher payoff than the current expected payoff from (1). The second and third terms capture the delegate's rejoice from having contributed 0 when this turns out to be advantageous, namely when contributing positive amounts is wasteful as the threshold is out of reach. That is, in this scenario the delegate cannot be pivotal as the group would still fail to reach the threshold. In addition, regardless of whether the actual loss is suffered (NTL) or not ($NTNL$), the payoff will be lower than that under the public good provision. In other words, $q(E - T/N) < qE$ and $(E - T/N) < E$, respectively. Note that if the delegate contributes T/N instead of nothing, the domain of the $R(\cdot)$ functions in (6) will take the

[7] For simplicity, we assume that $\mathbb{P}_{RT} = \begin{cases} \pi_i, & C_d \geq T/N \\ 0, & C_d < T/N \end{cases}$.

opposite sign. Then, the regret state will be replaced by rejoice, while the rejoice states will be replaced by regret. We state the implications of having the second term in (4) and the specification under (5) in Lemma 1 and Proposition 1.

Lemma 1: Assume that $R(\cdot)$ is continuous, $R' > 0$, and $R(0) = 0$. If the delegate's subjective beliefs on reaching the threshold T by contributing T/N is lower than a critical level ($\pi_i < \pi_i^R$), the regret utility $\eta(C_d|m^*)$ belonging to team i's delegate is higher when contributing $C_d = 0$ than when contributing $C_d = T/N$. Conversely, if $\pi_i > \pi_i^R$, the opposite holds: $\eta(C_d|m^*)$ is higher when contributing $C_d = T/N$.

Lemma 1 shows that the delegate's subjective belief about reaching the threshold T by contributing T/N determines how s/he evaluates the regret utility. While a subjective belief above a critical level favors targeting the provision equilibrium, a sufficiently low subjective belief favors shirking.

In the following, we also assume that $2\frac{T}{N} > E\ p\ (1-q)$. This implies that, in terms of absolute value, the magnitude of the third term is higher than the magnitude of the first term in (6), which is consistent with the parameters used in the experiment.

Proposition 1: Assume that $R(\cdot)$ is continuous, $R' > 0$, and $R(0) = 0$.

(i) If $R(\cdot)$ is *linear*, then the regret utility reinforces the delegate's standard preference described by $u(\cdot)$:

$$u(0) \lesseqgtr u(T/N) \Leftrightarrow \eta(0|m^*) \lesseqgtr \eta(T/N|m^*).$$

(ii) Let $u(\cdot)$ be continuous and $\bar{\pi}_i^R$ be the critical subjective belief under linear $R(\cdot)$. If $R(\cdot)$ is *strictly convex and* $R'''(\cdot) > 0$, then there exists some $\pi_i \in (\bar{\pi}_i^R, \pi_i^R)$ such that $u(0) < u(T/N)$, $\eta(0|m^*) > \eta(T/N|m^*)$, and $V(0|m^*) > V(T/N|m^*)$.

Next, we unpack both parts of the proposition. For linear $R(\cdot)$, the critical subjective belief introduced in Lemma 1 coincides with the subjective belief in (3). Suppose a delegate's subjective belief π_i favors, say, no contribution over contributing T/N in the absence of teammates' messages $\big(u(0) > u(T/N)\big)$. Then, the delegate would favor the opinion of the teammate who suggests not contributing owing to his/her regret utility: $\eta(0|m^*) > \eta(T/N|m^*)$. Thus, the delegate's perceived regret utility for $m^* = (m_h = T/N, m_l = 0)$ yields the same preferences as those that would be obtained without the teammates' messages.

On the other hand, for strictly convex $R(\cdot)$ and $R'''(\cdot) > 0$, the delegate values positive differences more than negative differences, which implies that the critical subjective belief will be higher than in the linear case (i.e., $\pi_i^R > \bar{\pi}_i^R$).[8] Then, for some $\pi_i \in (\bar{\pi}_i^R, \pi_i^R)$, the delegate would favor contributing T/N without the messages, $u(0) < u(T/N)$. However, realizing that s/he would feel more regret than rejoice if s/he contributed T/N after receiving messages m^*, $\eta(0|m^*) > \eta(T/N|m^*)$, s/he will prefer not to contribute: $V(0|m^*) > V(T/N|m^*)$.

We can now combine the results of Proposition 1 with the argument that teams (delegates) have a tendency towards inaction when the teammates play no role in the decision, as discussed at the end of section III A. Here, we conjecture that m_l will be focal. In other words, delegates are more likely to conform to a message that suggests a low contribution. We present an empirical confirmation of this hypothesis in section V.

Note that in this setup, a delegate receiving unanimous messages, $m^h \equiv (m_h, \dots, m_h)$ or $m^l \equiv (m_l, \dots, m_l)$, would have the same preferences. In Lemma 1 and Proposition 1, we compare $\eta(0|m^*)$ with $\eta(T/N|m^*)$. For unanimous high and low messages, we need to compare $\eta(0|m^h)$ and $\eta(T/N|m^l)$, respectively, with the zero regret utility. These conditions coincide with the condition in Lemma 1 and Proposition 1 and, thus, favor no contribution.

Note too that having a discrete threshold, together with the simplifying assumption that $\mathbb{P}_{RT} = \begin{cases} \pi_i, & C_d \geq T/N \\ 0, & C_d < T/N \end{cases}$, implies that contributing anything other than the NC strategy or the SPC strategy would waste the team's endowment. If the teammates suggest an intermediate contribution (or, equivalently, the delegate takes the mean of m^* into account), the delegate with $C_d = 0$ would feel rejoice by not following this suggestion in all three states. Instead, the delegate with $C_d = T/N$ would feel rejoice in $s = RT$ and regret in the other states owing to wasting more than the suggested amount.

In the above, we focused on the certain threshold case. Next, we briefly discuss the impact of threshold uncertainty. First, we have different states of the world. There are two other states that replace reaching the threshold (RT), namely reaching T_1 but not T_2 (RT_1NT_2) and reaching T_2 (RT_2). Threshold uncertainty deepens the coordination failure. In particular,

[8] Note that Loomes and Sugden (1982) show that the assumptions of strict convexity and $R'''(\cdot) > 0$ are necessary to explain the experimental results of Kahneman and Tversky (1979) with regret theory.

contributing according to SPC1 might cause additional regret because the team's endowment will be wasted if the realized threshold happens to be T_2. Similarly, contributing according to SPC2 might cause additional regret because the team's endowment will be wasted if the realized threshold happens to be T_1. These possible cases enter as rejoices if the delegate does not contribute. Thus, the presence of threshold uncertainty pushes delegates further towards the low suggested contribution $m^l = 0$ relative to the SPC1 and SPC2 strategies. Therefore, we hypothesize that threshold uncertainty has a negative impact on contributions and disaster avoidance. In Section V, we show empirical evidence from the experiment that broadly supports this claim.

IV. Experimental design

The experiment was conducted offline at Sogang University, Korea, in February 2013. The experiment consists of three treatments, with eight groups in each treatment, and four teams in each group. This gives a total of 96 teams (224 subjects distributed as follows: 32 in Treatment 1, 96 in Treatment 2, and 96 in Treatment 3). In every session, we randomly form $N = 4$ teams of variable size k (either one or three team members), which remain unchanged throughout the session. Each team is endowed with $E = 120$ laboratory dollars for every round. Subjects interact anonymously throughout the experiment by indicating their choices on sheets of paper that are distributed and collected by the experimenters. The collected information is shared with the subjects, when necessary, by means of projectors.

A. Phases, rounds, and targets

Each session consists of two phases, namely the practice phase (1 round) and the actual game phase, which consists of six independent rounds that are repeated to feature different values of p and to turn on threshold uncertainty. Subjects are informed about the two phases. However, in the actual game, they are only informed that they play multiple rounds, one of which is chosen randomly to determine the subjects' earnings at the end of the session. In each round, the decision makers play a one shot threshold public goods game. Here, the four teams decide simultaneously on how much to contribute to the public good (in multiples of 1 laboratory dollar) to reach a group threshold $T = 240$ laboratory dollars (or the corresponding uncertain and equally likely thresholds, $T_1 = 190$ or $T_2 = 290$). Subjects are made aware that failing to collectively reach the threshold means losing 90% of their remaining endowment with probability p (i.e., $q = 0.1$). The degree of loss uncertainty is parameterized with three values of $p \in \{0.55, 0.75, 0.95\}$, hence, ranging from highly uncertain (55% probability) to almost certain (95% probability) losses under non-provision. Table 1 summarizes the main parameters used in the experiment and the accompanying symmetric equilibria. Note that the game phase (i.e., the financially incentivized phase) is designed such that over the course of the six rounds, the teams face each value of p twice, once for certainty and once for uncertainty over the location of the threshold.

Table 1: Main Parameters and Equilibria

	Practice Phase	**Game Phase**					
		Round 1	**Round 2**	**Round 3**	**Round 4**	**Round 5**	**Round 6**
Loss Uncertainty (*p*)	0.55	0.75	0.55	0.95	0.95	0.55	0.75
Threshold Location Uncertainty	Uncertain $\tilde{T}$ (T_1=190 T_2=290)	Certain T (T=240)	Certain T (T=240)	Certain T (T=240)	Uncertain $\tilde{T}$ (T_1=190 T_2=290)	Uncertain $\tilde{T}$ (T_1=190 T_2=290)	Uncertain $\tilde{T}$ (T_1=190 T_2=290)
Damage (*q*)	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Highest Expected Payoff Equilibria	NC	SPC	NC=SPC	SPC	SPC2	NC	SPC2

B. Stages within rounds

Each round has two stages, namely the pledge stage and the contribution stage. Subjects first play the pledge stage, in which they announce how much they intend to contribute and how much they expect the other teams to contribute. After the pledge, they play the contribution stage, in which they input their actual contributions to the public good. In each of the first three rounds, they play the game with certain threshold T and probabilities p equal to 0.55, 0.75, and 0.95 (randomly drawn only once before the experiment, without replacement, and with the same order of rounds played in every session). In addition to the varying degree of *loss* uncertainty captured by the three values of p, the following three rounds are characterized by uncertainty over the *location* of the threshold $\tilde{T}$. Here, T_1 and T_2 have equal probability of materializing, and the mean of the two thresholds is 240, as in the first three rounds featuring threshold certainty.[9] For these parameter values, the symmetric

[9] A widely discussed paper (Rockström et al., 2009) identified a boundary for climate change "to ensure the continued existence of the large polar ice sheets," for which "there is a critical threshold between 350 and 550 ppmv [parts per million by volume]". Simplifying this evidence, we choose T_1 and T_2 such that they resemble the boundaries; for our choice of parameters, they are about 80% and 120% of T, respectively.

pure strategy Nash equilibrium attaining the highest expected payoff is shown in Table 1. Note that in all rounds, NC is always an equilibrium, but depending on the two types of uncertainty, provision can also be an equilibrium. Round 5 is designed to trigger the least contributions to the public good, as the only equilibrium is the no contribution case. Round 2 is next, as risk neutral players will be indifferent between NC and SPC. In the remaining rounds, public good provision is the Pareto-superior equilibrium. The difference between Rounds 1 and 3 and Rounds 4 and 6 is that, in the latter two, which feature threshold location uncertainty, the highest payoff is attained when the highest target is met.

We announce the results at the end of the session to minimize possible income effects owing to performance in a given round.[10] Moreover, we randomly allocate anonymous ID cards to subjects to determine teams and to control reputation effects.

C. ID cards

An ID card assigns a letter to determine each subject's team (or group, in the treatment with k = 1, as explained in section IV G) and seven numbers to determine the subject's unique member ID in each round. For example, ID A3112442 means the subject belongs to team A (or group A) and his or her ID number is 3 in the practice round, 1 in Round 1, 1 in Round 2, 2 in Round 3, and so on. In treatments with k = 3, subjects remain in the same team until the end. In each round, each subject knows only his or her own ID number. Since an ID card assigns a different number in each round, this design should eliminate possible reputation effects. In treatments with k = 3, subjects in a team share the same number, so they can follow the teammates' actions, if announced. As the number varies randomly round by round, there is no reputation effect regarding the other two teams.

D. Instructions and survey questions

Subjects are given written instructions, which are read aloud by the experimenters before the experiment begins. In addition, prior to beginning the practice phase, participants answer several control questions, which aim to ensure they understand the features of the experiment. Once we are satisfied with the answers to the control questions, the subjects are divided randomly into four teams by allocating the ID cards.

[10] After both phases of the game (and the ensuing questionnaire) are completed, each participant drew a number in front of the experimenter using the random number generator available at www.random.org. Participants knew that the draw would determine which of the six rounds would be selected for payment. If the selected round entailed threshold location uncertainty, a further draw determined which of the two thresholds T_1 and T_2 would count. Lastly, when the group's contribution did not exceed the threshold, another draw determined whether the cash after the contribution remained intact or was reduced.

After the experiment, the subjects are asked to fill out survey questions (see Table A.9 in the Appendix) about their motivation for their contribution decisions during the game, whether they would play the game in a different way, opinion about the game rules, their risk preferences, recycling experience, and their general opinion about climate change. The experiment and survey takes, on average, about one hour and 30 minutes.

E. Number of team members and exchange rate

In the treatment with k = 1, each "team" consists of only one member; in the other treatments each team consist of three members. To keep the earnings and, thus, the monetary incentives unchanged between treatments, we set the exchange rate between the laboratory dollar and the USD in the first treatment at 3 laboratory dollar = 1 USD. In the other treatments, the exchange rate is 1 laboratory dollar = 1 USD. The relevant information about the exchange rate is reported in the instructions. The show-up fee is 10,000 KRW (about 10 USD). The average earnings are 10,195 KRW, with a maximum of 40,000 and a minimum of 1,000.

F. Practice phase

After teams are formed, subjects are allocated to their team rooms. The session begins with the unpaid practice phase in which team members play a game *within* the team with uncertain threshold $\tilde{T}$ and probability $p = 0.55$. Each team member decides how much to pledge, as well as how much s/he expects other teams to contribute. This information is projected onto a screen, together with the subjects' IDs. Team members observe their teammates' pledges and expectations from other teams and decide how much to contribute, which is also projected onto the screen with the subjects' IDs. No information (pledges, expectations, and contributions) are revealed to other teams to avoid learning. The purpose of the practice round is twofold. First, the subjects get to rehearse the game. Second, they form an opinion about their teammates' willingness to invest in the public good by observing their pledges, expectations from the other teams, as well as how much they eventually contribute. The second reason is particularly important for the treatments with k = 3, in which each team elects a delegate after the pledge stage (before the contribution stage; see below).

To elect a delegate, every team member is a candidate and can vote for anyone, including him or herself. The majority voting eliminates ties and guarantees that a delegate is chosen, except in the case in which all subjects have one vote. In this case, another vote takes place to determine the least wanted candidate. Again, majority voting eliminates ties and one team member is chosen to not to be a delegate, except in the case of again all having one vote. In this case, we randomly eliminate one candidate. Majority voting then guarantees a delegate is chosen with two candidates and three votes. Random elimination was only needed 3 times out of 64 elections. Table 2 summarizes the main differences across the treatments.

G. Treatments

Table 2. Treatments

	Loss Uncertainty (p)	**Location Uncertainty** (T_1, T_2)	**Delegation**	**Messages**
NoD (N = 4, k = 1)	✓	✓ (Rounds 4–6)		
DnoM (N = 4, k = 3)	✓	✓ (Rounds 4–6)	✓	
DM (N = 4, k = 3)	✓	✓ (Rounds 4–6)	✓	✓

Treatment 1: No delegation (NoD)

Individual "delegates" represent only themselves, play six rounds, and receive all the team's earnings.

Treatment 2: Delegation; no messages (DnoM)

The elected delegates of the teams move to another room to play all six rounds. The delegates decide how much their team will contribute without communicating with their teammates. The information about the pledge stages in each round is revealed to the non-delegates and they are asked for their opinion on how much their delegate should contribute. Note that teammates know their delegate's pledge and their expectations regarding other teams, but they do not know the identities of the other teams between rounds, as this is controlled via ID cards. The earnings of the team are split evenly among the members.

Treatment 3: Delegation and messages (DM)

In contrast to DnoM, in DM, all elected delegates and the non-delegates move to a common room. The delegates are seated in the first rows and their teammates just behind them. Teammates do not see their delegate's decision sheet, but the delegate feels the pressure of his or her teammates sitting behind. All subjects know who the delegates are, since they sit in the front rows. They also know who their teammates are, but do not know which delegate represents each team in any round. Round 1 begins with the pledge stage in which delegates represent their teams and the pledges are declared to all. After the pledge stage, each non-delegate sends his opinion about how much the team should contribute to the team's delegate via the experimenters. The delegate checks the teammates' opinions and freely chooses the team's contribution level. Note that teammates only know their delegate's pledge and their expectations about the other teams. Furthermore, recall that the delegates' contributions are not revealed until the end of the session. The remaining rounds follow the same procedure. Finally, the earnings of the team are split evenly among the members. The main logistical features of the treatments are summarized in Table 3.

Table 3. Timing of the Treatments

NoD	DnoM	DM
One-member team	Three-member team	Three-member team
Practice phase in team room	Practice phase in team room	Practice phase in team room
	Team members elect a delegate via majority voting	Team members elect a delegate via majority voting
One-member teams move to common room	Delegates move to common room	Everyone moves to common room
		Four delegates sit on the front row; teammates sit behind them
Pledge and contribution: The four teams play six rounds	Pledge and contribution: The four teams play six rounds	Pledge and contribution: The four teams play six rounds
	Teammates share their opinion with the experimenter on their team's contribution	Teammates share their opinion on their team's contribution to the delegates via the experimenter

V. Empirical results

A. Characteristics of subjects

Table A.1 summarizes the subjects' characteristics across treatments. In total, we have 224 subjects. We have 32 subjects for the noD treatment and 96 (32 delegates and 64 non-delegates) for each of the DnoM and DM treatments. All subjects are undergraduate students at Sogang University, Korea. We collected basic background information, such as age, gender, and major, as well as some attitudinal variables and thoughts about their choices during the experiment via post-experiment surveys. Table A.1 shows that 56–62 percent of subjects are male, and the average age is 22–23. On average, they are enrolled for about five semesters, and approximately 60 percent of the students are economics or business majors. The last column presents the p-value of the Chi-square test of equality across treatments. Here, we find no significant differences in any background variable across treatments. This suggests that subjects are assigned randomly to observables across treatments. As mentioned, we also collected attitudinal variables, namely attitudes toward general risk, the lottery, global warming, and recycling. Again, none of these variables showed any difference across treatments.

B. Group contribution

For the purpose of our study, a key outcome is the total contribution of a group. Figure A.1 shows the average group contribution (there are eight groups per treatment) by treatment, disaster probability, and threshold uncertainty. There are three notable results. First, as the probability of loss increases (from 55% to 95%), the group contribution tends to be higher. This is not surprising, since the incentive to avoid the risk of the loss should be larger when the probability of loss is higher. Second, comparing the average group contribution between CT and UT for each probability and treatment, we find that participants tend to contribute less when they face uncertainty about thresholds. Lastly, we find that the average group contribution is the highest in the baseline treatment (noD), and lowest in the DM. Next, we compare the average group contribution by treatment for each probability and threshold uncertainty setting (CT or UT).

We confirm the above findings from unconditional mean differences by regression analysis (see Table A.2). We run the following regression at the group level:

$$\mathrm{C_{jr}} = \beta_0 + \beta_1 \mathrm{DnoM_j} + \beta_2 \mathrm{DM_j} + \gamma_1 \mathrm{p75_r} + \gamma_2 \mathrm{p95_r} + \gamma_3 \mathrm{UT_r} + \epsilon_{\mathrm{jr}},$$

where the dependent variable C_{jr} is the total contribution made by group j in round $r = 1, \dots, 6$. $DnoM_j$ (or DM_j) indicates whether the group belongs to treatment DnoM (or DM). The omitted treatment is noD. Then, $p75_r$ (or $p95_r$) indicates whether the probability of loss is 75% (or 95%) in round r. The omitted probability is 55%. Lastly, UT_r indicates whether the threshold in round r is uncertain.

The results in Table A.2 confirm our findings in Figure A.1. Column 1 shows the results for all group-round observations. First, compared to noD, the group contribution in DnoM is lower by about 17 lab \$. This gap is not statistically significant. However, the group contribution is significantly lower in DM, by about 51 lab \$. This pattern by treatment holds after we separate the sample by the probability of loss, from Columns 2, 3, and 4, although the statistical significance differs.

There may be concern about our experimental design in which subjects play multiple rounds within a fixed group, as there might be learning from repeated plays over rounds or some dynamic interaction between players within a group. To address this concern, in the last column, we use the sample of CT75%, which includes only the first round for each treatment. The number of observations is 24 (= 8 groups × 3 treatments). However, the group contribution remains significantly lower in DM than in noD.

Second, the group contribution is significantly higher, by 62 lab $, when the loss probability is 75%, and even higher, by 101 lab $, when it is 95%. Lastly, when the threshold is uncertain, the total group contribution is lower. The effect of threshold uncertainty increases with the probability of loss.

C. Team decisions

We find that the total group contribution is lower when decisions are made by delegates (in DnoM and DM), and particularly when delegates are informed of their team members' opinions (in DM). To explain this finding, we examine the individual team decisions, as well as how the experimental and contextual variables affect decision makers in the different treatments. Specifically, we estimate the following equation, which determines the individual team choices:

$$c_{ijr} = \beta_1 Pldg_{-ijr} + \beta_2 Exp_{-ijr} + \gamma_1 p75_r + \gamma_2 p95_r + \gamma_2 UT_r + M_{ijr}\delta + \alpha_{ij} + \tau_r + \epsilon_{jr},$$

where the dependent variable, c_{ijr}, is the contribution of team i in group j in round r, and $Pldg_{-ijr}$ and Exp_{-ijr} represent the average pledge and the expectation presented by the other teams in the same group, respectively. Then, M_{ijr} encapsulates the messages from the team's non-delegates, and, as a value, either takes the average of the two messages, or takes the higher or lower of the two messages.[11] Lastly, we include individual-team fixed effects α_{ij} and round-specific fixed effects τ_r.[12] The individual-team fixed effects control for any effects from each team's time-invariant characteristics, including delegates' demographic characteristics. In addition, the round-specific fixed effects control for any dynamic effect over rounds.

Table A.3 presents the regression results. First, it is notable that there is no effect from average pledges or from the expectations of other decision makers. This would appear to

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[11] Note that M_{ijr} cannot be included for noD since there is no delegation in this treatment. Non-delegates' opinions are not delivered to delegates in DnoM. Therefore, there should be no effect of non-delegates' opinions on delegates' decisions in DnoM. This will serve as a validity test of our experimental design.

[12] For round-specific fixed effects, although there are six rounds, we can only include three dummies owing to perfect linear collinearity with $p75_r$, $p95_r$, and UT_r.

suggest that, in accordance with standard economic theory, but in contrast to field and experimental evidence, communication does not facilitate coordination in this game. Second, the probability of loss significantly affects teams' contributions. Comparing Columns 1, 2, and 5, we find that the effects have similar magnitudes across treatments. Lastly, we find that threshold uncertainty negatively affects the team contribution in DM only. In other words, delegates contribute less when the threshold is uncertain only if they receive their teammates' messages.

Table A.4 presents the results without controlling for individual decision maker fixed effects. We run this regression to see how the decision makers' characteristics affect the level of the contribution. Overall, the results for the experimental control variables are similar to those in Table A.3. What is interesting in Table A.4 is that decision makers' individual characteristics, such as gender, major, and risk aversion, matter in the noD and DnoM treatments, but are statistically insignificant in DM. One interpretation is that with non-delegates' opinions available, delegates behave less as individuals and more as anonymous representatives of a team.[13]

D. The influence of non-delegates' messages

In section III, we show that delegates who take into account potential payoffs according to their teammates' messages are more likely to conform to the lowest opinion. In Column 6 of Table A.3, we find that delegates tend to follow the average of the non-delegates' opinions. Column 7 shows that the effect is largely driven by the lower value suggested by non-delegates. The higher opinion does not have any significant impact on the delegates' decisions. We find similar results in Table A.4, except that the higher opinion is also significant, but matters less than the lower opinion. The results are consistent with our theory's predictions. As expected, in both Table A.3 and A.4, it turns out that teammates' messages do not matter in DnoM. This is not surprising in that the messages are not delivered to delegates. On the other hand, the result indicates that the significant effects of the messages in DM are not driven by unobservable confounders that could affect both delegates and non-delegates, even with no communication between them.

Figure A.2 shows both delegates' contributions and non-delegates' messages for all 192 choices (32 delegates × 6 treatments) in DM. For each choice, the higher vertical bar

[13] Furthermore, the results about the age effect are intriguing. In noD, age does not matter, while it has a positive effect in DnoM, where older delegates contribute more. However, the effect is opposite in DM; older delegates contribute less after controlling for non-delegates' opinions. While interesting, one should be cautious about inferring from these results, given that there is little age variation among the subjects.

represents the higher non-delegate message, and the lower bar represents the lower message. Scatter dots represent delegates' choices. There are three types of dots: diamonds denote choices that are closer to the lower message; squares denote those closer to the higher message; and triangles denote choices outside the range. Figure A.2 shows that delegates are not only influenced by non-delegates' messages, but are also more inclined to the lower message. Of all 192 choices, 55% are closer to the lower opinion, while only 21% are closer to the higher opinion.

Furthermore, delegates are particularly sensitive to non-delegates' zero contribution messages. Panel B of Table A.5 shows that in 93 of the 192 choices, at least one non-delegate suggested a zero contribution and, in 63 of the 93 choices (68%), delegates actually contributed zero. Obviously, we find no effect of non-delegates' opinions in DnoM. However, the effect of the lower message is not solely driven by the zero contribution message. In Column 8 of Table A.3, we restrict the sample to the cases where the lower message is not zero. We still find that delegates are influenced by the lower message, but not significantly by the higher message. Here, the coefficient of the higher message turns out to be negative.

Lastly, in Table A.6, we check the robustness of the finding that delegates are more sensitive to the lower contribution message across various subsamples. Overall, we find that the result is robust. We find that delegates are more inclined to the lower message when they do not know anyone in the session or in their team. The asymmetric effect is also evident, regardless of whether they understand the game rules well and regardless of gender. The asymmetric effect is not affected by the average pledge or the expectation presented by the other delegates. An interesting finding is that the sensitivity to the lower suggestion is not statistically significant when the threshold is uncertain, although the effect of the lower suggestion is much larger than that of the higher one.

Table A.7 summarizes the non-delegates' opinions in DnoM and DM by round. The results for DnoM are quite surprising. Although the non-delegates' contribution decision is payoff-irrelevant, we find little difference between non-delegates and delegates. Non-delegates appear to be willing to contribute more, but that is not always the case.[14]

[14] As explained above, non-delegates in DM are different from those in DnoM in that those in DM may influence their delegates. However the results in Table A.7 show that non-delegates in DM did not behave differently from those in DnoM. Indeed, the last column shows that we cannot reject the null that non-delegates in DM are the same as those in DnoM. This means that the changes of delegates' decisions in DM are attributable to the fact that the delegates responded to the messages sent by the non-delegates.

E. Selection of delegates

Table A.8 presents the results for the voting outcomes. In Column 1, we estimate the Probit model, where the dependent variable is whether a subject is elected as a delegate. Since there are three members in each team and the delegate is determined by a majority vote, the voting outcome critically depends upon whether the subject votes for him/herself. Column 1 in Table A.8 shows that voting for oneself substantially increases the probability of being elected (by 38 percentage points). Since candidates are anonymous, it is not surprising to find that their observable characteristics do not affect the voting outcome. It is interesting to find that having ballot number 2 (middle number) increases the winning probability significantly (17.6 percentage points). This may be because they prefer a "medium" candidate in this extremely low-information election.

In Columns 2 and 3, we divide the sample by treatment, namely DnoM and DM. Being the delegate is presumably more stressful owing to the need to process and reflect on the messages. However, the results in Table A.8 show that the voting behavior is no different between DnoM and DM. The estimates in the two columns are not statistically different.

Column 4 in Table A.8 shows the results for the Probit model concerning those who actually voted for themselves. We find only one significant result, namely that males are more likely to vote for themselves. In Column 4, we add the dummy variable for treatment DM to see if the propensity to vote for oneself changes by treatment, but we find no statistically significant effect. The sample mean of voting for oneself is actually higher in DM (50%) than it is in DnoM (41%).

VI. Discussion

We theoretically and empirically analyzed the provision of a discrete public good, which only has value if enough has been contributed collectively, either because the scale of the project requires a minimum investment, or owing to its non-scalability. To mimic the challenges to cooperation faced by parties deciding on an equilibrium to coordinate efforts in the presence of uncertainty, all treatments feature both uncertainty on the location of the threshold and on the consequences of non-provision. We test the impact of delegation and peer pressure in the form of payoff-immaterial messages to the delegate by comparing provision levels to a baseline treatment in which subjects directly decide on the contribution to the public good.

We find that, without the peer pressure of non-delegates, delegation of the investment decision to an appointed leader slightly reduces the overall group contributions. However, in the presence of teammates' messages to their delegate, the contribution to the public good drops significantly further, even if the messages do not alter the delegate's incentives. In accordance with the model developed in section III, the empirics presented in section V suggest that this effect is attributable to the fact that delegates tend to focus on the lowest contribution level suggested by non-delegates. Hence, negative examples can be detrimental to cooperation.

The simple setup utilized here, while arguably more conducive to cooperation than the more complex real-world task of avoiding dangerous climate change, provides stark implications for climate policy. For example, consider the parallel between the experimental setting and the emissions reduction problem. Reaching an agreement on emission trajectories that are compatible with safe levels of global warming requires collaboration between negotiators (acting on behalf of their national constituencies) and their foreign counterparts. The stakes are indisputably high according to the scientific evidence on the losses associated with substantial warming, such that the collectively rational decision would be to coordinate efforts to avert abrupt future changes in the climate. In the terminology of our game, this is the provision equilibrium, and if all parties do their part, the cost of reducing emissions, relative to business as usual, is more than compensated for by the expected future savings from avoiding dangerous climate changes.

However, as in the game, individual free-riding incentives mean that unilateral deviations from the provision strategy can quickly destabilize cooperation: once a (sufficiently large) country defects, reaching the target may be unfeasible or uneconomical. We can think of this as strategic uncertainty about co-players' actions. The game also captures another feature that has the potential to jeopardize climate cooperation, namely scientific uncertainty on the location and impact of crossing the threshold. As expected, we find that scientific uncertainty reduces the contributions to the public good and, consequently, the probability of coordination on the cautious equilibrium. Lastly, the negative effect of signaling by the constituency points to the dark side of leading by words: delegates appear to be quick to follow suggestions only when these entail pursuing a risky gamble on the climate commons.

As mentioned above, the real 'climate game' is likely to be more complicated. The present setup restricts attention to small groups of symmetric subjects in terms of expected payoffs. Asymmetries entail different stakes for different parties, and a larger group size amplifies the problem of deterring unilateral deviations from the provision strategy. Thus, it appears that, in the face of uncertainty, without a strong call for action at the sub-national level, negotiators may be reluctant to commit to sizeable emission reductions and may selectively listen to those who suggest staying with the status quo.

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Appendix: Proofs

Proof of Lemma 1

Let us call $x_{RT} = f_{RT}(T/N) - f_{RT}(0)$, $x_{NTL} = f_{NTL}(0) - f_{NTL}(T/N)$, and $x_{NTNL} = f_{NTNL}(0) - f_{NTNL}(T/N)$, and note that $x_i > 0$ for all $i \in \{RT, NTL, NTNL\}$. The condition below shows that $\eta(C_d = 0|m^*) \geq \eta(C_d = T/N|m^*)$:

$$\pi_i R(-x_{RT}) + p(1-\pi_i)R(x_{NTL}) + (1-p)(1-\pi_i)R(x_{NTNL}) \geq$$
$$\pi_i R(x_{RT}) + p(1-\pi_i)R(-x_{NTL}) + (1-p)(1-\pi_i)R(-x_{NTNL}), \quad (7)$$

which can be rewritten as:

$$\pi_i\big(R(-x_{RT}) - R(x_{RT})\big) + p(1-\pi_i)\big(R(x_{NTL}) - R(-x_{NTL})\big) +$$
$$+(1-p)(1-\pi_i)\big(R(x_{NTNL}) - R(-x_{NTNL})\big) \geq 0. \quad (8)$$

While the first term favors contributing T/N owing to the belief in reaching the threshold, the second and third terms favor no contribution. Given the parameters of the model (p, q, N, T, E), and the assumption that $R(\cdot)$ is continuous, increasing, and degenerate for degenerate domain ($R(0) = 0$), there is a unique π_i^R such that (8) holds with equality. Thus, for any $\pi_i < \pi_i^R$, the inequality (8) holds strictly, since it increases the weights for the positive rejoice terms and decreases the negative regret terms, completing the proof.

Proof of Proposition 1

(i) Let $R(\cdot)$ be linear. The critical subjective belief in (8) becomes $\bar{\pi}_i^R = \frac{T(1-p(1-q))}{(EN-T)p(1-q)}$, which is the same as in (3). The result follows immediately.

(ii) Let $R(\cdot)$ be strictly convex and $R''' > 0$. We can rewrite (7) as follows, where the first row contains the regret terms and the second row accounts for rejoice:

$$\pi_i R(-x_{RT}) - (1-\pi_i)\Big(\underbrace{pR(-x_{NTL}) + (1-p)R(-x_{NTNL})}_{A}\Big) -$$
$$-\pi_i R(x_{RT}) + (1-\pi_i)\Big(\underbrace{pR(x_{NTL}) + (1-p)R(x_{NTNL})}_{B}\Big) \geq 0. \quad (9)$$

Note that for $2\frac{T}{N} > E\,p\,(1-q)$, we have either $x_{NTNL} > x_{RT} \geq x_{NTL}$ or $x_{NTNL} > x_{NTL} \geq x_{RT}$. In either case, for a given π_i, the first row becomes more negative in the case of convex

$R(\cdot)$ compared with the case of linear $R(\cdot)$ in (i). This is because A is the convex combination of $R(-x_{NTL})$ and $R(-x_{NTNL})$. Therefore, the regret terms favor contributing T/N more for convex $R(\cdot)$ than in the case of linear $R(\cdot)$. On the other hand, following a similar argument for B, for a given π_i the second row becomes more positive in the case of convex $R(\cdot)$ compared with the case of linear $R(\cdot)$ in (i). Thus, the rejoice terms favor no contribution more for convex $R(\cdot)$ than in the case of linear $R(\cdot)$. The net effect is that the terms giving rejoice increase more than the terms giving regret in (9), because $R' > 0$, $R'' > 0$ and $R''' > 0$. Therefore, the critical subjective belief in (9) becomes $\pi_i^R > \bar{\pi}_i^R$.

At $\pi_i = \bar{\pi}_i^R$, $u(0) = u(T/N)$ by (3), and $\eta(0|m^*) > \eta(T/N|m^*)$, since $\pi_i = \bar{\pi}_i^R < \pi_i^R$. Therefore, $V(0|m^*) > V(T/N|m^*)$. By the continuity of $R(\cdot)$ and $u(\cdot)$, for some $\pi_i = \bar{\pi}_i^R + \mathcal{E}$, where $\mathcal{E} > 0$, we have $u(0) < u(T/N)$, $\eta(0|m^*) > \eta(T/N|m^*)$, and $V(0|m^*) > V(T/N|m^*)$, completing the proof.

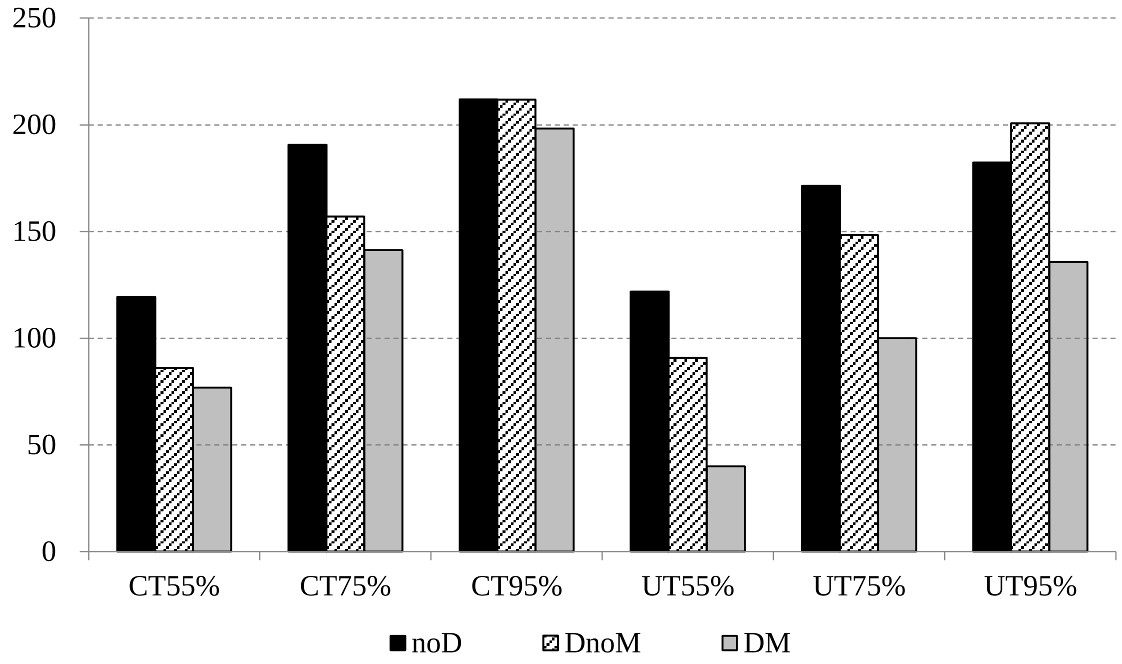
Appendix: Tables and Figures

Table A.1. Subjects' Characteristics across Treatments: Random Assignment

Treatment	noD (Baseline)	DnoM	DM	p-value of equality test
Male	0.563	0.563	0.615	0.736
	(0.504)	(0.499)	(0.489)	
Age	22.468	23.156	22.739	0.708
	(2.016)	(6.204)	(2.128)	
Enrolled semesters	5.094	5.125	4.927	0.549
	(2.277)	(2.084)	(2.001)	
ECON/BUS major	0.625	0.583	0.604	0.906
	(0.492)	(0.496)	(0.492)	
General risk (0-10 scale)	4.250	4.885	4.821	0.507
	(1.901)	(2.352)	(2.356)	
Lottery (1-5)	4.469	3.990	4.074	0.543
	(1.244)	(1.326)	(1.331)	
Global warming (0-10)	6.438	6.313	6.358	0.645
	(1.950)	(2.104)	(2.138)	
Recycling (0-10)	7.188	7.500	7.495	0.574
	(2.007)	(1.886)	(2.093)	
Number of subjects	32	96	96	

Notes: noD = Individuals; DnoM = Delegates without non-delegates' messages; DM = Delegates with non-delegates' messages.

Figure A.1. Average Group Contributions across Treatments



Notes: CT55% = Certain threshold with probability of loss 55%; CT75% = Certain threshold with probability of loss 75%; CT95% = Certain threshold with probability of loss 95%; UT55% = Uncertain threshold with probability of loss 55%; UT75% = Uncertain threshold with probability of loss 75%; UT95% = Uncertain threshold with probability of loss 95%.

Table A.2. Treatment Effects on Group Contribution

	(1) All	(2) p = 55%	(3) p = 75%	(4) p = 95%	(5) First round (CT75%)
DnoM	-17.15	-32.19	-28.31	9.06	-33.63
	(18.96)	(25.16)	(24.15)	(21.03)	(25.12)
DM	-50.92***	-62.19**	-60.38***	-30.19	-49.38*
	(17.91)	(23.65)	(21.48)	(17.95)	(25.46)
Loss prob. = 75%	62.27***				
	(8.86)				
Loss prob. = 95%	100.98***				
	(10.19)				
Uncertain thresholds	-22.42**	-9.83	-23.04*	-34.38**	
	(8.65)	(9.03)	(11.81)	(13.17)	
Constant	123.1***	125.5***	192.5***	214.4***	190.6***
	(14.04)	(18.66)	(16.83)	(12.45)	(16.24)
Observations	144	48	48	48	24
R-squared	0.471	0.209	0.225	0.193	0.152

Notes: Robust standard errors, clustered by group, are presented in parentheses. Each group played 6 rounds. Significance level: *** 1%, ** 5%, * 10%.

Table A.3. Determinants of Team Contribution: Individual Fixed Effect

Treatment	noD	DnoM			DM			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Avg. pledge by others	-0.040	0.053	0.053	0.051	0.039	0.061	0.065	0.060
	(0.102)	(0.066)	(0.066)	(0.067)	(0.047)	(0.051)	(0.049)	(0.137)
Avg. expecation by others	-0.044	0.319	0.319	0.325	-0.186	-0.169	-0.183	0.187
	(0.213)	(0.235)	(0.237)	(0.231)	(0.137)	(0.166)	(0.163)	(0.328)
75% chance of disaster	18.739***	15.068**	15.082***	15.154***	15.084***	8.177*	8.733*	13.595
	(5.353)	(5.541)	(5.440)	(5.487)	(5.336)	(4.733)	(4.734)	(8.665)
95% chance of disaster	24.859***	30.286***	30.303***	30.554***	29.065***	16.877***	16.889***	19.470**
	(5.243)	(6.528)	(6.562)	(6.623)	(6.266)	(5.758)	(5.921)	(9.073)
Uncertain thresholds	-3.878	-4.512	-4.508	-4.216	-9.601*	-12.065**	-11.495**	-21.257**
	(5.494)	(5.928)	(5.961)	(5.954)	(5.333)	(4.761)	(4.729)	(9.235)
Team members' opinions								
Average			-0.001			0.483***		
			(0.116)			(0.119)		
Lower				0.025			0.342***	0.411*
				(0.089)			(0.115)	(0.213)
Higher				-0.032			0.136	-0.334
				(0.107)			(0.084)	(0.298)
Constant	38.342*	-4.724	-4.705	-3.931	-15.904	-13.386	-12.074	19.275
	(22.410)	(12.597)	(12.692)	(13.892)	(18.516)	(19.755)	(19.091)	(32.907)
Team FE	Y	Y	Y	Y	Y	Y	Y	Y
Round FE	Y	Y	Y	Y	Y	Y	Y	Y
Observations	192	192	192	192	192	192	192	99
R-squared	0.478	0.588	0.588	0.589	0.614	0.672	0.676	0.604

Notes: Robust standard errors, clustered by team, are presented in parentheses. Significance level: *** 1%, ** 5%, * 10%.

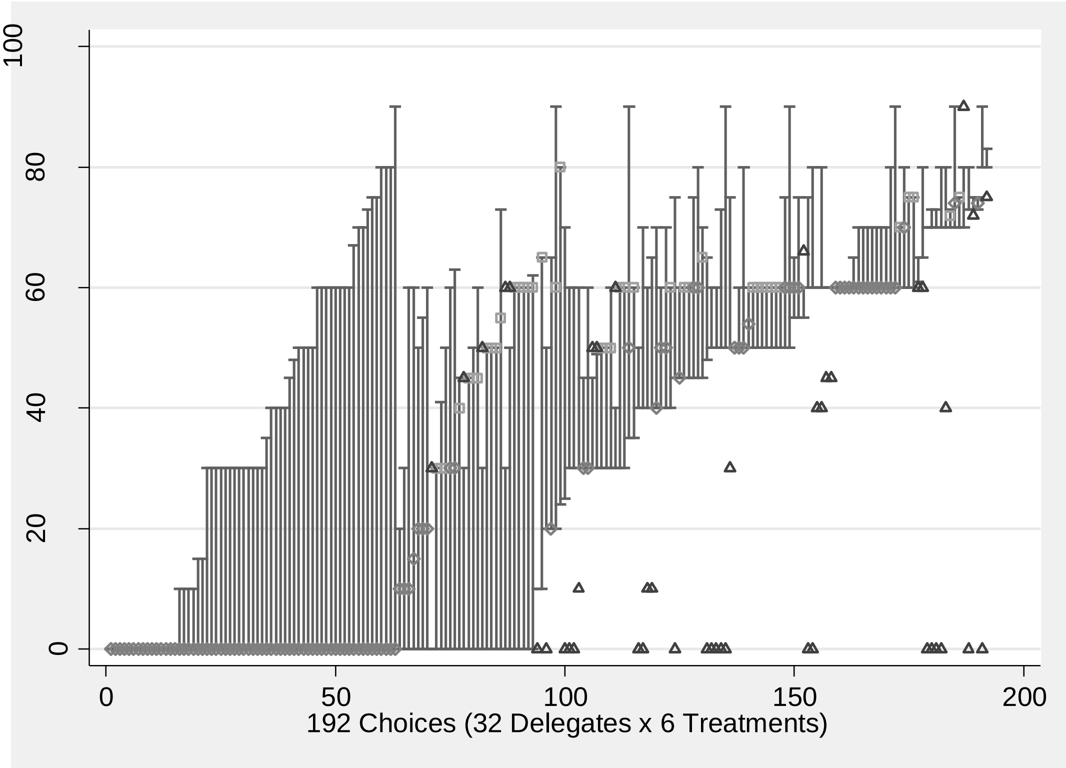
Table A.4. Determinants of Team Contribution: OLS controlling for decision-maker's characteristics

Treatment	noD	DnoM			DM		
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Avg. pledge by others	-0.005	0.103*	0.101	0.097	0.032	0.066	0.070
	(0.083)	(0.059)	(0.060)	(0.061)	(0.063)	(0.045)	(0.045)
Avg. expectation by others	-0.247	0.003	-0.013	0.010	0.304	0.067	0.034
	(0.203)	(0.238)	(0.234)	(0.226)	(0.224)	(0.221)	(0.209)
75% chance of loss	18.591***	14.649**	14.323**	14.479**	15.974***	5.463	6.502
	(4.859)	(5.468)	(5.646)	(5.665)	(5.378)	(4.669)	(4.524)
95% chance of loss	24.438***	28.705***	28.210***	28.810***	29.543***	11.575**	12.071**
	(5.184)	(6.550)	(6.732)	(6.608)	(6.597)	(5.391)	(5.469)
Uncertain thresholds	-3.557	-4.369	-4.421	-3.807	-11.269**	-13.979***	-13.040***
	(5.270)	(5.516)	(5.503)	(5.604)	(4.906)	(4.348)	(4.377)
Decision-maker's characteristics							
Male	-15.486***	-11.192*	-11.054*	-11.150*	2.366	9.481	10.039
	(4.089)	(6.147)	(6.127)	(6.097)	(8.414)	(6.486)	(6.472)
Age	-0.100	0.318***	0.303**	0.295**	-1.280	-3.155**	-3.335**
	(0.940)	(0.108)	(0.124)	(0.124)	(1.350)	(1.156)	(1.223)
ECON/BUS major	-9.864**	-11.022**	-11.070**	-11.036**	7.266	4.250	4.739
	(4.068)	(5.237)	(5.238)	(5.212)	(5.632)	(5.538)	(5.664)
Risk averse	10.768**	5.930	5.566	5.271	7.544	7.483	7.289
	(4.242)	(6.246)	(6.381)	(6.336)	(7.572)	(5.305)	(5.176)
Team members' opinions							
Average			0.037			0.705***	
			(0.127)			(0.099)	
Lower				0.073			0.484***
				(0.091)			(0.107)
Higher				-0.052			0.195**
				(0.103)			(0.088)

Constant	57.489*	11.489	12.214	13.700	16.884	49.644	58.578*
	(28.907)	(12.904)	(12.554)	(13.067)	(36.808)	(30.366)	(30.676)
Round FE	Y	Y	Y	Y	Y	Y	Y
Observations	192	192	192	192	192	192	192
R-squared	0.290	0.353	0.353	0.356	0.246	0.468	0.480

Notes: Robust standard errors, clustered by team, are presented in parentheses. Significance level: *** 1%, ** 5%, * 10%.

Figure A.2. Team Members' Messages and Delegate's Decision: DM.



Notes: Bars represent the higher and lower suggestions by team members. Diamonds represent delegates who are more inclined to the lower suggestion, Squares those who are more inclined to the higher suggestion. Triangles represent delegates who are out of the range of team members' suggestions. To draw the graph, 192 subjects are ordered by the lower suggestion they received.

Table A.5. Zero Messages and Zero Contribution

A. DnoM

		Delegate's contribution		
		Positive	Zero	Total
Any team member proposed zero?	No	78	22	100
		(78.0)	(22.0)	(52.1)
	Yes	57	35	92
		(62.0)	(38.0)	(47.9)
	Total	135	57	192
		(70.3)	(29.7)	(100.0)

B. DM

		Delegate's contribution		
		Positive	Zero	Total
Any team member proposed zero?	No	78	21	99
		(78.8)	(21.2)	(51.6)
	Yes	30	63	93
		(32.3)	(67.7)	(48.4)
	Total	108	84	192
		(56.3)	(43.8)	(100.0)

Notes: There are 192 choices in each treatment, DnoM and DM. We present the number of choices corresponding to each cell. Percentages are presented in parentheses. In each panel, the percentages in the first two columns and two rows are the conditional probabilities given whether any team member proposed zero contribution.

Table A.6. Sensitivity to Lower Message: Robustness across Subsamples

Subsamples	Lower message	Higher message	N	R-squared
All strangers in experiment	0.344**	0.214*	126	0.732
	(0.137)	(0.106)		
All strangers in team	0.313**	0.149	168	0.714
	(0.116)	(0.091)		
Understood game rules very well	0.407**	0.030	114	0.651
	(0.169)	(0.099)		
Understood game rules not very well	0.331***	0.291**	78	0.789
	(0.107)	(0.124)		
Male delegate	0.285**	0.090	126	0.659
	(0.123)	(0.114)		
Female delegate	0.334*	0.192	66	0.791
	(0.170)	(0.134)		
Single certain threshold	0.571***	0.269*	96	0.812
	(0.172)	(0.155)		
Double uncertain thresholds	0.136	0.005	96	0.705
	(0.159)	(0.141)		
Higher pledges by others	0.404**	0.370***	91	0.774
	(0.163)	(0.123)		
Lower pledges by others	0.310**	0.152	101	0.730
	(0.147)	(0.124)		
Higher expectation by others	0.314*	0.127	114	0.683
	(0.159)	(0.130)		
Lower expectation by others	0.418**	0.253	78	0.815
	(0.200)	(0.273)		

Notes: In all regressions, all control variables and fixed effects in Table 3 are controlled for. Robust standard errors, clustered by team, are presented in parentheses. Significance level: *** 1%, ** 5%, * 10%.

Table A.7. Average Contributions of Delegates and Non-delegates

	DnoM		DM		
	Non-delegates	Delegates	Non-delegates	Delegates	Non-delegates DnoM = DM
CT55%	27.94	21.50	25.47	19.22	0.744
	(25.81)	(25.17)	(26.97)	(25.12)	
CT75%	40.45	39.25	38.95	35.31	0.598
	(25.58)	(25.22)	(26.28)	(26.94)	
CT95%	42.97	52.94	49.30	49.56	0.205
	(31.67)	(20.08)	(24.05)	(23.62)	
UT55%	26.02	22.72	26.61	10.00	0.998
	(25.69)	(28.38)	(28.90)	(20.32)	
UT75%	45.05	37.09	44.03	25.00	0.902
	(30.18)	(28.82)	(30.08)	(28.30)	
UT95%	52.97	50.19	52.95	33.94	0.849
	(30.01)	(25.12)	(27.69)	(30.11)	

Notes: Standard deviations are presented in parentheses. P-values of equality tests are presented in the last column.

Table A.8. Voting Results

Dependent variable	(1) Elected All	(2) Elected DnoM	(3) Elected DM	(4) Vote for self All	(5) Vote for self All
Vote for self	0.380***	0.253**	0.516***		
	(0.069)	(0.105)	(0.092)		
Male	-0.048	0.030	-0.111	0.240***	0.239***
	(0.079)	(0.109)	(0.160)	(0.077)	(0.076)
Age	0.011	0.013	-0.010	0.018	0.018
	(0.012)	(0.016)	(0.050)	(0.018)	(0.016)
Enrolled semester	0.011	-0.003	0.043	-0.018	-0.016
	(0.019)	(0.027)	(0.049)	(0.023)	(0.022)
ECON/BUS major	0.034	-0.040	0.120	0.023	0.023
	(0.072)	(0.104)	(0.104)	(0.076)	(0.076)
General risk preference	0.014	0.000	0.029	0.019	0.020
	(0.015)	(0.022)	(0.021)	(0.016)	(0.016)
Ballot number 2	0.176**	0.175	0.206*	0.083	0.084
	(0.077)	(0.109)	(0.119)	(0.079)	(0.079)
Treatment DM					0.086
					(0.074)
Observations	191	96	95	191	191
Pseudo R squared	0.168	0.112	0.291	0.074	0.079

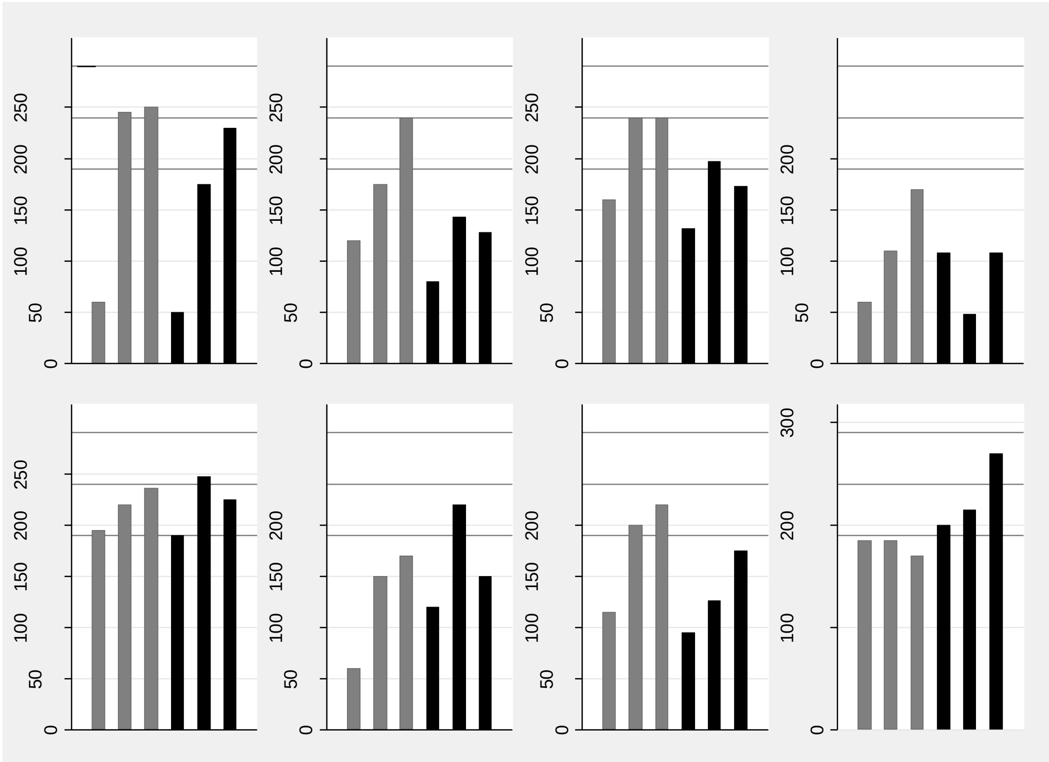
Notes: Marginal effects from Probit. One subject is dropped because of missing risk preference. Standard errors are presented in parentheses. Significance level: *** 1%, ** 5%, * 10%.

Table A.9. Post-experiment Survey Responses

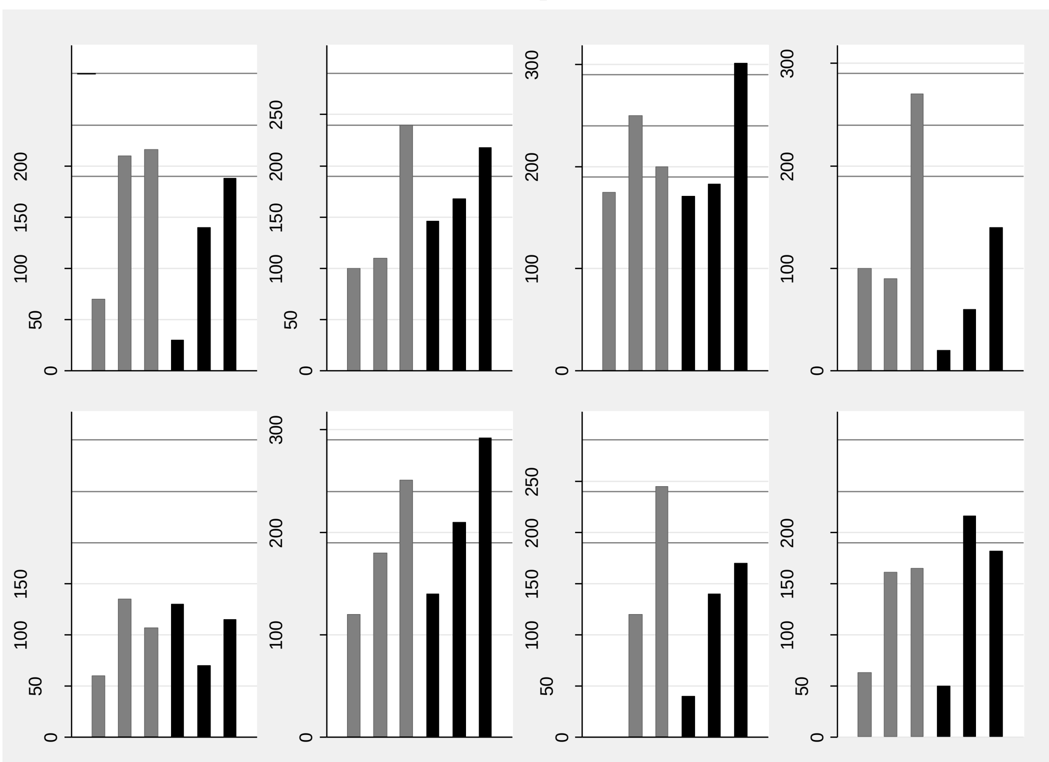
Survey questions	Responses	**noD**	**DnoM** Del	**DM** Del	**DnoM** Non-del	**DM** Non-del
Hard to understand game rules	Very difficult	0%	0%	0%	0%	0%
	A bit difficult	0%	3%	3%	8%	8%
	Medium	3%	13%	6%	19%	19%
	A bit easy	34%	34%	31%	39%	42%
	Very easy	63%	50%	59%	34%	31%
Main consideration	Threshold	25%	16%	9%	14%	13%
	Cash after contribution.	13%	22%	22%	22%	6%
	Other participants	34%	31%	28%	27%	38%
	Missing threshold	28%	31%	41%	38%	44%
Affected by the other participants' pledges	Yes	87%	72%	56%	69%	61%
Affected by the other participants' expectation	Yes	42%	38%	22%	25%	30%
Contribution as delegate (hypothetical)	Same	38%				
	More	63%				
	Less	0%				
Contribution as individual (hypothetical)	Same		69%	63%		
	More		16%	9%		
	Less		16%	28%		
Concerned about team members' knowing about pledges and expectation (0 not at all-10 very seriously)	Average		3.19	3.38		
Opinion about delegate's pledge	Too low				17%	19%
	Too high				36%	11%
	Appropriate				47%	70%
Opinion about delegation	Satisfied				81%	80%
	Unfair				19%	20%
Willing to be delegate	Yes				91%	83%
Number of subjects =		32	32	32	64	64

Figure B.1. Group Contributions by Group and Treatment

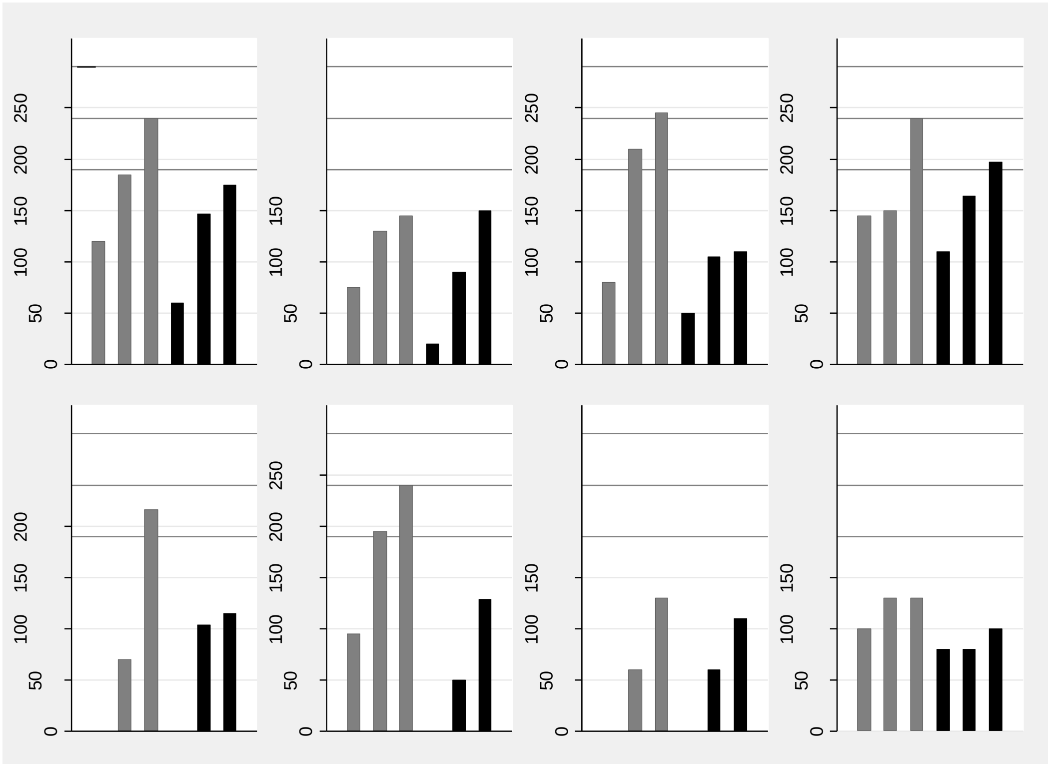
A. **noD**: 8 Groups and 6 Rounds



B. **DnoM**: 8 Groups and 6 Rounds

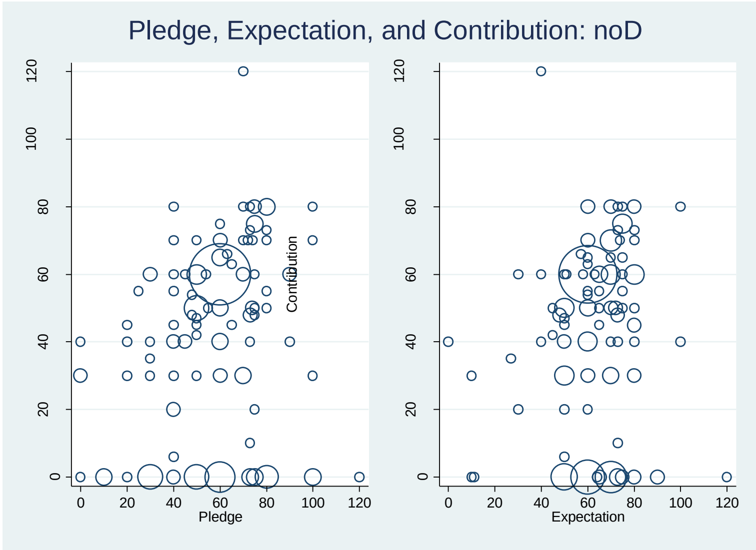


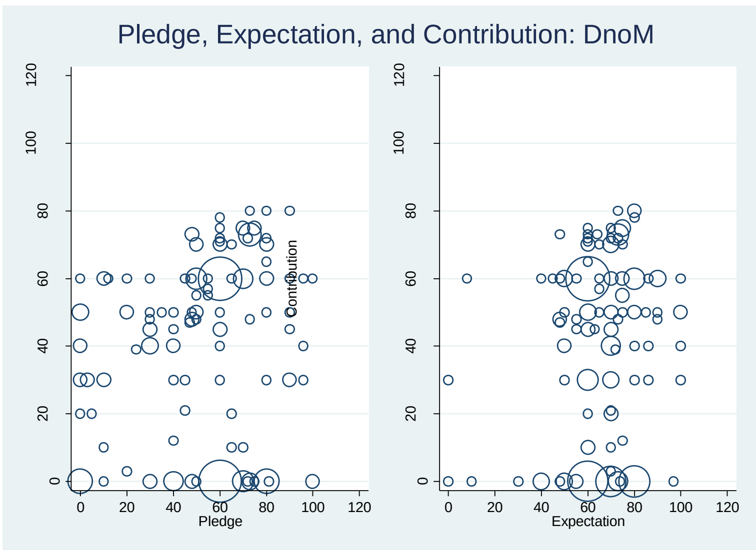
C. **DM**: 8 Groups and 6 Rounds

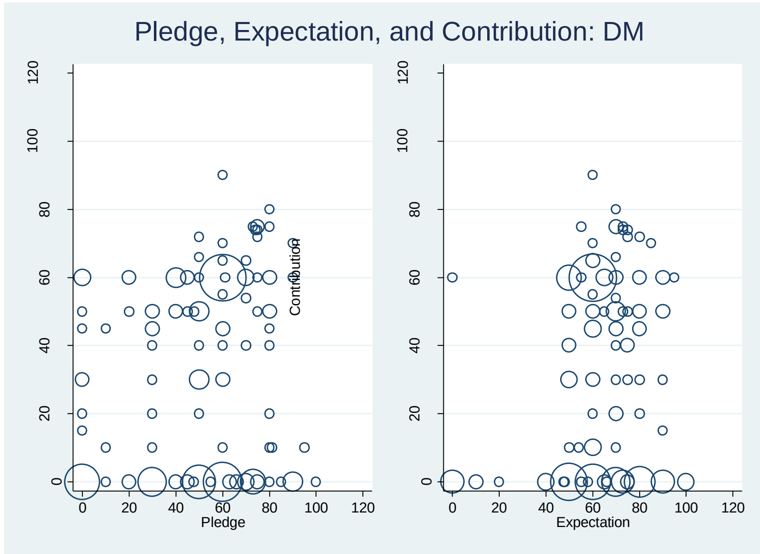


Notes: In each treatment, there are 8 groups. Each bar graph shows a group's total contribution in each treatment, ordered as follows; CT55%, CT75%, CT95%, UT55%, UT75%, and UT95%. That is, the gray bars represent total contributions when there is a single and certain threshold. The black bars represent total contributions when there are two uncertain thresholds. In case of no contribution (zero), there is no bar. Three horizontal lines represent thresholds, from the highest, higher (290), middle (240) and lower threshold (190).

Figure B.2. Pledges, Expectation and Contribution







Pledge, Expectation, and Contribution: DM
Contribution
Pledge
Expectation
0
20
40
60
80
100
120

Table B.1. Teams' Pledges and Contributions

	Pledge	Expectation	Contribution	Contribution > Pledge	Contribution = Pledge	Contribution < Pledge
noD	57.81	62.69	41.57	0.19	0.32	0.47
	(19.79)	(14.37)	(27.40)	(0.39)	(0.47)	(0.50)
DnoM	52.78	65.70	37.28	0.30	0.24	0.46
	(25.49)	(15.29)	(28.04)	(0.46)	(0.43)	(0.50)
DM	50.17	62.58	28.84	0.18	0.25	0.57
	(25.09)	(18.64)	(28.56)	(0.39)	(0.43)	(0.50)

Notes: Standard deviations are presented in parentheses.