The Political Hare and the Stag Hunt

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Abstract

We theoretically and experimentally study an indefinite dynamic game intended to capture two main aspects of the political process – elections in which opposing factions compete by spending resources and policy-making in which those same factions are required to cooperate for the successful legislature. The main theoretical result is that limits on spending in the election contest increase cooperation. On the experimental side, we first test and confirm theoretical predictions and then explore whether such limits could arise endogenously. We find that a majority of subjects are successful in establishing a consensus on low limits, leading to higher cooperation and welfare.

JEL classification: *C73, C92, D91*

Keywords: Political Economy, Endogenous Institutions, Dynamic Games, Cooperation, Coordination, Contest, Experiments

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1 Introduction

Can a campaign finance reform increase inter-party cooperation on legislature? In this paper, we address this question by theoretically and experimentally investigating a dynamic game that combines elections, modeled as contests (e.g., Tullock, 1967), with policy legislation, modeled as collective action problems central to the provision of public goods (e.g., Hardin, 1971; Bergstrom, Blume, and Varian, 1986; Ostrom, Walker, and Gardner, 1992). In particular, during an election stage, political factions use spending to influence the voting outcomes and acquire "political power" (e.g., Baron, 1994; Grossman and Helpman, 1996).[1] Next, during the policy legislation stage, the factions decide between a safe option (e.g., no compromise on the party platform) and a risky option that could generate a surplus (e.g., agreeing to compromise). Specifically, the policy legislation is akin to the multiplayer stag-hunt game (Rousseau, 1754), except the benefits of cooperation are divided according to political power. Thus, we combine the political contest and collective action game into an indefinite dynamic game with two alternating stages – a political contest, which determines power over the division of resources, and policy coordination, which determines total resources available for consumption and the next political contest.

Our approach to address the question of interest is three-fold. First, on the theoretical front, we show that exogenous limits on expenditures in the contest can increase cooperation in the policy legislation stage. Specifically, we prove the stability of cooperative myopic-best-response equilibria if the contest expenditure limits are low enough. Second, on the experimental front, we confirm theoretical predictions and show that exogenously specified limits work in improving cooperation among human decision-makers. In particular, the improvement is substantial, both in the overall levels (73% vs. 37% across all decision rounds) and when focusing on long-term outcomes (60% vs. 15% in rounds eight and above). Finally, we use experiments to explore whether such limits could arise endogenously and whether resulting institutions can be effective in promoting cooperation. We find positive answers on both dimensions – a majority of players learn to agree on spending limits, and the limit is effective in substantially improving cooperation and welfare relative to the scenario when players do not agree to impose spending limits. Combined, our results show that in a dynamic political framework with interdependent cooperative and competitive stages, campaign finance limits in the election contests are an effective tool in improving cooperative legislative outcomes.

Our work contributes to several streams of literature in economics and political science. First, we contribute to the research on the design of political institutions and the impact such institutions have on cooperation and economic outcomes (North, 1990; Eggertsson, 1990; Crawford and Ostrom, 1995; Acemoglu, Johnson, and Robinson, 2004). Related literature on institutions includes Hurwicz (1996a); Pénard (2008); Powers, Van Schaik, and Lehmann (2016); Currie, Campenni, Flitton, Njagi, Ontiri, Perret, and Walker (2021); Acemoglu and Robinson (2008, 2013). Among these

[1] According to the Federal Election Commission of the United States, during the 24 months of the 2019–2020 election cycle, combined election expenditures across presidential candidates, congressional candidates, political parties, and political action committees totaled over 23 billion USD.

papers, the closest to ours is Acemoglu and Robinson (2008), who examine a dynamic interplay between political institutions and economic outcomes. Our model differs in that the political power directly determines the share of economic surplus from policy coordination. In addition, political power is a key component of the incumbency advantage, which is modeled as complementarity between political power and election expenditures.[2] Importantly, incumbency advantage creates dynamic incentives to spend in the election contests in order to accumulate even more political power, which is the reason why infinitesimal inequality in power snowballs into substantial inequality and results in the collapse of cooperation. By setting a campaign spending limit that is low enough, a central planner can bound dynamic incentives associated with the incumbency advantage and restore cooperation in the policy coordination stage as a stable equilibrium outcome. Thus, since economic surplus in our framework is created via cooperation at the collective action stage, lower contest limits lead to greater welfare.

The second broad stream of literature that we contribute to studies dynamic and repeated games. Work in this field has focused on behavior in common-pool resources games (Gardner, Ostrom, and Walker, 1990; Stoddard, Walker, and Williams, 2014; Vespa, 2020), dynamic Prisoner's dilemma games (Vespa and Wilson, 2019; Rosokha and Wei, 2020; Bigoni, Casari, Salvanti, Skrzypacz, and Spagnolo, 2024), dynamic helping games (Camera, Hohl, and Weder, 2023; Bigoni, Camera, and Casari, 2019), dynamic public good games (Noussair and Soo, 2008; Rockenbach and Wolff, 2017; Gächter, Mengel, Tsakas, and Vostroknutov, 2017), dynamic contests (Deck, Dorobiala, and Jindapon, 2024), and dynamic coordination games (Houle, Ruck, Bentley, and Gavrilets, 2022; Rosokha, Lyu, Tverskoi, and Gavrilets, 2024, 2023). In particular, using a similar framework to ours Rosokha, Lyu, Tverskoi, and Gavrilets (2024) establish that cooperation rates predictably respond to the parameters of the game (e.g., the maximum benefit to cooperation) and Rosokha, Lyu, Tverskoi, and Gavrilets (2023) show that incumbency advantage leads to cooperation breakdown such that even though cooperation starts high (~75%) it quickly breaks down (~15%).[3] Combined, the previous studies motivate our search for mechanisms that could prevent cooperation breakdown when election contests are subject to incumbency advantage. Other related papers are Cadigan, Wayland, Schmitt, and Swope (2011) and Rockenbach and Wolff (2017) who study dynamic public good games with carryover. In particular, in their setting, players' endowments in a period are determined by payoffs obtained in the previous period. Our work is unique in that we study a dynamic game that is a combination of two games – collective action and contest – such that endowment in a contest is determined by payoffs in the collective action, and payoffs in the collective

[2]Our approach to incumbency advantage is related to Gill and Lipsmeyer (2005); Pastine and Pastine (2012); Avis, Ferraz, Finan, and Varjão (2022) who model incumbency advantage as fundraising efficiency, which, in turn, affects electoral competition.

[3]There are several other distinctions. Rosokha, Lyu, Tverskoi, and Gavrilets (2024) is the first to introduce an explicit contest for power with players choosing the expenditure in the political contest and test the role of this contest relative to prior work (e.g., Tverskoi, Senthilnathan, and Gavrilets, 2021; Houle, Ruck, Bentley, and Gavrilets, 2022) which considered a pre-determined rule. Houle, Ruck, Bentley, and Gavrilets (2022) also link economic inequality with social unrest in 75 countries between 1991 and 2016 predictions using country-level data. Rosokha, Lyu, Tverskoi, and Gavrilets (2023) focus on the role of decision-making units – groups vs. individuals.

action depend on the power obtained in the contest (see section 2 for more details).[4]

Third, our work contributes to the experimental literature that studies institutions that help solve social dilemmas (see, Dannenberg and Gallier (2020), for a recent review). In particular, existing work has found that in order to increase cooperation in the collective-action problems subjects are able to self-organize and create institutions that promote cooperation. Our approach is based on a general theoretical framework for modeling institutions which considers two interrelated games: an "economic game" and a "political game" (Hurwicz, 1996b; Powers, van Schaik, and Lehmann, 2016; Gavrilets and Currie, 2022). Thus, the outcome of the economic game reflects the payoffs to the agents from social interactions, whereas the political game involves separate interactions that establish rules that affect the economic game. For example, in prisoner dilemma settings, the political game could involve subjects choosing the game structure and/or payoffs, and the economic game could involve subjects making the choice in the game (Grimm and Mengel, 2009, 2011; Dal Bó, Foster, and Putterman, 2010; Dal Bó, Dal Bó, and Eyster, 2018; Bigoni, Camera, and Casari, 2019; Brekke, Hauge, Lind, and Nyborg, 2011). In public goods games, subjects could choose rewards or sanctions that increase voluntary contribution (Kosfeld, Okada, and Riedl, 2009; Sutter, Haigner, and Kocher, 2010; Putterman, Tyran, and Kamei, 2011; Özgür Gürerk, Irlenbusch, and Rockenbach, 2014; Markussen, Putterman, and Tyran, 2014). Consistent with previous findings, in our experiment, we find that subjects can agree on an effective institution to increase cooperation and improve welfare. In addition, they exhibit the "wisdom of the crowd" (Markussen, Putterman, and Tyran, 2014; Kamei, Putterman, and Tyran, 2015) such that in the later matches, subjects agree on low limits that reduce both inequality in power and resource depletion in competition.

The rest of the paper is organized as follows. In section 2, we provide details of the environment and derive theoretical predictions. In section 3, we describe the details of the experimental design. In section 4, we present the main results. Finally, in section 5, we conclude.

2 Environment and Theoretical Predictions

The environment studied in this paper is similar to the endogenous-contest treatments of Rosokha, Lyu, Tverskoi, and Gavrilets (2024, 2023). In particular, we consider a society composed of $I = \{1, \ldots, n\}$ players interacting over an indefinite sequence of rounds with a probability of continuation $\delta \in (0, 1)$. In each round $t \in \{1, 2, 3, \ldots\}$, players face a coordination game (stage 1) and a contest for power (stage 2). Specifically, in stage 1 of round t, each player i chooses between cooperation ($a_{i,t} = 1$) and defection ($a_{i,t} = 0$). For convenience, let $a_t = (a_{i,t}, a_{-i,t}) = (a_{1,t}, \ldots, a_{n,t})$ denote the action profile in round t, and let $a_{-i,t}$ denote an action profile of all players excluding i. The payoff from cooperation, $F(\bar{a}_t)$, is an S-shaped function of the proportion of players who decide to

[4] Some of the elements of our environment have been studied separately in the experimental literature. For example, Schmitt, Shupp, Swope, and Cadigan (2004) study a multi-period contest with carryover, while Swope (2002) study public goods game with exclusion.

cooperate, $\bar{a}_t = \frac{\sum_{i \in I} a_{i,t}}{n}$, as follows:

$$F(\bar{a}_t) = b \frac{(\bar{a}_t)^{\kappa}}{(\bar{a}_t)^{\kappa} + (a_0)^{\kappa}}, \tag{1}$$

where $b > 0$ is the maximum benefit to cooperation, $a_0 \in (0, 1)$ is the "half-effort" parameter that determines the average cooperation required to produce half of the maximum benefit, $(\frac{b}{2})$, and $\kappa \geq 1$ is the parameter that determines the steepness of the production function (Gavrilets, 2015; Gavrilets and Richerson, 2017).[5]

Unlike the widely studied stag-hunt or public-goods games, the share of the production that player i gets in round t depends on their political power $f_{i,t} \in [0, 1]$.[6] Specifically, player i's payoff in stage 1 is

$$\pi_i^1(a_t, f_t) = R_0 + a_{i,t}\Big(\frac{f_{i,t}}{a_t \cdot f_t} F(\bar{a}_t) - c\Big), \tag{2}$$

where $c > 0$ is the cost of cooperation, $a_t \cdot f_t = \sum_{i \in I} a_{i,t} f_{i,t}$ is the sum of powers of cooperating players, and $R_0 > c$ is an endowment. That is, we consider a club-good setting in which the benefits of cooperation are split among cooperating players according to their political power.[7]

In stage 2 of round t, each player i chooses how much to spend in the contest for political power, $e_{i,t} \in [0, min\{L, \pi_i^1(a_t, f_t)\}]$, where $L > 0$ is the limit on expenditures. The main focus of this paper and the novelty relative to Rosokha, Lyu, Tverskoi, and Gavrilets (2024) and Rosokha, Lyu, Tverskoi, and Gavrilets (2023) is on how this limit affects the dynamics of cooperation, expenditures in the contest, and political power. We postulate that given the vector of expenditures, $e_t = (e_{i,t}, e_{-i,t}) = (e_{1,t}, ..., e_{n,t})$, political power of player i in round $t+1$ is defined as[8]

$$f_{i,t+1} = \phi_i\big(e_t, f_t\big) = \frac{e_{i,t} f_{i,t}}{e_t \cdot f_t} \tag{3}$$

Here we assume there is an incumbency advantage modelled as complementarity between the current power and expenditure in the contest.[9] Thus, the political power next round, f_{t+1}, depends on both the current political power, f_t, and the current expenditure, e_t. Notice that equation (3) is related to the Tullock contest (Tullock, 1980; Konrad, 2009) as well as to the replicator equation in evolutionary biology and evolutonary game theory (Taylor and Jonker, 1978; Hofbauer and Sigmund, 1988).

[5] In a similar framework to ours, Rosokha, Lyu, Tverskoi, and Gavrilets (2024) theoretically and experimentally establish that cooperation responds to the parameters n, b, and a_0. In a setting of indefinitely repeated helping game Camera, Kim, and Rojo Arjona (2023) show the impact of "half-effort" and group size.

[6] $\sum_{i=1}^{n} f_{i,t} = 1$

[7] There are two special cases stemming from the possibility of the denominator being zero. First, when cooperating players have zero political power (i.e., $a_t \cdot f_t = 0$ and $a_t \cdot \mathbb{1} \neq 0$), we define $\pi(a_t, f_t) = R_0 + a_{i,t}\Big(\frac{1}{a_t \cdot \mathbb{1}} F(\bar{a}_t) - c\Big)$. Second, when there are no cooperating agents ($a_t \cdot \mathbb{1} = 0$), we define $\pi(a_t, f_t) = R_0$.

[8] In the special case of $e_t \cdot f_t = 0$, we define $f_{i,t+1} = f_{i,t}$.

[9] The impact of the incumbency parameter is theoretically and experimentally examined in Rosokha, Lyu, Tverskoi, and Gavrilets (2023).

Finally, the total payoff in round t is

$$\pi_i(a_t, f_t, e_t) = \pi_i^1(a_t, f_t) - e_{i,t}. \tag{4}$$

2.1 Myopic Best-Response and the Long-Term Outcomes

For theoretical guidance, we rely on a model of myopic best-response. There are three reasons for this choice. First, a fully forward-looking equilibrium concept does not provide a clear prediction in our environment because both cooperation and defection are stage-game Nash equilibria. Therefore, any sequence of cooperation and defection could be supported as a subgame perfect equilibrium (SPE) even without any limits. For example, a trigger strategy that prescribes cooperating in stage 1 and zero spending in stage 2 as long as the other also cooperates and spends zero would be an SPE. Any deviation, either by defecting in stage 1 or by changing the amount in stage 2, will trigger a punishment of defection forever. Second, myopic best response has a long history among economists (Kandori, Mailath, and Rob, 1993; Young, 1993; Kandori and Rob, 1995; Hopkins, 1999) and evolutionary game theorists (Smith, 1982; Matsui, 1992; Sandholm, 1998; Alós-Ferrer, 2003; Roca, Cuesta, and Sánchez, 2009; Szolnoki and Perc, 2014) as a model for long-term evolution of cooperation. Finally, on the behavioral side, there is evidence that human decision-makers tend to be more adaptive and less strategic in complex environments Offerman, Sonnemans, and Schram (2001). More specifically, recent papers on repeated coordination games (Mäs and Nax, 2016) and dynamic coordination games similar to the current framework (Rosokha, Lyu, Tverskoi, and Gavrilets, 2024) offer empirical support for a model of myopic best-response.

In the model, there are two inter-related decisions: the decision to cooperate in collective action at stage 1, $a_{i,t} \in \{0, 1\}$ and the decision to spend in the contest for power at stage 2, $e_{i,t} \in [0, min\{L, \pi_i^1(a_t, f_t)\}]$, where L is the limit on expenditures. Specifically, the expenditure in stage 2 of round t directly affects not only the current round t payoff but also the next round $t+1$ payoff (which also depends on the next round cooperation decision, $a_{i,t+1}$). Therefore, to make the theoretical analysis manageable, we assume each player simultaneously chooses the expenditure $e_{i,t}$ in stage 2 of round t and the action $a_{i,t+1}$ in stage 1 of round $t+1$ to maximize her expected total earnings by best responding to the previous choices (a_t, e_{t-1}). That is, in stage 2 of round t, player i chooses

$$(a_{i,t+1}, e_{i,t}) = BR_i^{a,e}(a_t, e_{t-1}, f_t) =$$

$$= \underset{a_i \in \{0,1\}, e_i \in [0, min\{L, \pi_i^1(a_t, f_t)\}]}{\operatorname{argmax}} \left\{ -e_i + \delta \pi_i^1 \Big((a_i, a_{-i,t}), \phi\big((e_i, e_{-i,t-1}), f_t\big) \Big) \right\}, \tag{5}$$

where $\phi\big((e_i, e_{-i,t-1}), f_t\big) = \Big(\phi_1\big((e_i, e_{-i,t-1}), f_t\big), .., \phi_n\big((e_i, e_{-i,t-1}), f_t\big)\Big)$, $a_{-i,t} \cdot e_{-i,t-1} = \sum_{j \in I \setminus \{i\}} a_{j,t} e_{j,t-1}$ is the total expenditure of all cooperating players except i, and $\delta \in (0, 1)$ is the probability of continuing the game to the next round.

Definition 1 *A strategy profile* (a^*, e^*) *is a myopic-best-response equilibrium if*

$$(a_i^*, e_i^*) = BR_i^{a,e}(a^*, e^*, \hat{f}), \forall i \in I, \tag{6}$$

where

$$\hat{f}_i = \phi_i(e^*, \hat{f}), \forall i \in I. \tag{7}$$

Definition 2 *Let* (a^*, e^*) *be a myopic-best-response equilibrium with the corresponding powers* $\hat{f}$ *defined by equations (6) and (7). We say that* (a^*, e^*) *is stable to small perturbations in expenditures and powers if* $(e^*, \hat{f})$ *is a locally stable equilibrium of the system*

$$e_{i,t} = \psi_i(e_{t-1}, f_t), \forall i \in I, \tag{8}$$

$$f_{i,t+1} = \phi_i(e_t, f_t), \forall i \in I, \tag{9}$$

where $\psi_i(e_{t-1}, f_t) = \text{argmax}_{e_i \in [0, \min\{L, \pi_i^1(a^*, f_t)\}]} \left\{ -e_i + \delta \pi_i^1 \Big(a^*, \phi\big((e_i, e_{-i,t-1}), f_t\big) \Big) \right\}$.

Theorem 1 ***Existence and stability of myopic-best-response equilibria.*** *The following stable myopic-best-response equilibria exist in the model:*

- *With all defectors spending zero expenditures and having equal powers* $\frac{1}{n}$ *if*

  $$F(1/n) < c.$$

- *With two cooperators having powers* $\hat{f} \in \Omega(2) \subset (0,1)$ *and* $1 - \hat{f}$*, respectively, and the same expenditure* $e_C^* = \delta \hat{f}(1 - \hat{f}) F(2/n)$ *not exceeding the limit* L *if* $F(2/n) \geq 4c$ *and*

  $$L > \delta \cdot max \left\{ \sqrt{cF(2/n)} - c, \frac{F(2/n)}{8} \right\}.$$

  Defectors (if exist) have zero expenditures and powers.

- *With* $n_C \in \{3, .., n\}$ *cooperators having powers* $(\hat{f}_1, ..., \hat{f}_{n_C}) \in \Omega(n_C) \subset \Delta(n_C)$[10]*, respectively, and spending the maximum expenditure* $e_C^* = L$ *if*

  $$L \leq \delta \left[\frac{F(n_C/n)}{n_C} - max \left\{ \frac{F(n_C/n)}{n_C^2}, c \right\} \right]$$

  Defectors (if exist) have zero expenditures and powers.

The proof of Theorem 1 can be found in Appendix A. The main takeaway is that if the limit L on expenditures is higher than a threshold, there are at most two cooperators in a stable equilibrium. However, lowering the limit L on expenditures below the threshold leads to the emergence of stable equilibria supporting high levels of cooperation (i.e., with 3 or more cooperators).

[10] $\Delta(n_C)$ is an $(n_C - 1)$ dimensional simplex in R^{n_C}. Sets $\Omega(n_C)$ are defined in Appendix A.

2.2 Experimental parameters and predictions

For the experiment, we fix parameters $b = 232$, $n = 3$, $a_0 = 0.812$, $R_0 = 60$, $c = 20.4$, $\kappa = 12$, $\delta = 0.875$, and $e_{i,0} = 0$, $\forall i \in I$. For example, when players' powers are equal—as will be the case in Round 1 of every supergame—the stage-game is a three-player stag hunt with a safe action D that yields a payoff of 60 regardless of what everyone else does and a risky action C that yields a payoff of 110 if everyone else chooses C (see left panel of Figure 1a for the full stage-game payoff matrix). However, if the power is unequal, as can be the case because of players' previous choice, the payoff to mutual cooperation changes such that the more power a player has, the more payoff that player will receive (see the central panel of Figure 1a and an example in the right panel of Figure 1a).

The exogenous limit treatments of the experiment vary the limit on expenditure in the political contest, denoted by L. In particular, we consider three cases: *No Limit* ($L \to \infty$), *High Limit* ($L = 50$), and *Low Limit* ($L = 10$). Figure 1b presents regions of existence and stability of myopic-best-response equilibria for the three cases. In each case, we denote the fixed set of parameters as $T1$. Specifically, for the T1 parameter combination, defection is the only equilibrium in the No Limit and the High Limit cases, whereas full cooperation is an equilibrium in the Low Limit case. The explanation is as follows. If the limit L on expenditures is relatively high (so that the optimal expenditure of each cooperator in equilibrium with 3 cooperators does not exceed the limit), the cooperative equilibrium is unstable to small perturbations in power and expenditures. Namely, even infinitesimal differences in power and expenditures between the three cooperating agents are amplified because more powerful agents can accumulate even more power by increasing their expenditures in the contest due to the incumbency advantage. However, if the limit L on expenditures is relatively low (so that all cooperators spend the maximum expenditure $e_C^* = L$ in equilibrium with 3 cooperators), more powerful agents have no chance of utilizing the incumbency advantage by increasing their expenditures. As a result, the equilibrium with 3 cooperators is stable. Thus, based on our theoretical predictions, we formulate the following hypothesis:

Hypothesis 1 *Cooperation is higher in the Low Limit treatment ($L = 10$) than in the High Limit ($L = 50$) and No Limit ($L \to \infty$) treatments.*

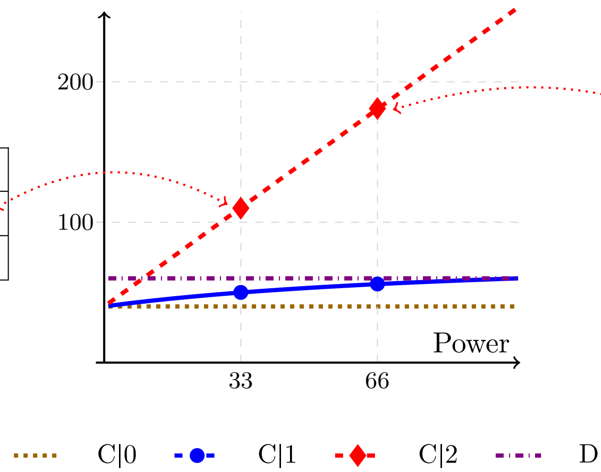
3 Experimental Design

Our experiment contains four between-subject treatments. To test the theoretical predictions, we have three exogenous treatments that vary the limit amounts: Low Limit ($L = 10$), High Limit ($L = 50$), and No Limit ($L \to \infty$). To examine whether subjects can come up with and agree on a low enough limit, we introduce a fourth treatment that we call the Voting treatment. The Low Limit, High Limit, and Voting treatments were conducted in March, 2024, whereas the No Limit treatment was conducted in February and March, 2023 as part of Rosokha, Lyu, Tverskoi, and Gavrilets (2023). Each treatment included four sessions with 12 subjects for a total of 144 subjects. All sessions took place at the Vernon Smith Experimental Economics Laboratory at Purdue University.

Figure 1: Parameters and Theoretical Predictions

Stage 1 payoffs when power is 33

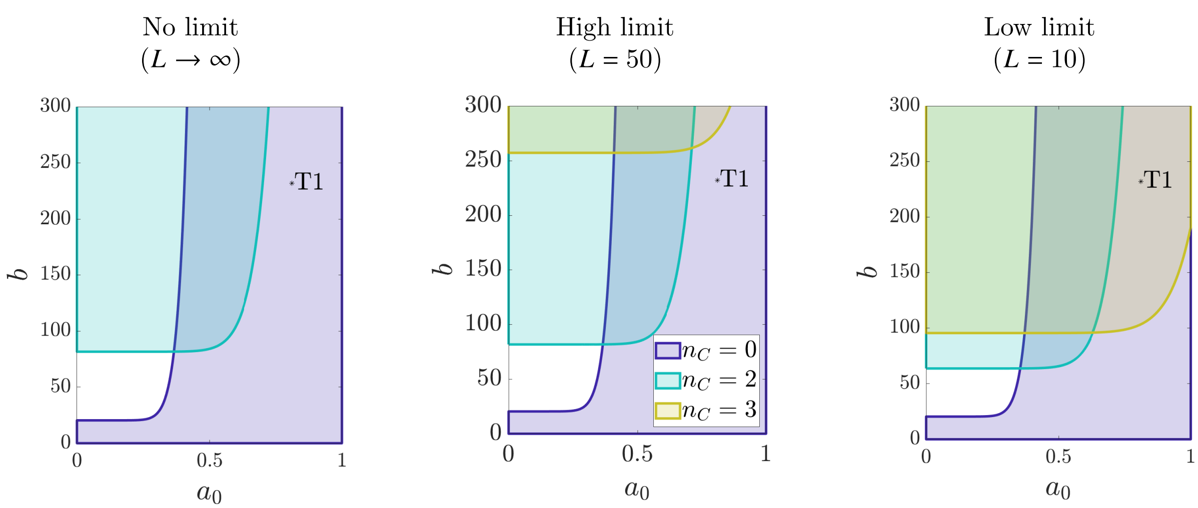
	0	1	2
C	40	50	110
D	60	60	60



Stage 1 payoffs when power is 66

	0	1	2
C	40	56	181
D	60	60	60

(a) Stage-game Payoffs as a Function of Power



(b) Stable Myopic Best Response Equilibria

Notes: **(a)** Stage 1 Payoffs as a function of power. Columns denote how many other players choose C (out of $n-1$). All players have a power of 33 in Round 1 but may have unequal power in other rounds depending on players' choices in previous rounds. **(b)** Regions of existence and stability of equilibria with n_C cooperators and $n-n_C$ defectors as a function of the maximum benefit to cooperation b and the proportion of the group a_0 required to produce benefit $\frac{b}{2}$. Parameters corresponding to the experimental treatment are marked by $\star T1$.

Each session began with a demographic questionnaire and 11 matrix-reasoning questions (see Appendix D.1 for an example), for which subjects receive a flat rate of 3 US Dollars. Next, subjects had 20 minutes to go through a set of interactive instructions and 10 incentivized quiz questions, earning 0.50 US Dollars for each correct answer. After the instructions, the experiment began. In particular, each subject faced a sequence of 20 indefinite three-player dynamic games. Each dynamic game, referred to as a "match," consisted of a group of three subjects interacting over a random number of rounds determined using a random termination protocol with a probability of continuation $\delta = .875$. For the experiment, we drew four sets of match lengths to use across four sessions of each treatment (see Table B-2 in the Appendix for sequence realizations). At the end of each match, subjects were randomly rematched. As is common in experiments on repeated and dynamic games, subjects accumulated points across all matches. At the end of the experiment points were converted to US Dollars at a pre-specified exchange rate.[11]

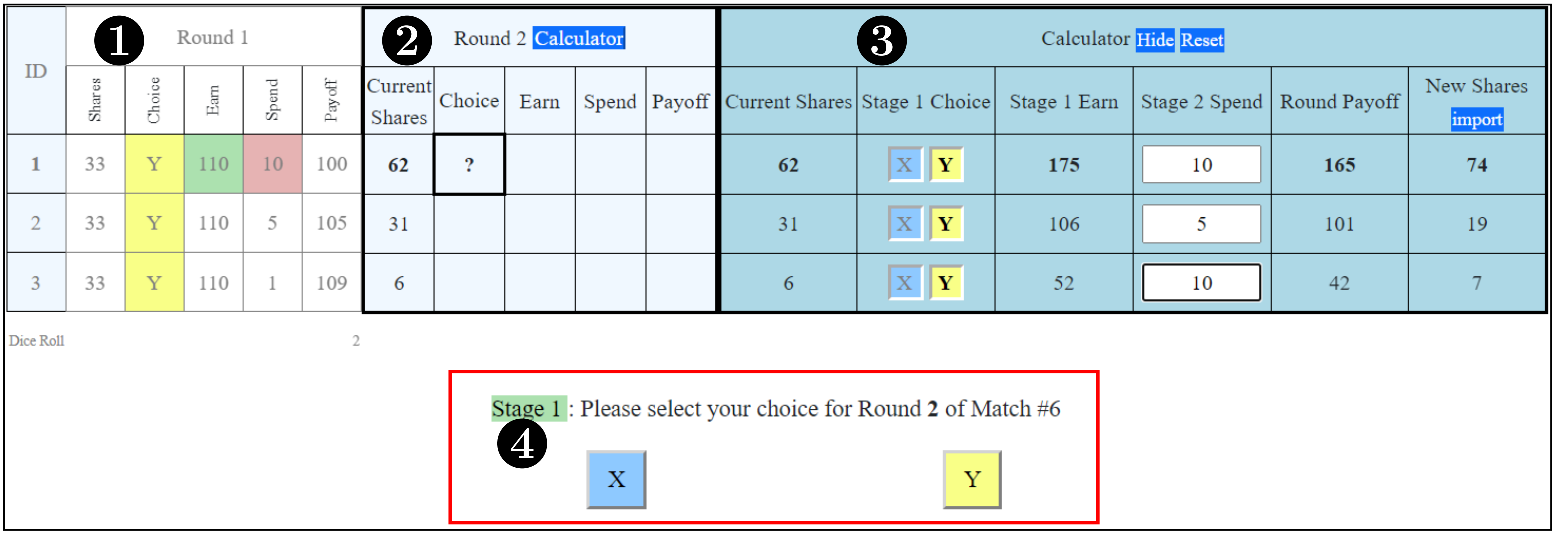
Each round contained two decisions: a collective action decision in stage 1 and a contest for power decision in stage 2. The screenshots of the interface are presented in Figure 2. We used neutral language in the instructions with labels X and Y representing defection and cooperation, respectively, and "shares" representing "political power." Given the complexity of our environment, we undertook multiple steps to ensure subjects understood the interface and the consequences of decisions in both stages. First, we designed the program to actively engage subjects throughout the details of the instructions. Some of the notable features of the interactive instructions included requiring subjects to click buttons to reveal information and providing multiple randomly generated examples. Second, we included incentivized quiz questions within the instructions to test participants' understanding. After answering each question, subjects received immediate feedback to clarify any misunderstandings they may have had. Finally, at every point during the experiment (including waiting pages), subjects had access to a hypothetical calculator (3 in Figure 2). Thus, they could experiment with hypothetical choices to view the resulting payoffs and the power distribution for the next round.

The exogenous and endogenous limits were introduced as a surprise announcement prior to match six. In particular, for the exogenous limit treatments, subjects were told that from match 6 onward, the maximum number of points they can spend in stage 2 is limited at either 50 points (High Limit) or 10 points (Low Limit). In the Voting treatment, subjects are instructed that they will go through the following two-step procedure prior to each match: First, each of the three subjects votes on whether to impose a limit for the duration of the match. Second, if the majority agrees to impose a limit, each subject proposes a limit, and the median of these proposals is selected as the limit for the match. If the majority doesn't agree to impose a limit, the match proceeds without a limit, identical to match 1-5. A similar endogenous procedure has been used in (Bigoni, Camera, and Casari, 2019; Camera, Hohl, and Weder, 2023). Notice that prior to match 6, subjects across all four treatments faced exactly the same experimental procedures. We made this design choice in order to ensure that instructions (including the quiz), the initial learning about the environment,

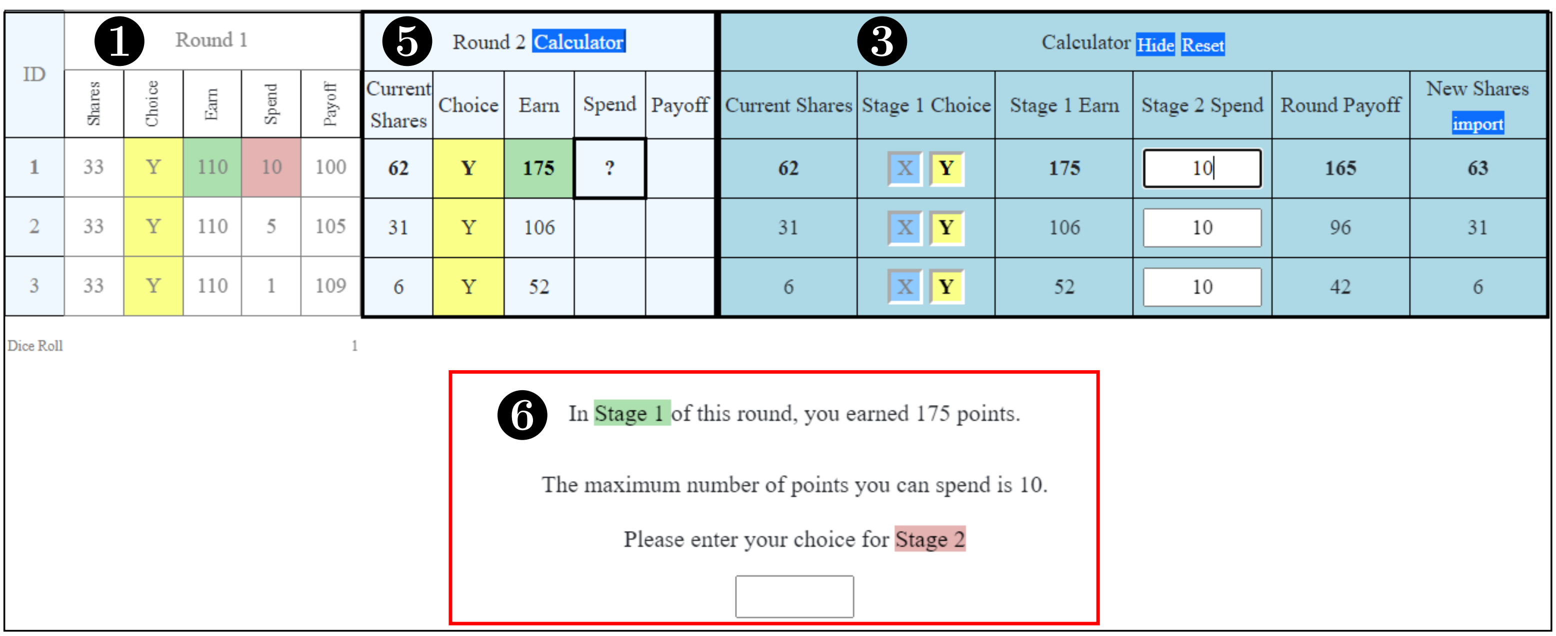
[11] See Appendix D for the instructions used in the experiment.

and the initial decision complexity were comparable across the four treatments.

Figure 2: Interface Screenshots



(a) Stage 1 Decision



(b) Stage 2 Decision

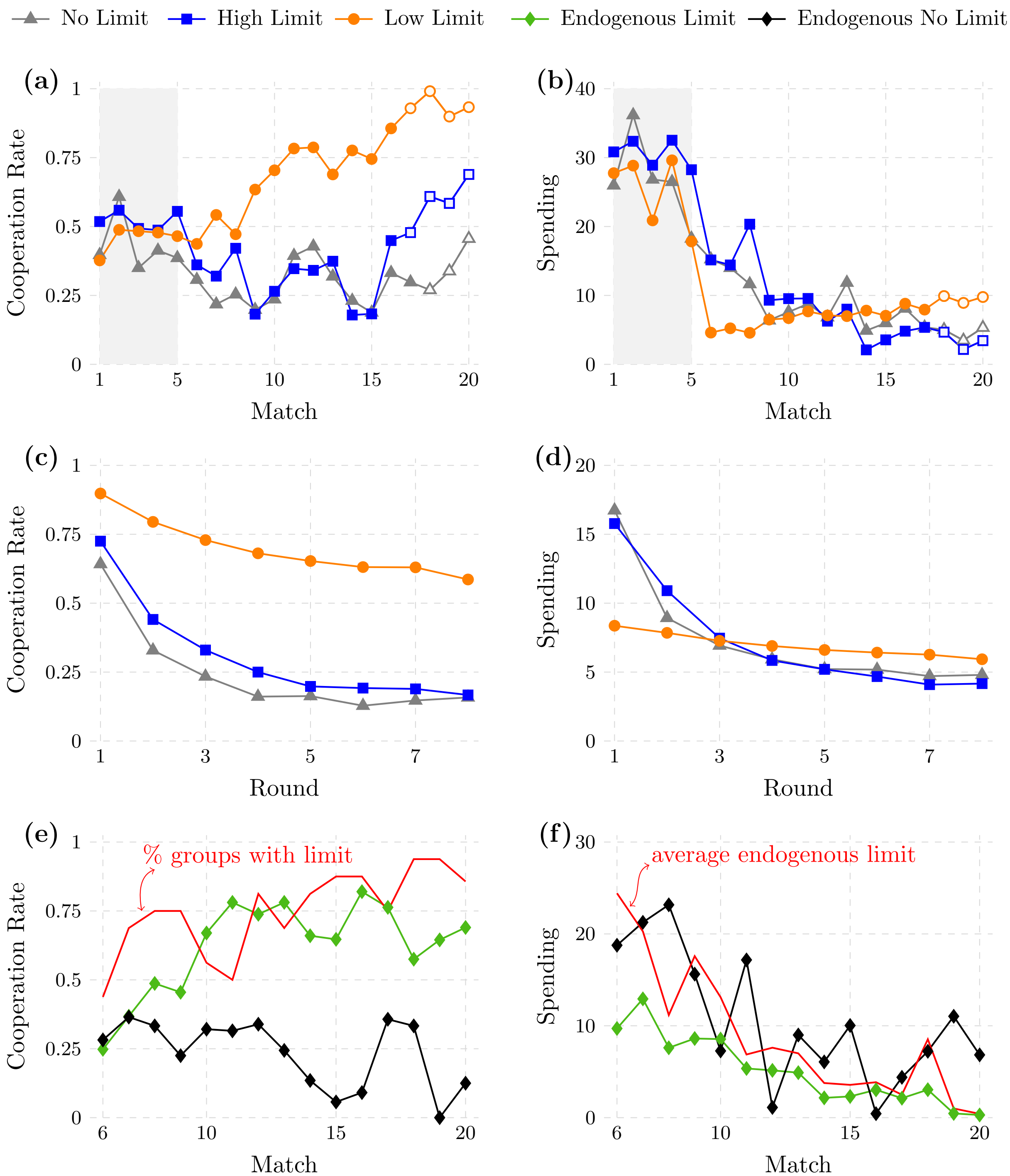
Notes: **(a)** stage 1 screenshot including (1) the history of decisions in previous rounds, (2) the current-round summary with power distribution in the first column (neutral "current shares" was used instead of "power") and a question mark denoting the current decision, (3) a hypothetical payoff calculator, (4) decision entry in stage 1 (neutral action labels X and Y were used instead of D (defect) and C (cooperate), respectively). **(b)** stage 2 screenshot including (5) the updated current-round summary that reflects all stage 1 choices, their stage 1 earnings, and a question mark denoting that the decision moves to stage 2, (6) decision entry in stage 2. The reminder about the spending limit is only displayed for matches 6 and onward. In Voting treatment, if the group doesn't agree to set a maximum, no reminder will be shown on the page.

4 Experimental Results

Figure 3 presents raw experimental data. In particular, Panels (a) and (b) present the average cooperation and spending across matches of the No Limit, High Limit, and Low Limit treatments. We use a gray background to highlight that in matches 1–5 the spending limits have not been introduced yet.[12] Panels (c) and (d) present the same three treatments from a within-a-match perspective (i.e., averaged across rounds using data from matches 6–20). Panels (e) and (f) present data from the Voting treatment. In particular, we distinguish between groups that agreed to impose a limit from those that did not. In addition, we present the average proportion of groups that agreed to impose the limit and the average magnitude of the endogenous limit.

[12]The average cooperation rates for the first 5 matches are comparable across treatments. Specifically: .43 (No Limit), .52 (High Limit), .46 (Low Limit), where F statistic is 2.22, with $p = .11$.

Figure 3: Cooperation and Spending Across and Within Matches



Notes: Panels (a) and (b) present the average cooperation rate and the average spending across matches. The grey-shaded region indicates Phase 1 of the experiment before additional instructions regarding limits were introduced. The No Limit treatment is from Rosokha et al 2024 and not have any instructions regarding the limits. Empty markers indicate that not all four sessions reached this match. See Appendix B for session details. Panels (c) and (d) present the average cooperation rate and the average spending within matches during Phase 2. Panels (e) and (f) present the average cooperation rate and the average spending within matches during Phase 2 of the endogenous voting treatment.

There are several important observations from Figure 3. First and foremost, consistent with our theoretical predictions, the panels (a) and (c) show a clear difference in cooperation between the Low Limit and the High Limit treatments. In addition, when compared to the No Limit treatment (average cooperation rate = .29), the average cooperation rate is significantly higher in the Low Limit treatment (.73 vs. .29, p = .031) but not significantly different in the High Limit treatment (.37 vs .29, p = .401).[13] Panel (b) and (d) present the average spending for the three treatments. As with cooperation, starting from match 6, the average spending in the Low Limit differs significantly from High Limit and No Limit. When considering spending within a match, we uncover potential explanations for the difference in cooperation outcomes. Namely, subjects tend to spend a lot more in the first round of the No Limit and High Limit cases, which leads to greater inequality in the following rounds that is accompanied by cooperation breakdown and a decrease in expenditures. In contrast, for the Low Limit treatment, subjects consistently spend at the upper limit boundary of 10, resulting in more equal power distribution and easier collective action problems in the subsequent rounds. Combined, it is clear that for the No limit and High Limit, the majority of subjects converge to the equilibrium of full defection and zero spending, whereas for the Low Limit treatment, many subjects choose to cooperate and spend 10, consistent with the cooperative equilibrium. We therefore summarize our first result as the following:

Result 1 *Cooperation is higher in the Low Limit treatment (*$L = 10$*) than in the High Limit (*$L = 50$*) and No Limit (*$L \to \infty$*) treatments.*

Panels (e) and (f) of Figure 3 present the cooperation and competition for the Voting treatment. We find that the percentage of groups agreeing to implement a limit on stage 2 spending increases over time, as indicated by the red solid line in panel (e). Second, the average cooperation rates diverge depending on the group's vote on implementing a limit. Specifically, the average cooperation rate is .63 for groups that impose a limit and .27 for groups that don't impose a limit. Third, as indicated by the red line in panel (f), subjects not only learn to impose a limit, but also learn to lower the limit over time. The average limit agreed decreases from 26.2 to .4. Accordingly, the average spending across matches tends to be lower for groups that imposed a limit compared to those that don't impose a limit.

[13] For these tests, p-values are obtained using non-parametric permutation tests with session as unit of observation. Later, in Table 2, we present results from random-effects regressions with standard errors clustered at the session level that confirm these results.

Table 1: Cooperation and Competition Conditional on History

	R1	Overall	Conditional on history			
My choice in stage 1 of round $t-1$			C		D	
Others' choices in stage 1 of round $t-1$			CC	DD	CC	DD
No Limit	64.2	29.5	80.1	40.2	19.1	3.0
High Limit	72.5	36.8	86.0	32.6	26.2	1.4
Low Limit	89.8	73.3	96.8	31.4	37.2	3.2
Voting						
— No Limits, 25%	48.3	27.2	73.1	50.0	21.9	2.6
— With Limits	74.5	63.1	97.3	58.0	35.2	4.0
— Limits > 10, 16%	54.1	39.0	91.2	53.1	43.6	3.3
— Limits ≤ 10, 59%	79.9	69.5	98.1	59.9	31.4	4.4

Notes: Data contains all rounds in matches 6-20. The average cooperation rate is in the next round. Since subjects can observe the stage 1 choice in the same round, the average spending is reported for the same round.

Table 1 provides an additional breakdown of the cooperation choices based on round, conditional history, and the limits imposed. We find similar general patterns for round 1 and all round decisions: the average cooperation rate is the highest with an exogenous low limit and the lowest with no limit. The same order is also present in the Voting treatment: compared to groups that don't agree on a limit, the average cooperation rate is higher for groups that agree on a limit. Furthermore, the cooperation rate is higher when limits are relatively low (Limits ≤ 10) compared to when limits are relatively high (Limits > 10). Conditional on history, we observe cooperation is more stable for the Low Limit treatment, compared to No Limit and High Limit treatment. In particular, the probability of choosing C conditional on mutual cooperation in the previous round is higher for Low Limit treatment (96.8%) compared to the other two treatments (80.1% for No Limit and 86% for High Limit). We also find that in the Voting treatment, full cooperation is relatively fragile when the groups do not agree on a limit (73.1% choose C following mutual cooperation) but very robust when groups agree on a limit (97.3% choose C following mutual cooperation). Interestingly, subjects in the Voting treatment are willing to continue cooperating even after both other players defect (50% choose C following the other two players defecting). We summarize these observations with Result 2:

Result 2 *In the voting treatment: (a) a majority of subjects learned to implement a limit on spending, (b) groups that implemented a lower limit achieved higher cooperation*

Table 2: Cooperation and Competition

	(1)	(2)	(3)	(4)	(5)	(6)
	Cooperation		Spending		Limit	Limit
	R1	All rounds	R1	All rounds	Agree	Proposed
High limit	-0.008	-0.004	-1.602	-0.577		
	(0.088)	(0.062)	(3.376)	(2.214)		
Low limit	0.141**	0.369***	-7.396**	0.209		
	(0.058)	(0.081)	(3.104)	(2.081)		
Voting	0.002	0.212**	-7.978**	-1.039		
	(0.081)	(0.086)	(3.584)	(2.518)		
Own R1 cooperation in M1	0.193***	0.105***			-0.068	1.937
	(0.045)	(0.023)			(0.061)	(5.329)
Own R1 spending in M1			0.058*	0.017	-0.001	0.236
			(0.030)	(0.012)	(0.002)	(0.152)
Others' R1 cooperation in M$(t-1)$	0.113***	0.132***			0.015	-1.226
	(0.027)	(0.042)			(0.032)	(4.981)
Others' R1 spending in M$(t-1)$			0.153***	0.060**	-0.001	0.422***
			(0.035)	(0.023)	(0.001)	(0.081)
Group agreed on a limit in M$(t-1)$					0.190***	3.326**
					(0.038)	(1.607)
Length of M$(t-1)$ / 100		0.438**		11.753***	-0.168	-5.604
		(0.216)		(4.499)	(0.239)	(11.432)
Match	0.012***	0.020***	-0.775***	-0.419**	0.013**	-0.767***
	(0.004)	(0.006)	(0.236)	(0.172)	(0.005)	(0.209)
Age under 20	0.010	0.020	-2.096	-0.593	0.217	-5.693
	(0.038)	(0.019)	(1.797)	(1.288)	(0.166)	(3.669)
Female	-0.151***	-0.047	1.056	0.541	-0.228	8.645**
	(0.044)	(0.032)	(1.795)	(1.251)	(0.140)	(4.381)
Major in STEM	-0.023	-0.091**	-3.063	-3.771*	-0.079	-7.109*
	(0.040)	(0.042)	(3.011)	(1.989)	(0.115)	(4.198)
High school in US	0.107*	0.031	-3.329	-2.088	0.054	-12.085***
	(0.061)	(0.037)	(2.362)	(1.952)	(0.078)	(4.183)
Standardized cognitive score	0.078***	0.022*	-1.694***	-1.580***	0.043	-0.697
	(0.019)	(0.013)	(0.600)	(0.558)	(0.029)	(1.566)
Constant	0.370***	-0.102	27.845***	14.415***	0.521*	22.416
	(0.068)	(0.126)	(7.102)	(4.687)	(0.286)	(13.930)
Observations	2,745	24,203	2,745	24,203	666	513
Number of subjects	192	192	192	192	48	48

Notes: The table reports results from random-effects regressions using data across all treatments in match 6-20. In columns (1) and (2), the dependent variable is 1 if subjects chose "Y"(cooperation) in stage 1, and 0 otherwise. In columns (3) and (4), the dependent variable is subjects' spending in stage 2. Columns (5) and (6) are restricted to data in voting treatment, match 6-20. The dependent variable in column (5) is 1 if subjects vote to agree to impose a limit for the match, and 0 otherwise. Column (6) contains all individual proposed limits when the group has agreed on a limit. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

Table 2 presents results of random-effects regressions that control for treatments, experience, and demographic variables. The first three rows include treatment dummies, with the No Limit treatment being the reference category. The regression results confirm Result 1. Specifically, consistent with the raw data, being in the Low Limit treatment significantly increases cooperation relative to the No Limit treatment (by 14.1% in round 1 and by 37% across all rounds), whereas being in the High Limit treatment does not (both differences are less than 1%). Regarding spending, being in the Low Limit treatment significantly reduces spending in round 1, but this effect is not significant for spending across all as we demonstrated with the raw data. Nevertheless, the reduction in round 1 spending and consistent spending across all rounds help prevent power inequalities, thereby leading to higher cooperation.

Rows 6–10 of Table 2 indicate that subjects' initial choices and the game-play experience are significant predictors of cooperation and competition behaviors in subsequent interactions. For example, the initial decision to cooperate ("own R1 cooperation in M1") is significantly and positively correlated with their cooperation across all rounds of the experiment. A similar but smaller impact is observed for subjects' spending behaviors as well. We also find evidence that subjects respond to others' choices in the previous matches. For example, interacting with a group that exhibited higher cooperation in the previous match significantly increases the probability of cooperating in the next match. Similarly, others' round 1 spending in the previous match has a lasting impact on subjects' spending in round 1 and subsequent rounds. Finally, we find that the experience with longer matches increases subjects' cooperation and spending across all rounds, indicating that subjects recognize the long-term benefits associated not only with cooperation but also with having greater political power. All these observations are consistent with findings by numerous repeated game studies (e.g., Dal Bó and Fréchette, 2018; Gill and Rosokha, 2020).

Regarding individual characteristics (rows 11–15 of Table 2), we find that subjects' cognitive scores matter for both cooperation and competition. For example, columns (1) and (3) show that one standard deviation increase in the cognitive ability score is associated with a 7.8% increase in round 1 cooperation and a 1.7 point decrease in round 1 contest expenditure. Combining both, the evidence suggests that subjects with higher cognitive scores are more likely to reach a more efficient outcome characterized by full cooperation and low spending. This finding aligns with previous research by Proto, Rustichini, and Sofianos (2019, 2022), which indicates that subjects with higher cognitive scores are more likely to achieve a more efficient equilibrium in an indefinitely repeated prisoner dilemma game.

Columns (5) and (6) of Table 2 explore the subjects' decisions in the Voting treatment. Recall that prior to each match subjects face a two-step process. First, each subject independently votes on whether to impose a limit. Second, if a majority (of the three subjects) supported imposing a limit, each submits the proposed limit (with the median proposal to be implemented). Column (5) treats the voting decision as the dependent variable, whereas column (6) treats all the proposed limit as a dependent variable for groups that agreed on a limit in the first stage of the voting phase. Among the main takeaways, the regression results confirm Result 2a, that subjects learn to reach a limit over time, and the limit is decreasing. However, we find no evidence that cognitive ability scores affect agreement on a limit.

5 Conclusion

In this paper, we investigate whether a limit on campaign spending could restore cooperation in the presence of incumbency advantage. First, we theoretically demonstrate that a sufficiently low limit on political contest spending can fully restore cooperation in the economic game. Second, we conduct controlled economic experiments to support our theoretical predictions empirically. Third, we show that subjects can endogenously agree on a low enough spending limit within the experimental environment. In particular, we identify a potential institution–campaign spending limits–that can stabilize cooperation and confirm that subjects can effectively utilize the democratic process to reduce both resource depletion in the contest and power inequality, thereby restoring cooperation.

Our work opens many interesting avenues for future investigation. First, it would be valuable to examine whether our results are robust to different parameters of the game. Our current environment requires full cooperation in the economic game to produce a surplus large enough to offset the cost of cooperation. However, one may argue that different legislation or policy implementation may vary in the degree of cooperation (e.g., two-thirds vs majority vote). Requiring full cooperation makes our environment tolerant of power inequality since cooperating remains a payoff-dominant action for quite unequal power distribution (a decision maker needs to obtain less than 9% power to make cooperation return less payoff than defection). However, it also makes defection more threatening and may cause subjects to focus more on reducing inequality in the power contest. Our environment is flexible to address this by studying a smaller a_0 parameter for the new scenario. Second, unlike previous findings (Tyran and Feld, 2006; Ertan, Page, and Putterman, 2009; Sutter, Haigner, and Kocher, 2010; Dal Bó, Foster, and Putterman, 2010; Putterman, Tyran, and Kamei, 2011; Markussen, Putterman, and Tyran, 2014; Marcin, Robalo, and Tausch, 2019), we do not find the endogenous institution is more efficient than the exogenous treatment. It could be interesting to explore the reasons why that is the case. One potential explanation is that in the Low Limit treatment, subjects continuously spend 10 in stage 2 and this non-negative spending keeps them invested and cooperating. Another explanation is that we use majority voting. It would be worthwhile to explore whether our results are robust to alternative voting rules (e.g., unanimity). This would help us understand how different decision rules may lead to different outcomes in coordination and cooperation Miller (1985); Dougherty and Edward (2005); Dougherty, Pitts, Moeller, and Ragan (2014); Merkel and Vanberg (2023). Third, our model allows for further extensions to explore other interesting mechanisms and structures. For example, in our current setting, we limit the spending in the power contest to stage 1 earnings. It would be interesting to extend this setting by allowing subjects to borrow and carry over spending across matches.

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Appendix A Additional details on theoretical predictions

Here we prove Theorem 1 in the main text. In Proposition 1, we classify all the existing myopic-best-response equilibria and derive conditions for their existence. In Proposition 2, we examine the stability of the above equilibria. We combine all the results in Corollary 1, which is essentially Theorem 1 formulated in an auxiliary coordinates.

Proposition 1 ***Classification and existence of myopic-best-response equilibria.*** *Four types of myopic-best response equilibria with n_C cooperators exist in the model (see below). Let $A = \frac{L}{\delta F(n_C/n)}$ and $B = \frac{c}{F(n_C/n)}$. Note that defectors (if they exist) have zero expenditures $e_D^* = 0$ and the same power $\hat{f}_D$. $\hat{f}_D = \frac{1}{n_C}$ if all agents are defectors. Otherwise, $\hat{f}_D = 0$.*

- *Type 1. The symmetric equilibrium with no cooperators (i.e., with $n_C = 0$). Exists if $B > 1$.*
- *Type 2. A family of equilibria with 2 cooperators (i.e., with $n_C = 2$) who have powers $\hat{f} \in (0,1)$ and $1-\hat{f}$, respectively, and the same expenditure $e_C^* = \delta \hat{f}(1-\hat{f})F(2/n)$ not exceeding the limit. Such an equilibrium exists if*
$$A > \frac{1}{4}, B \le \frac{1}{4}, \text{ and } f \in \left[\sqrt{B}, 1-\sqrt{B}\right]$$
or
$$A \le \frac{1}{4}, \sqrt{B} < \frac{1}{2} - \sqrt{\frac{1}{4} - A}, \text{ and}$$
$$\hat{f} \in \left[\sqrt{B}, \frac{1}{2} - \sqrt{\frac{1}{4} - A}\right) \cup \left(\frac{1}{2} + \sqrt{\frac{1}{4} - A}, 1-\sqrt{B}\right].$$
- *Type 3. Symmetric equilibria with more than two cooperators (i.e., with $n_C \ge 3$) who have the same power $\hat{f}_C = 1/n_C$ and the same non-zero expenditure $e_C^* = \delta\left(1 - \frac{1}{n_C}\right)\frac{F(n_C/n)}{n_C}$ not exceeding the limit. Such an equilibrium exists if*
$$A > \frac{1}{n_C}\left(1 - \frac{1}{n_C}\right) \text{ and } B \le \frac{1}{n_C^2}.$$
- *Type 4. A family of equilibria with two or more cooperators (i.e., with $n_C \ge 2$) who have powers $\hat{f}_1, ..., \hat{f}_{n_C}$, respectively, and spend the maximum expenditure $e_C^* = L$. Such an equilibrium exists if*
$$A \le \frac{1}{n_C}\left(1 - \frac{1}{n_C}\right)$$
and
$$\sqrt{B} \le \frac{1}{2} - \sqrt{\frac{1}{4} - A} \text{ and } \begin{cases} \hat{f}_1, .., \hat{f}_{n_C-1} \ge \frac{1}{2} - \sqrt{\frac{1}{4} - A}, \\ \hat{f}_1 + .. + \hat{f}_{n_C-1} \le \frac{1}{2} + \sqrt{\frac{1}{4} - A}, \\ \hat{f}_{n_C} = 1 - \hat{f}_1 - .. - \hat{f}_{n_C-1}, \end{cases}$$
or
$$\sqrt{B} \in \left(\frac{1}{2} - \sqrt{\frac{1}{4} - A}, \sqrt{\frac{1}{n_C} - A}\right] \text{ and } \begin{cases} \hat{f}_1, .., \hat{f}_{n_C-1} \ge A + B, \\ \hat{f}_1 + .. + \hat{f}_{n_C-1} \le 1 - A - B, \\ \hat{f}_{n_C} = 1 - \hat{f}_1 - .. - \hat{f}_{n_C-1}. \end{cases}$$

Proof. Let us consider equilibrium characteristics of cooperators and defectors.

1. As follows from Proposition 1 in Rosokha, Lyu, Tverskoi, and Gavrilets (2023), all defectors (if they exist) have zero expenditures $e_D^* = 0$ and the same power $\hat{f}_D$. $\hat{f}_D = \frac{1}{n_C}$ if all agents are defectors. Otherwise, $\hat{f}_D = 0$. The equilibrium with all defectors (i.e., with $n_C = 0$) exists if $B > 1$.

2. As follows from Proposition 1 in Rosokha, Lyu, Tverskoi, and Gavrilets (2023), an equilibrium with one cooperator (i.e., with $n_C = 1$) does not exist and all cooperators (if they exist) have non-zero powers and expenditures.

3. All cooperators (if they exist) spend the same expenditure e_C^* to the contest. To show this, consider the equations governing the dynamics of power at equilibrium for two cooperators i and k:

$$\hat{f}_i = \frac{\hat{f}_i e_i^*}{\sum_{j \in I} a_j^* \hat{f}_j e_j^*} \text{ and } \hat{f}_k = \frac{\hat{f}_k e_k^*}{\sum_{j \in I} a_j^* \hat{f}_j e_j^*},$$

which implies

$$\sum_{j \in I} a_j^* \hat{f}_j e_j^* = e_i^* = e_k^* = e_C^*.$$

As a result, either all cooperators (if exist) have the same expenditure not exceeding the limit (i.e., $e_C^* < L$) or all cooperators spend the same maximum expenditure (i.e., $e_C^* = L$).

4. Consider equilibria with $n_C = 2$ cooperators spending the same expenditure $e_C^* < L$. According to Proposition 5 in Rosokha, Lyu, Tverskoi, and Gavrilets (2023), the two cooperators have powers $\hat{f}$ and $1-\hat{f}$, respectively, where

$$\hat{f} \in \left[\sqrt{B}, 1 - \sqrt{B}\right].$$

Then, the cooperators spend the same expenditure $e_C^* = \delta F(2/n)\hat{f}(1 - \hat{f})$. Such an equilibrium exists if $B \le \frac{1}{4}$. Here we also need to check if $e_C^* < L$, which yields

$$A > \frac{1}{4} \text{ or } A \le \frac{1}{4} \text{ and } \hat{f} \in \left(0, \frac{1}{2} - \sqrt{\frac{1}{4} - A}\right) \cup \left(\frac{1}{2} + \sqrt{\frac{1}{4} - A}, 1\right).$$

Combining all the above conditions, we obtain the conditions for the existence of an equilibrium with $n_C = 2$ cooperators spending the same expenditure $e_C^* < L$:

$$A > \frac{1}{4}, B \le \frac{1}{4} \text{ and } f \in \left[\sqrt{B}, 1 - \sqrt{B}\right]$$

or

$$A \le \frac{1}{4}, \sqrt{B} < \frac{1}{2} - \sqrt{\frac{1}{4} - A}, \text{ and}$$

$$\hat{f} \in \left[\sqrt{B}, \frac{1}{2} - \sqrt{\frac{1}{4} - A}\right) \cup \left(\frac{1}{2} + \sqrt{\frac{1}{4} - A}, 1 - \sqrt{B}\right].$$

5. Consider equilibria with $n_C \ge 3$ cooperators spending the same expenditure $e_C^* < L$. According to Proposition 1 in Rosokha, Lyu, Tverskoi, and Gavrilets (2023), $e_C^* = \delta\left(1 - \frac{1}{n_C}\right)\frac{F(n_C/n)}{n_C}$ and cooperators have the same power $\hat{f}_C = \frac{1}{n_C}$. Such an equilibrium exists if

$$B \le \frac{1}{n_C^2}.$$

We also need to check that $e_C^* < L$, which yields

$$A > \frac{1}{n_C}\Big(1 - \frac{1}{n_C}\Big).$$

6. Consider the case of $n_C \geq 2$ cooperators spending the same expenditure $e_C^* = L$. According to Lemma 1 in Rosokha, Lyu, Tverskoi, and Gavrilets (2023), cooperator i with power $\hat{f}_i$ is motivated to spend maximum expenditures in the contest if

$$\frac{1}{\hat{f}_i}\left(\sqrt{\delta F(n_C/n)\hat{f}_i S_{-i}} - S_{-i}\right) \geq L,$$

where $S_{-i} = L\big(1 - \hat{f}_i\big)$, which entails

$$A \leq \frac{1}{4} \text{ and } \hat{f}_i \in \left[\frac{1}{2} - \sqrt{\frac{1}{4} - A}, \frac{1}{2} + \sqrt{\frac{1}{4} - A}\right]. \tag{10}$$

Finally, we need to show that: (a) for each defector (if exists) $(a_i^*, e_i^*) = (0, 0)$ is the best rsponse strategy to the optimal strategies of others for given powers of all players; and (b) for each cooperator, $(a_i^*, e_i^*) = (1, L)$ is the best rsponse strategy to the optimal strategies of others for given powers of all players. Condition (a) is straightforward and is satisfied for all values of the model parameters. To check condition (b), we need to explicitly consider the expected earnings E_i of cooperator i to ensure that

$$E_i(1, L) \geq E_i(0, 0) \Leftrightarrow -L + \delta\big(R_0 - c + \hat{f}_i \cdot F(n_C/n)\big) \geq \delta R_0 \Leftrightarrow \hat{f}_i \geq A + B. \tag{11}$$

Combining conditions 10 and 11, we obtain

$$A \leq \frac{1}{4}$$

and one of the two following conditions hold:

$$\sqrt{B} \leq \frac{1}{2} - \sqrt{\frac{1}{4} - A} \text{ and } \big(\hat{f}_1, .., \hat{f}_{n_C - 1}\big) \in \Omega_1,$$

or

$$\sqrt{B} \in \left(\frac{1}{2} - \sqrt{\frac{1}{4} - A}, \frac{1}{2} + \sqrt{\frac{1}{4} - A}\right] \text{ and } \big(\hat{f}_1, .., \hat{f}_{n_C - 1}\big) \in \Omega_2, \tag{12}$$

where Ω_1 and Ω_2 are subsets of a unit simplex in R^{n_C} such that for each cooperator i:

$$\hat{f}_i \in \left[\frac{1}{2} - \sqrt{\frac{1}{4} - A}, \frac{1}{2} + \sqrt{\frac{1}{4} - A}\right]$$

or

$$\hat{f}_i \in \left[A + B, \frac{1}{2} + \sqrt{\frac{1}{4} - A}\right],$$

respectively. The set Ω_1 is not empty if

$$(n_C - 1)\left(\frac{1}{2} - \sqrt{\frac{1}{4} - A}\right) \leq \frac{1}{2} + \sqrt{\frac{1}{4} - A}$$

which yields

$$A \leq \frac{1}{n_C}\Big(1 - \frac{1}{n_C}\Big).$$

Similarly, the set Ω_2 is not empty if

$$(n_C - 1)(A + B) \leq 1 - A - B$$

which yields

$$A + B \leq \frac{1}{n_C}. \tag{13}$$

Combining conditions 12 and 13, we conclude that

$$A \leq \frac{1}{n_C}\Big(1 - \frac{1}{n_C}\Big) \text{ and } \sqrt{B} \in \Bigg(\frac{1}{2} - \sqrt{\frac{1}{4} - A}, \sqrt{\frac{1}{n_C} - A}\Bigg],$$

which gives us the required conditions for the existense of the studied equilibria. **The proposition is proved.**

Proposition 2 ***Stability of myopic-best-response equilibria.***

- *Type 1 and Type 4 equilibria are stable to small perturbations in expenditures and powers.*
- *Type 2 equilibria are stable to small perturbations in expenditures and powers if*

$$\hat{f}_C \in \Big(\frac{1}{2} - \frac{1}{2\sqrt{2}}, \frac{1}{2} + \frac{1}{2\sqrt{2}}\Big).$$

- *Type 3 equilibria are unstable to small perturbations in expenditures and powers.*

Proof. The results on the stability of Type 1, Type 2, and Type 3 equilibria follows from Propositions 2 and 6 in Rosokha, Lyu, Tverskoi, and Gavrilets (2023). The proof for Type 4 equilibria is trivial.

Indeed, consider a Type 4 equilibrium with n_C cooperators spending expenditures $e^* = (L, .., L)$ and having powers $\hat{f}$ belonging to a unit $(n_C - 1)$-dimensional simplex. Let I_C be the set of cooperators. We will show that there exists a neighbourhood O of $(e^*, \hat{f})$, such that for all (e, f) in this neighbourhood the system governing the dynamics of powers and expenditures of cooperators takes the form of

$$e_{i,t} = L, \forall i \in I_C,$$

$$f_{i,t+1} = \frac{f_{i,t} e_{i,t}}{\sum_{k \in I_C} f_{j,t} e_{j,t}} = f_{i,t}, \forall i \in I_C,$$

which implies the above equilibrium is stable to small perturbations in expenditures and powers.

To construct O, consider two functions for each cooperator i:

$$G_i(e, f) = -e_i + \delta F(n_C/n) \frac{f_i e_i}{\sum_{k \in I_C} f_k e_k} - \delta c$$

and

$$H_i(e, f) = \frac{1}{f_i}\Bigg(\sqrt{\delta F(n_C/n) f_i \sum_{k \in I_C} f_k e_k} - \sum_{k \in I_C} f_k e_k\Bigg).$$

Note that for each cooperator i, $G_i(e^*, \hat{f}) > 0$ (as each cooperator is not motivated to defect) and $H_i(e^*, \hat{f}) > L$ (since each cooperator is motivated to spend maximum expenditures to the contest). Since G_i and H_i are continuous on $Z = (0, +\infty)^{n_C} \times (0,1)^{n_C}$, there exist open sets $U_i \subset Z$ and $V_i \subset Z$, such that:

$$(e^*, \hat{f}) \in U_i \text{ and } \forall (e,f) \in U_i : G_i(e,f) > 0$$

and

$$(e^*, \hat{f}) \in V_i \text{ and } \forall (e,f) \in V_i : H_i(e,f) > L.$$

Then,

$$O = \bigcup_{i \in I_C} \Big(U_i \cap V_i \Big).$$

The proposition is proved.

Combining the above propositions, we derive conditions for the existence and stability of myopic-best-response equilibria.

Corollary 1 ***Existence and stability of myopic-best-response equilibria.*** *The following stable myopic-best-response equilibria exist in the model:*

- *With all defectors spending zero expenditures and having equal powers $\frac{1}{n}$ if*

$$B > 1.$$

- *With two cooperators having powers $\hat{f} \in \Omega(2) \subset (0,1)$ and $1 - \hat{f}$, respectively, and the same expenditure $e^*_C = \delta \hat{f}(1-\hat{f})F(2/n)$ not exceeding the limit L if*

$$A \geq \frac{1}{4} \text{ and } B \leq \frac{1}{4}$$

or

$$A \in \left(\frac{1}{8}, \frac{1}{4} \right) \text{ and } \sqrt{B} < \frac{1}{2} - \sqrt{\frac{1}{4} - A}.$$

Defectors (if exist) have zero expenditures and powers.

- *With $n_C \in \{3, .., n\}$ cooperators having powers $(\hat{f}_1, ..., \hat{f}_{n_C}) \in \Omega(n_C) \subset \Delta(n_C)$[14], respectively, and spending the maximum expenditure $e^*_C = L$ if*

$$A \leq \frac{1}{n_C} - max\left\{ \frac{1}{n_C^2}, B \right\} \text{ and } B \leq \frac{1}{n_C}.$$

Defectors (if exist) have zero expenditures and powers.

Remark. In the above corollary

$$\Omega(2) = \begin{cases} \left[\frac{1}{2} - \frac{1}{2\sqrt{2}}, \frac{1}{2} - \sqrt{\frac{1}{4} - A} \right) \cup \left(\frac{1}{2} + \sqrt{\frac{1}{4} - A}, \frac{1}{2} + \frac{1}{2\sqrt{2}} \right], \text{ if } A \in \left(\frac{1}{8}, \frac{1}{4} \right] \text{ and } \sqrt{B} < \frac{1}{2} - \frac{1}{2\sqrt{2}}; \\ \left[\sqrt{B}, \frac{1}{2} - \sqrt{\frac{1}{4} - A} \right) \cup \left(\frac{1}{2} + \sqrt{\frac{1}{4} - A}, 1 - \sqrt{B} \right], \text{ if } A \in \left(\frac{1}{8}, \frac{1}{4} \right] \text{ and } \sqrt{B} \in \left[\frac{1}{2} - \frac{1}{2\sqrt{2}}, \frac{1}{2} - \sqrt{\frac{1}{4} - A} \right); \\ \left(\frac{1}{2} - \frac{1}{2\sqrt{2}}, \frac{1}{2} - \frac{1}{2\sqrt{2}} \right), \text{ if } A > \frac{1}{4} \text{ and } B \leq \frac{3}{8} - \frac{1}{2\sqrt{2}}; \\ \left(\sqrt{B}, 1 - \sqrt{B} \right), \text{ if } A > \frac{1}{4} \text{ and } B \in \left(\frac{3}{8} - \frac{1}{2\sqrt{2}}, \frac{1}{4} \right]; \end{cases}$$

[14] $\Delta(n_C)$ is an $(n_C - 1)$ dimensional simplex in R^{n_C}.

and

$$\Omega(n_C) = \begin{cases} \Omega^1(n_C), & \text{if } \sqrt{B} \le \frac{1}{2} - \sqrt{\frac{1}{4} - A}; \\ \Omega^2(n_C), & \text{if } \sqrt{B} \in \big(\frac{1}{2} - \sqrt{\frac{1}{4} - A}, \sqrt{\frac{1}{n_C} - A}\big]; \end{cases}$$

where $\mathbf{\Omega}^1(n_C)$ is the set of all powers $(\hat{f}_1, ..., \hat{f}_{n_C})$ such that

$$\begin{cases} \hat{f}_1, .., \hat{f}_{n_C-1} \ge \frac{1}{2} - \sqrt{\frac{1}{4} - A}, \\ \hat{f}_1 + .. + \hat{f}_{n_C-1} \le \frac{1}{2} + \sqrt{\frac{1}{4} - A}, \\ \hat{f}_{n_C} = 1 - \hat{f}_1 - .. - \hat{f}_{n_C-1}, \end{cases}$$

and $\mathbf{\Omega}^2(n_C)$ is the set of all powers $(\hat{f}_1, ..., \hat{f}_{n_C})$ such that

$$\begin{cases} \hat{f}_1, .., \hat{f}_{n_C-1} \ge A + B, \\ \hat{f}_1 + .. + \hat{f}_{n_C-1} \le 1 - A - B, \\ \hat{f}_{n_C} = 1 - \hat{f}_1 - .. - \hat{f}_{n_C-1}. \end{cases}$$

Appendix B Experiment Administration

Table B-1: Summary of Experiment Administration

Treatment	Administration			Demographics		
	Sessions	Subjects	Earnings	% Male	% STEM	% US HS
No Limit	4	48	23.5*	43.8	70.8	75.0
			(0.5)	(7.2)	(6.6)	(6.3)
High Limit	4	48	32.0	41.7	68.8	79.2
			(0.6)	(7.2)	(6.8)	(5.9)
Low Limit	4	48	37.7	52.1	66.7	75.0
			(0.6)	(7.3)	(6.9)	(6.3)
Voting	4	48	34.8	41.7	58.3	72.9
			(0.6)	(7.2)	(7.2)	(6.5)
All	12	144	34.8	45.1	64.6	75.7
			(0.4)	(4.2)	(4.0)	(3.6)

Notes: Standard errors are in parentheses. % STEM denotes proportion of participants that are in STEM majors. % US HS denotes the proportion of participants that completed high school in the US. The conversion rate is 500 points = $1. *No Limit treatment was ran as part of Rosokha et al. 2024b experiment. The conversion rate was 700 points = $1.

Table B-2: Match Lengths

Match Number:	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**
Realization #1:	7	4	18	7	1	6	2	17	11	8	7	1	24	6	14	23	7	5	3	3
Realization #2:	11	4	13	11	4	17	10	10	9	5	2	4	7	11	18	6	3	8	11	6
Realization #3:	17	3	1	7	3	25	11	3	8	2	8	20	4	11	8	2	2	3	19	12
Realization #4:	1	6	5	1	15	3	14	2	12	19	3	9	1	21	7	4	8	3	16	2

Table B-3: Session Details

Date	Treatment	Realization #	Matches Finished
2/17/2023	No Limit	1	20
3/22/2023	No Limit	2	18
2/23/2023	No Limit	3	20
3/9/2023	No Limit	4	20
3/22/2024	High Limit	1	16
3/27/2024	High Limit	2	20
3/27/2024	High Limit	3	20
3/26/2024	High Limit	4	20
3/22/2024	Low Limit	1	20
3/26/2024	Low Limit	2	17
3/22/2024	Low Limit	3	20
3/26/2024	Low Limit	4	20
3/22/2024	Voting	1	20
3/26/2024	Voting	2	20
3/22/2024	Voting	3	20
3/26/2024	Voting	4	20

Appendix C Additional Tables and Figures

Table C-1: Cooperation and Competition

	(1)	(2)	(3)	(4)	(5)	(6)
		Cooperation			Spending	
	Round 1	All rounds	All rounds	Round 1	All rounds	All rounds
High Limit	-0.008	-0.007	-0.023	-2.439	-1.009	-1.099
	(0.088)	(0.057)	(0.050)	(4.311)	(2.595)	(2.536)
Low Limit	0.141**	0.370***	0.182**	-11.119***	-2.828	-4.068*
	(0.058)	(0.081)	(0.072)	(4.242)	(2.290)	(2.257)
Voting	0.002	0.211***	0.061	-10.016**	-2.795	-4.002
	(0.082)	(0.078)	(0.063)	(4.530)	(2.842)	(2.846)
Power inequality / 100			-0.528***			-6.003***
			(0.059)			(1.129)
My power			0.089***			0.496
			(0.023)			(1.110)
Own R1 coop in M1	0.193***	0.103***	0.077***	1.806	0.440	0.273
	(0.045)	(0.023)	(0.019)	(2.572)	(1.181)	(1.147)
Others' R1 coop in previous match	0.113***	0.134***	0.100***	0.271	0.547	0.424
	(0.028)	(0.042)	(0.036)	(1.134)	(0.956)	(0.968)
Length of previous match / 100	0.093	0.135	0.058	4.776	4.380	3.978
	(0.082)	(0.235)	(0.179)	(4.164)	(3.654)	(3.106)
Round number / 10		-0.189***	-0.052**		-3.384***	-1.915***
		(0.024)	(0.024)		(0.587)	(0.454)
Match number / 10	0.120***	0.186***	0.061*	-10.860***	-6.539***	-7.451***
	(0.035)	(0.056)	(0.036)	(2.639)	(1.597)	(1.665)
Age under 20	0.010	0.022	0.017	-2.260	-0.756	-0.763
	(0.038)	(0.019)	(0.017)	(1.797)	(1.288)	(1.274)
Female	-0.151***	-0.046	-0.037	0.372	0.492	0.533
	(0.044)	(0.031)	(0.025)	(1.898)	(1.244)	(1.181)
Major in STEM	-0.023	-0.091**	-0.071**	-3.189	-3.722*	-3.548*
	(0.040)	(0.042)	(0.035)	(2.950)	(2.067)	(2.045)
High school in US	0.107*	0.029	0.014	-3.491	-2.394	-2.457
	(0.061)	(0.035)	(0.030)	(2.560)	(2.064)	(2.037)
IQ score	0.035***	0.009	0.009**	-0.839***	-0.800***	-0.775***
	(0.008)	(0.006)	(0.004)	(0.254)	(0.248)	(0.237)
Money at hand				0.077	0.097***	0.056**
				(0.049)	(0.030)	(0.028)
Constant	0.125	0.011	0.415***	36.036***	21.041***	27.360***
	(0.091)	(0.133)	(0.081)	(6.669)	(5.252)	(5.368)
Observations	2,745	24,203	24,203	2,745	24,203	24,203
Number of subjects	192	192	192	192	192	192

Notes: The table reports results from random-effects regressions using data across all treatments in match 6-20. The dependent variable is 1 if subjects chose "Y"(cooperation) in stage 1, and 0 otherwise. The dependent variable is subjects' spending in stage 2. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

Table C-2: Voting Treatment Decisions (Robustness)

	(1)	(2)	(3)	(4)
	Probit: Agree on a limit		Tobit: Limit proposal	
Age under 20	0.669	1.025*	-13.601***	-18.181***
	(0.488)	(0.527)	(4.164)	(5.260)
Female	-0.747	-0.738**	16.583*	18.404***
	(0.461)	(0.361)	(8.545)	(6.537)
Major in STEM	-0.169	-0.070	-11.431**	-11.093**
	(0.444)	(0.430)	(4.704)	(5.624)
High school in US	0.015	0.053	-14.888***	-14.981**
	(0.213)	(0.238)	(5.657)	(6.001)
IQ_score	0.055	0.015	0.820	1.379
	(0.047)	(0.084)	(1.970)	(2.281)
Match Number / 10	0.462**	0.276	-16.526***	-17.153***
	(0.200)	(0.194)	(2.129)	(3.084)
Own R1 coop in M1	-0.290	-0.246	-5.235	-8.593
	(0.341)	(0.229)	(6.393)	(8.610)
Own R1 spend in M1	0.210	0.452***	8.951	8.330
	(0.259)	(0.079)	(5.778)	(6.191)
Others' R1 coop in previous match	0.342	0.113	4.662	2.651
	(0.231)	(0.250)	(11.669)	(10.832)
Others' R1 spend in previous match	-0.010***	-0.008**	0.690***	0.811***
	(0.004)	(0.003)	(0.182)	(0.152)
Length of previous match / 100	-0.438	-1.087	-15.961*	-20.916**
	(0.685)	(1.020)	(9.368)	(9.891)
Initially agreed on a limit		0.876**		-10.558*
		(0.346)		(6.065)
Had a limit in previous match		0.998***		5.998
		(0.143)		(5.105)
Constant	-0.176	-0.917	27.806	29.326
	(0.844)	(0.969)	(26.197)	(23.509)
Observations	714	666	534	513

Notes: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

Appendix D Experimental Instructions

Experiment Overview

Today's experiment will last about 120 minutes.

You will be paid a show-up fee of $5 together with any money you accumulate during this experiment. The amount of money you accumulate will depend partly on your actions, partly on the actions of other participants, and partly on chance. This money will be paid at the end of the experiment in private and in cash.

It is important that during the experiment you remain **silent**. If you have a question or need assistance of any kind, please **raise your hand, but do not speak** - and an experiment administrator will come to you, and you may then whisper your question.

In addition, please **turn off your cell phones and put them away now**.

Anybody who breaks these rules will be asked to leave.

Agenda:

- Part 1
- Part 2
- Questionnaire

Appendix D.1 Part 1

Part 1

This part is made up of 11 questions. You will have 7 minutes to complete this part.

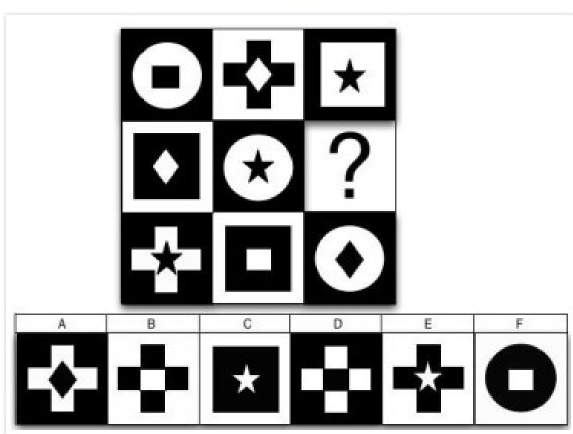
The top right-hand corner of the screen will display the time remaining.

You will get a flat payment of $3.

The answers you give in the task will not affect part 2 of the experiment in any way.

Example Task:

Sample item:



Appendix D.2 Part 2

Part 2

At the beginning of Part 2, you will be randomly split into 2-person teams that will remain fixed for the remainder of the experiment.

Part 2 of the experiment is made up of **20 matches**.

At the start of each match your team will be randomly paired with another 2 teams in this room.

Your team will then play a number of rounds with those 2 teams (this is what we call a "match").

Next, you will have **20 minutes** to go through the instructions and ten quiz questions. **You will get $0.50 for each question you answer correctly.**

Appendix D.2.1 Match Overview

How Matches Work (1/10)

Each match will last for a random number of **rounds**:

- At the end of each round the computer will roll a eight-sided fair dice.
- If the computer rolls a number less than 8, then the **match continues** for at least one more round.
- If the computer rolls a 8 , then the **match ends** after the current round.

To test this procedure, click the 'Test' button below. You will need to test this procedure 5 times.

Round

Dice Roll

Remember that at the end of each round the computer rolls a eight-sided fair dice. The match ends when the computer rolls a 8.

Quiz

Question 1: What is the probability that the match will continue to the next round?

Hint: At the end of each round the computer will roll a eight-sided fair dice. If the computer rolls a 8 , then the match ends after the current round.

0 %	12.5 % (1/8)	25 % (2/8)	37.5 % (3/8)	50 % (4/8)	80 % (8/10)	87.5 % (7/8)	90 % (9/10)	100 %

Appendix D.2.2 Round Overview

Round Overview (2/10)

Each round has two decision stages.

Stage 1

- Your team and the other 2 teams need to <u>choose</u> either action X or action Y.
  - If your team chooses action X , your team will earn 60 points.
  - If your team chooses action Y , your team will earn 40 points plus a **proportion** of either 0 , 20 , 210 points depending on how many teams choose Y, how many shares your team owns, and how many shares other teams who choose Y own.
    - At the beginning of each match, each team has the same number of shares.
    - The number of shares that your team and other teams own in each round will be known before the decisions in Stage 1.
    - The number of shares will be revised at the end of each round based on decisions in Stage 2.

Stage 2

- Your team and the other 2 teams can purchase shares by spending points that were earned in Stage 1.
- The number of shares your team gets in the next round will be determined in part by what percentage of total points spent in Stage 2 that was spent by your team and in part by how many shares your team had in the current round (rounded to the nearest integer).

Your payoff of each round = points your team earns in Stage 1 − points your team spends in Stage 2

Notice that you and your teammate will each get your team's earnings.

At the end of the experiment, your total payoff (accumulated across all rounds and matches) will be converted into cash at the exchange rate of 700 points = $1.00.

Next, we will provide more details about each stage, including examples.

Quiz

Question 2: (True or False) At the beginning of each new match, you will have the same teammate in your team, face different teams, and restart with equal shares.

True False

Recap

- *Your teammate will be the same for the entire experiment*
- *You will be randomly matched with other teams in a new match. It is very unlikely to face the same teams*
- *You will restart with equal shares in the match. The shares you gained in the last match will not be carried over*

Appendix D.2.3 Stage 1 Details

Stage 1 Details (3/10)

ID	Example Round				
	Current Shares	Choice	Earn	Spend	Payoff
1	**33**	**?**			
2	33				
3	33				

Dice Roll

At the beginning of each round, your team will see shares of all teams in a match presented in a table like the one above. Your team's ID will always be 1 in the table.

In Stage 1, your team and other teams will choose either action X or action Y. Currently, your team's choice is marked with a '?' denoting that the choice has not yet been made.

If your team chooses action X, your team will earn **60 points** regardless of what the other 2 teams chooses and regardless of how many shares your team and other teams own.

If your team chooses action Y, your team will earn **40 points** + amount * **proportion** , where

- amount is either 0, 20, 210 points depending on whether 0, 1, or 2 other teams choose Y,
- **proportion** is your proportion of shares among those who chose Y.

Throughout the experiment, you will be provided with a calculator to check different scenarios.

Stage 1 Examples (4/10)

ID	Example Round				
	Current Shares	Choice	Earn	Spend	Payoff
1	**40**	**Y**	**40**		
2	50	X	60		
3	10	X	60		

Dice Roll

To see an example, click the 'Example' button below. You will need to see 5 examples.

Example #1

Suppose your team owns 40 shares, and the other 2 teams own 50 and 10 shares.

Suppose that only your team chooses Y.

Your team will earn **40 points** $= 40 + \frac{40}{40} \times 0$.

To elaborate, because only your team chooses Y, the amount to be divided is 0 points.

Your team's proportion of that amount is **1** because your team is the only team who chooses Y.

Recap

*If your team chooses action X, you will earn **60 points** regardless of what the other 2 teams chooses and regardless of how many shares you and the other 2 teams own.*

*If your team chooses action Y , you will earn **40 points** + amount * **proportion** , where*

- *amount is either 0, 20, 210 points depending on whether 0, 1, or 2 other teams choose Y*
- ***proportion** is your proportion of shares among those who chose Y*

Quiz

Question 3: (True or False) The more shares your team have, the more earnings your team will get in stage 1.

True False

Recap

- *Shares only influence your team's earnings when your team chooses action Y;*
- *The earnings of choosing Y also depends on how many other teams chose Y.*

Appendix D.2.4 Stage 2 Details

Stage 2 Details (5/10)

ID	Example Round				
	Current Shares	Choice	Earn	Spend	Payoff
1	**33**	**X**	**60**	**?**	
2	33	X	60		
3	33	X	60		

Dice Roll

Once all teams in the match have chosen their actions in Stage 1, the summary table will be updated to reflect that choice and the experiment will proceed to Stage 2.

In Stage 2, each team will choose how many points earned in Stage 1 to spend on shares for the next Round. Currently, your team's choice is marked with a '?' denoting that it has not yet been made.

The number of shares your team gets in the next round will be determined in part by what percentage of total weighted points spent in Stage 2 that was spent by your team and in part by how many shares your team had in the current round:

$$\text{weighted points} = \text{your team's stage 2 spending} \times \text{number of your team's current shares}$$

$$\text{new shares} = \text{percentage of total weighted points spent by your team in the current round}$$

(If no one spent any points, each team will keep the current shares in the next round)

Again, you will be provided with a calculator to check different scenarios.

Stage 2 Examples (6/10)

ID	Example Round					Next Round				
	Current Shares	Choice	Earn	Spend	Payoff	New Shares	Choice	Earn	Spend	Payoff
1	**33**	**X**	**60**	**3**	**57**	$\boxed{3}$				
2	33	X	60	55	5	52				
3	33	X	60	47	13	45				

Dice Roll

To see an example, click the 'Example' button below. You will need to see 5 examples.

Example #1

Suppose your team spends 3 points, and the other teams spend 55, 47 points.

Then, your payoff in this round is 57 points.

If the match continues to a new round,

Your team's weighted points are $3 \times 33 = 99$,

team 2's weighted points are $55 \times 33 = 1815$,

team 3's weighted points are $47 \times 33 = 1551$,

the number of shares you will own at the beginning of next round will be $\frac{99}{99+1815+1551} \times 100 = 3$.

Recap

- ***Your payoff in a round*** = *points your team earns in Stage 1* - *points your team spends in Stage 2*
- *You and your partner will each get your team's earnings (they will not be split between you)*
- ***Weighted points*** $=$ ***your team's stage 2 spending*** $\times$ ***number of your team's current shares***
- ***New shares*** $=$ ***percentage of total weighted points spent by your team in the current round***
  (If no one spent any point, each of you will keep the current shares in the next round)
- *At the end of each round the computer will roll a eight-sided fair dice. If the computer rolls a number less than 8, then the match continues for at least one more round.*

Quiz

Question 4: (True or False) Your team's next round shares only depend on how much you spend in the current round.

True False

Recap

- ***Weighted points*** $=$ ***your team's stage 2 spending*** $\times$ ***number of your team's current shares***
- ***New shares*** $=$ ***percentage of total weighted points spent by your team in the current round***
  (If no one spent any points, each of you will keep the current shares in the next round)

Quiz

ID	Round 1 Calculator				
	Current Shares	Choice	Earn	Spend	Payoff
1	**33**	**X**	**60**	?	
2	33	X	60		
3	33	X	60		

Dice Roll

Question 5: Suppose your team and the other 2 teams made choices as shown in the table, what will be the maximal points your team can spend in this round?

Hint: In stage 2, your team can spend at most what you've earned in stage 1.

integer points

Submit

Appendix D.2.5 How to use the calculator

How to use the Calculator (7/10)

ID	Example Round Calculator					Calculator Hide Reset					
	Current Shares	Choice	Earn	Spend	Payoff	Current Shares	Stage 1 Choice	Stage 1 Earn	Stage 2 Spend	Round Payoff	New Shares import
1	**33**	**?**				**33**	X **Y**	**50**	1	**49**	**17**
2	33					33	**X** Y	60	2	58	33
3	33					33	X **Y**	50	3	47	50

Dice Roll

Click the Calculator button above. This will open the calculator.

Specify the choices in the "Stage 1 Choice" column. Once all of the choices are filled in you will see how much you earn in Stage 1.

Specify how much is spent in Stage 2 by typing amounts for each team. Once all choices and spendings are specified, the rest of the table will be automatically filled. You will see your payoff for this round and shares in the next round.

Click the import button above. This will import the "New Shares" column into the "Current Shares" column.

Click the Reset button above. This will reset the table.

Click the Hide button above. This will hide the table.

Quiz

ID	Round 2					Round 3					Round 4 Calculator				
	Shares	Choice	Earn	Spend	Payoff	Shares	Choice	Earn	Spend	Payoff	Current Shares	Choice	Earn	Spend	Payoff
1	33	X	60	6	54	38	Y	40	4	36	**29**	**?**			
2	33	Y	50	5	45	31	X	60	6	54	35				
3	33	Y	50	5	45	31	X	60	6	54	35				
Dice Roll					5					3					

Question 6: If in this round your team choose X and the other 2 teams chooses Y , what will your team's earning from stage 1 be?
Hint: If you open the calculator and select X for your team and select Y for all other teams , your team's earning from stage 1 are presented in the first row of the 'Earn' column.

integer points
Submit

Question 7: If in this round your team choose Y and the other 2 teams chooses X and Y, what will your team's earning from stage 1 be?
Hint: If you open the calculator and select Y for your team and select X, Y for other teams , your team's earning from stage 1 are presented in the first row of the 'Earn' column.

integer points
Submit

ID	Round 2					Round 3					Round 4 Calculator				
	Shares	Choice	Earn	Spend	Payoff	Shares	Choice	Earn	Spend	Payoff	Current Shares	Choice	Earn	Spend	Payoff
1	33	X	60	6	54	38	Y	40	4	36	**29**	**Y**	**49**	**?**	
2	33	Y	50	5	45	31	X	60	6	54	35	X	60		
3	33	Y	50	5	45	31	X	60	6	54	35	Y	51		
Dice Roll					5					3					

Question 8: If each of you spent 10% of the earnings (round to the nearest integer), what will your payoff in the current round be?

Hint: 10% of the earnings in stage 1 correspond to 5,6,5, points respectively. If you open the calculator, specify the current scenario, and input the spends, `Round Payoff' column will present your payoff in the current round.

Submit

Question 9: If each of you spent 10% of the earnings (round to the nearest integer), what will your shares in the next round be?

Hint: 'New Shares' column will present the shares in the next round.

Submit

Question 10: In the next round, if all of you choose Y, what will your earnings be?

Hint: Use the "import" button to import the new shares to the "Current share" column, select Y for you and all other participants, your earnings from stage 1 are presented in the first row of the 'Stage 1 Earn' column.

Submit

Appendix D.2.6 How history will be recorded

How History Will be Recorded (8/10)

ID	Round 2					Round 3					Round 4				
	Shares	Choice	Earn	Spend	Payoff	Shares	Choice	Earn	Spend	Payoff	Current Shares	Choice	Earn	Spend	Payoff
1	33	X	60	6	54	38	Y	40	4	36	**29**	**?**			
2	33	Y	50	5	45	31	X	60	6	54	35				
3	33	Y	50	5	45	31	X	60	6	54	35				
Dice Roll					5					3					

The history of all variables will be recorded as presented in the example table above.

You will be able to see the full history of your current match by scrolling to the left of the history.

The history table will be cleared at the beginning of each new match.

Appendix D.3 Main Experiment

Appendix D.3.1 Remainder

Reminders

1. Part 2 of the experiment is made up of 10 matches. You are paired with the same teammate throughout the experiment.

2. At the start of each match your team will be randomly matched with 2 other teams.

3. In each round of a match your team will select either X or Y. The other teams will also select either X or Y.

4. The match will last a random number of rounds.

5. When the match ends, your team will again be randomly matched with 2 other teams for the next match.

Appendix D.3.2 Surprise Announcement (Low Limit) Before Match 6

Additional Instructions for Matches 6—20

Matches 6—20 of the experiment are identical to Matches 1—5 with one difference:

The maximum number of points that can be spent in stage 2 is **10** .
This limit will apply to all participants in your group for the duration of each Match.

Appendix D.3.3 Surprise Announcement (Voting) Before Match 6

Additional Instructions for Matches 6—20

Matches 6—20 of the experiment are identical to Matches 1—5 with one difference:

You and the other 2 participants in your group will decide on the maximum number of points that can be spent in stage 2 using the following procedure:

- Before each match, you will vote on whether to set the maximum.
- If a majority agrees to set the maximum, each of you will propose a number.
  The median of the three proposed numbers will be implemented as the maximum.
  This limit will apply to all participants in your group for the duration of the match.
- If a majority agrees not to set the maximum, you will play the match without a limit as in Matches 1—5.

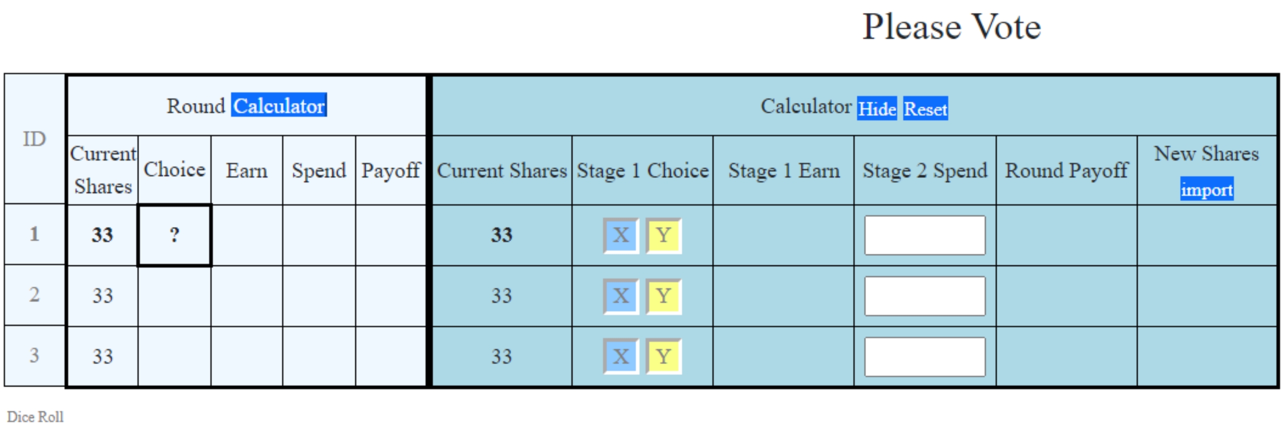


Figure D-1: Stage 1 of Voting Before Each Match

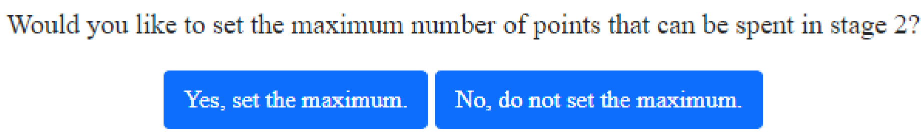


Figure D-2: Propose a Number Conditional on Majority Agreement

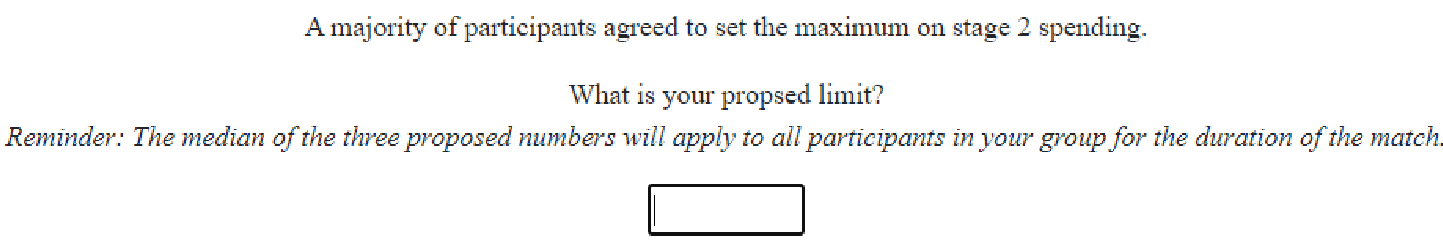
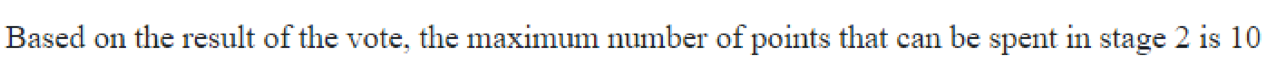


Figure D-3: Result for Pre-match Voting



Appendix D.3.4 Stage 1 Decision Page

ID	Round 1					Round 2 Calculator					Calculator Hide Reset					
	Shares	Choice	Earn	Spend	Payoff	Current Shares	Choice	Earn	Spend	Payoff	Current Shares	Stage 1 Choice	Stage 1 Earn	Stage 2 Spend	Round Payoff	New Shares import
1	33	Y	110	10	100	**62**	**?**				**62**	X **Y**	**175**	10	**165**	**74**
2	33	Y	110	5	105	31					31	X **Y**	106	5	101	19
3	33	Y	110	1	109	6					6	X **Y**	52	10	42	7
Dice Roll					2											

Stage 1 : Please select your choice for Round **2** of Match #6

X Y

Appendix D.3.5 Stage 2 Decision Page

ID	Round 1					Round 2 Calculator					Calculator Hide Reset					
	Shares	Choice	Earn	Spend	Payoff	Current Shares	Choice	Earn	Spend	Payoff	Current Shares	Stage 1 Choice	Stage 1 Earn	Stage 2 Spend	Round Payoff	New Shares import
1	33	Y	110	10	100	**62**	**Y**	**175**	**?**		**62**	X **Y**	**175**	10	**165**	**63**
2	33	Y	110	5	105	31	Y	106			31	X **Y**	106	10	96	31
3	33	Y	110	1	109	6	Y	52			6	X **Y**	52	10	42	6
Dice Roll					1											

In Stage 1 of this round, you earned 175 points.

The maximum number of points you can spend is 10.

Please enter your choice for Stage 2