Cooperation under the Shadow of Political Inequality

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Abstract

We study cooperation among individuals and groups facing a dynamic social dilemma in which the benefits of cooperation are divided according to political power obtained in a contest. The main theoretical and experimental results focus on the role of the incumbency advantage. Specifically, an incumbency advantage in the political contest leads to a rapid breakdown of cooperation in the social dilemma. In addition, we provide simulations based on the individual evolutionary learning model of Arifovic and Ledyard (2012) to shed light on the difference between the behavior of individuals and groups.

JEL classification: *C73, C92, D91*

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1 Introduction

Political parties have to cooperate on policy after elections in which they were adversaries. The elections are traditionally modeled as contests with spending influencing voting outcomes (e.g., Baron, 1994; Grossman and Helpman, 1996). At the same time, empirical papers in economics and political science have documented the presence of an incumbency advantage both in US politics (e.g., Gelman and King, 1990; Prior, 2006; Fowler and Hall, 2014) and on the international stage (Boas and Hidalgo, 2011). In this paper, we incorporate an incumbency advantage into the political contest and focus on the decision to cooperate in the subsequent policy-coordination game. Specifically, we model the policy-coordination game as a decision between a safe option (e.g., no compromise on the party platform) and a risky cooperation decision that could generate a surplus (e.g., agreeing to compromise). We assume the surplus is distributed among cooperating factions according to the political power that they hold. Thus, the policy coordination is a collection action problem akin to the multiplayer stag-hunt game (Rousseau, 1754), except the benefits to cooperation are divided according to political power. We then combine the political contest and policy coordination game into an infinitely repeated dynamic game with two alternating stages – a political contest, which determines political power, and policy coordination, which determines resources available for the contest.

We model the incumbency advantage in the political contest as complementarity between the current political power and the expenditure on the contest. That is, expenditures on the contest are amplified by the party's political power.[1] We then use a three-fold approach of theory, agent-based simulations, and experiments to show that an incumbency advantage leads to a breakdown in cooperation in the policy-coordination game. In particular, on the theoretical front, we characterize myopic best-response equilibria and show that an increase in the incumbency advantage in the political contest leads to lower cooperation in the coordination stage. On the computational front, we use the individual evolutionary learning model (henceforth IEL) of Arifovic and Ledyard (2011, 2012) to run agent-based simulations and show how cooperation breakdown unfolds over time. Finally, on the experimental front, we conduct controlled experiments in which we vary the complementarity between the current power and spending in the political contest to confirm theoretical and computational predictions regarding the role of the incumbency advantage.

In addition to the main result on the role of the incumbency advantage, we use experiments in combination with agent-based simulations to investigate the difference between the behavior of individuals and groups. After all, the elections may be between parties (e.g., parliamentary elections) or between individuals (e.g., presidential elections). Therefore, understanding whether the difference in the decision-making entities could lead to a difference in cooperation is important. Although we do not have a theoretically driven motivation for this difference, existing research in economics and psychology has demonstrated that groups behave differently than individuals (Cooper and Kagel, 2005). To gain insight into the difference between individuals and groups, we

[1] An example of complementarity between spending on an election and political power is when opposition leaders are jailed or disallowed from running for office (Egorov and Sonin, 2014).

model a group consisting of IEL agents. Each agent in a group proposes a strategy, and then one of those strategies is selected to be implemented by the group.[2] Simulation results using parameters from Arifovic and Ledyard (2012) suggest that groups will be less cooperative than individuals. We then test this prediction with human-subject experiments. We find that in the absence of an incumbency advantage, groups are less cooperative than individuals. When the incumbency advantage is strong, however, neither groups nor individuals cooperate, and hence, we find no difference between the two.

Our paper contributes to three broad strands of literature. The first is the literature on coordination games (see Cooper and Weber (2020) for a review). More specifically, our paper fits within the stream that studies dynamic coordination games in combination with contests. The most closely related paper in this stream is Rosokha, Lyu, Tverskoi, and Gavrilets (2022), who use the same environment to show that cooperation in the collective-action stage predictably responds to the fundamental parameters of the game. In addition, Rosokha et al. (2022) show that cooperation depends on the nature of the political contest. Specifically, if the contest is an unrestricted proportional prize, cooperation is lower than when the contest is an exogenously restricted proportion of earnings. Other papers in this literature include Houle, Ruck, Bentley, and Gavrilets (2022) and Tverskoi, Senthilnathan, and Gavrilets (2021), who theoretically and computationally study the environment with an exogenously specified contest. In addition to the theory and simulations, Houle, Ruck, Bentley, and Gavrilets (2022) use cross-country data on social unrest as a proxy for the breakdown of cooperation in society and find evidence that a measure of the rule of law (which may be relevant for an incumbency advantage) is highly indicative of cooperation breakdown. Our paper is different along several dimensions. First, it is the first to explicitly vary the incumbency advantage in conjunction with an unrestricted proportional-prize Tullock contest underlying the contest for power. Second, this paper is the first to conduct a controlled economics experiment to study the complementarity between political power and expenditure in the contest. Finally, the focus on the difference between the behavior of individuals and groups is a distinct feature of this paper.

The second strand of literature that we contribute to compares individual and group decision-making. Research by Cooper and Kagel (2005) indicates that groups play more strategically and that this difference is especially pronounced in complex games. Most closely related to our work, however, are papers studying cooperation in social dilemmas. In particular, Cooper and Kagel (2022) find that groups are more cooperative in the prisoner's dilemma, Cason and Mui (2019) find no difference in cooperation between groups and individuals in a noisy version of the prisoner's dilemma, and Nielsen, Bhattacharya, Kagel, and Sengupta (2019) find that groups are less cooperative in the trust game with pre-play communication. We find that groups cooperate less than individuals in treatments in which positive cooperation can be sustained as a myopic best-response equilibrium. Notably, our setting is more complex than the above studies and includes a distinct

[2]To the best of our knowledge, this paper offers the first attempt to model group decision-making with IEL. The advantage of this approach is that heterogeneity across individuals' other-regarding preferences is explicitly incorporated into a group decision. See section 3 for more details.

competitive stage. We also contribute to this literature, by providing an agent-based model of group decision-making.

The third strand of literature that we contribute to uses agent-based models to complement human-subject experiments to study cooperation (see, Duffy, 2006; Arifovic and Duffy, 2018, for a review). Early papers in this literature include Arifovic (1994), who compares results from human-subject experiments with simulations based on a genetic algorithm (Holland, 1975) in the context of a cobweb model.[3] More recently, Arifovic and Ledyard (2011, 2012) developed an individual evolutionary model inspired by a genetic algorithm that incorporates some of the behavioral factors documented within the experimental economics literature (i.e., other-regarding preferences). In particular, Arifovic and Ledyard (2012) study cooperation in a repeated public-goods game and show that the model calibrated on data from human experiments from Isaac and Walker (1988) is transferable to other settings and can also match human-subject behavior in Andreoni (1988), Croson (1996), and Andreoni (1995).[4] We adapt the IEL model to a group-decision setting. Specifically, we construct groups composed of distinct IEL agents, so that each agent is characterized by unique behavioral characteristics, maintains their own set of strategies, and learns on their own. At the same time, the group-decision process means that strategies proposed by one of the other agents in the group could be implemented. The results of simulations show that in the complex dynamic environment studied in this paper, groups tend to cooperate less than individuals.

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 present the agent-based model and carry out simulations to shed additional insights into the problem at hand. In section 4, we describe the details of the experiment designed to test the theoretical and computational predictions. In section 5, we present the main experimental results. Finally, in section 6, we conclude.

2 Environment and Theoretical Predictions

The environment studied in this paper is similar to the endogenous-contest treatment of Rosokha et al. (2022).[5] Specifically, we consider a society composed of $I = \{1, \dots, n\}$ decision-making units, whereby each decision-making unit is composed of K individuals.[6] For the purposes of the theoretical analysis presented in this section, we will refer to decision-making units as players. Players interact over an infinite sequence of rounds. In each round, $t \in \{1, 2, 3, \dots\}$, players face a

[3] Subsequent literature that combined learning via genetic algorithm and human subject experiments includes Arifovic (1995) and Arifovic (1996) who study inflationary economies; Arifovic and Eaton (1995) who study coordination problems in a two stage signalling game; and Romero and Rosokha (2019) who study cooperation in the indefinitely repeated Prisoners' Dilemma.

[4] IEL has also been used as a model of behavior in other settings. In particular, Anufriev, Arifovic, Ledyard, and Panchenko (2013) and Anufriev, Arifovic, Ledyard, and Panchenko (2022) study continuous double auction; Arifovic and Ledyard (2018) study alternation in the Battle of Sexes game; Arifovic, Boitnott, and Duffy (2019) study behavior in games with correlated equilibria; Arifovic, Duffy, and Jiang (2023) study adoption of payment methods. In all instances, the authors found a reasonably good match between IEL and results from human subject experiments.

[5] An environment with an exogenous contest is studied in Houle, Ruck, Bentley, and Gavrilets (2022).

[6] $K = 1$ corresponds to the individual decision-making setting studied in the prior work. $K > 1$ corresponds to the group decision-making setting.

coordination game (stage 1) and a contest for power (stage 2). Specifically, in stage 1 of period t, each player i chooses between cooperation ($a_{i,t} = 1$) and defection ($a_{i,t} = 0$). For convenience, let $a_t = (a_{i,t}, a_{-i,t}) = (a_{1,t}, \dots, a_{n,t})$ denote the action profile in period 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 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 proportion of the group 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.

Unlike the widely studied stag-hunt or public-goods games, the share of the production that player i gets in period t depends on their political power $f_{i,t} \in [0, 1]$.[7] 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.[8]

In stage 2 of period t, each player i chooses how much to spend in the contest for political power, $e_{i,t} \in [0, \pi_i^1(a_t, f_t)]$. The main focus of this paper and the novelty relative to Rosokha et al. (2022) is the incumbency advantage. We chose to model the incumbency advantage as complementarity between the current power and expenditure in the contest. In particular, let $\varepsilon \in [0, 1]$ be the incumbency-effect parameter. Then, given the vector of expenditures, $e_t = (e_{i,t}, e_{-i,t}) = (e_{1,t}, ..., e_{n,t})$, political power of an individual i at time step $t + 1$ is defined as

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

Thus, if $\varepsilon = 0$, the political power, f, is determined as the relative expenditure in the contest, whereas if $\varepsilon = 1$, the political power in the next period depends on both the current power and the expenditure.[9] In general, the larger ε is, the stronger the complementarity between the current power and the current expenditure. Notably, in the absence of the incumbency advantage, $\varepsilon = 0$, the political power only guarantees a higher share of the current cooperation benefit, whereas when the incumbency advantage, $\varepsilon > 0$ captures the interdependence of current political power and future political power and, thus, the future cooperation benefit. [10]

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

[8] There are two special cases stemming from the possibility of the denominator being zero. First, when cooperating agents have zero political power ($a_t \cdot f_t = 0$ 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 $\pi(a_t, f_t) = R_0$.

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

[10] For example, consider a two-player game where player 1 has 0.6 power and player 2 has 0.4 power. Suppose in

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 Parameters

In the experiment, we vary the incumbency parameter $\varepsilon \in \{0, 1\}$ and fix $b = 232$, $n = 3$, $a_0 = 0.812$, $R_0 = 60$, $c = 20.4$, $\kappa = 12$, and $e_{i,0} = 0$, $\forall i \in I$ (experimental treatment T1). The resulting stage game payoffs for the case of equal power are presented in Table 1. Notice that the game is the three-player stag-hunt game 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.

Table 1: Stage-Game Payoffs when All Players Have the Same Power

	0	1	2
C	40	50	110
D	60	60	60

Notes: Payoff for choosing C(cooperate) and D(defect) when all players have equal power. Columns denote how many other players choose C (out of $n-1$). Players always have equal power in Round 1 of a match, but may have equal power in other rounds depending on players' choices in prior rounds.

2.2 Myopic Best-Response, Contest for Power, and the Long-Term Outcomes

In our model, there are two interrelated 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, $e_{i,t} \in [0, \pi_i^1(a_t, f_t)]$. In particular, the expenditure in stage 2 of period t directly affects not only the current period t payoff but also the next period $t+1$ payoff (which also depends on the next period cooperation decision, $a_{i,t+1}$). Therefore, to make the theoretical analysis manageable, we assume the individual simultaneously chooses the expenditure $e_{i,t}$ in stage 2 of period t and the action $a_{i,t+1}$ in stage 1 of period $t+1$ to maximize her expected total earnings by best responding to the previous choices (a_t, e_{t-1}). That is, if $a_{-i,t} \cdot e_{-i,t-1} \neq 0$ or $a_{-i,t} = 0$ in stage 2 of period t, player i chooses[11]

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

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

stage 1, the benefit to cooperation is 100. Then, if both players cooperate in stage 2, Player 1 earns 60, and player 2 earns 40. Suppose that in stage 2 both players choose to spend 10 in the contest. If $\varepsilon = 0$, their next round powers will be equal, while $\varepsilon = 1$, their next round power will stay the same. Thus, as ε increases, players maintain their power advantage more easily.

[11]For simplicity, here we assume (a) $\varepsilon \in [0, 1)$, and (b) $f_{i,t+1} = 1/n$ in formula (3) if $e_t \cdot (1 - \varepsilon + \varepsilon f_t) = 0$.

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 in the model if*

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

where

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

Proposition 1 ***Existence of myopic-best-response equilibria.*** *A symmetric myopic-best-response equilibrium is characterized by at most two types of players: defectors and cooperators. All* $n_C \in \{0, 1, .., n\} \setminus \{1\}$ *cooperators (if they exist) have the same power* $\hat{f}_C = 1/n_C$ *and have the same non-zero expenditure* $e_C^* = \delta\Big(1 - \frac{1}{n_C}\Big)\frac{F(n_C/n)}{n_C}$*; and all* $n - n_C$ *defectors (if they exist) have the same power* $\hat{f}_D = 0$ *and the same expenditure* $e_D^* = 0$*.*

The conditions for equilibrium existence as well as the proof of Proposition 1 can be found in Appendix A.2 and Appendix A.1, respectively.[12]

Definition 2 *Let* (a^*, e^*) *be a myopic-best-response equilibrium with the corresponding power* $\hat{f}$ *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*

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

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

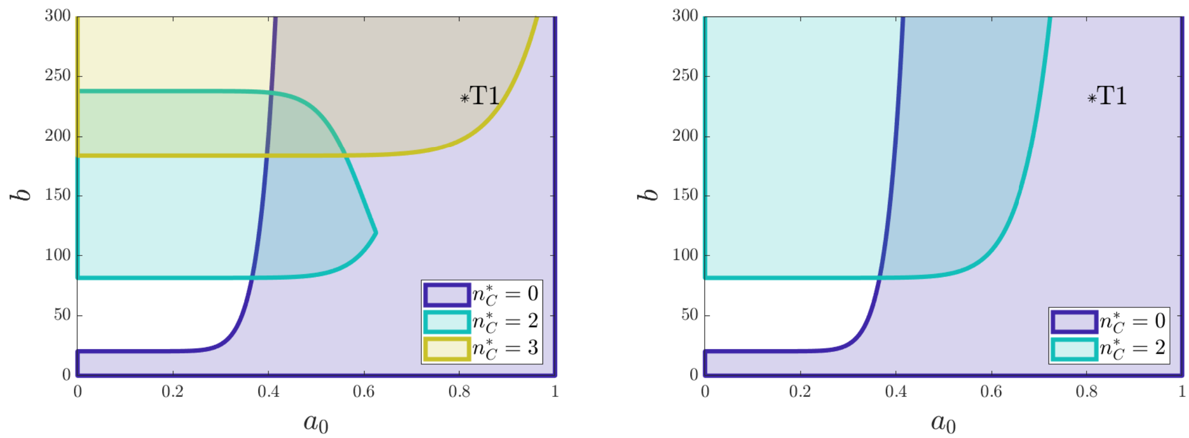
where $\psi_i(e_{t-1}, f_t) = \operatorname{argmax}_{e_i \in [0, \pi_i^1(a^*, f_t)]} \Big\{ -e_i + \delta \pi_i^1\Big(a^*, \phi\big((e_i, e_{-i,t-1}), f_t\big)\Big)\Big\}$.

Proposition 2 ***Stability of symmetric myopic-best-response equilibria.*** *The symmetric equilibrium with* $n_C = 0$ *cooperators is stable. Consider a symmetric myopic-best-response equilibrium with* $n_C \in \{2, .., n\}$ *cooperators. If* $\varepsilon < \frac{n_C}{2(n_C - 1)}$ *and* $n_C \leq 3$*, the equilibrium is stable to small perturbations in expenditures and powers.*

The proof of Proposition 2 can be found in Appendix A.3. The main takeaway is that the stability of a symmetric equilibrium depends only on the incumbency-effect parameter ε and the number of cooperators n_C, and not on the parameters capturing the benefits and costs of cooperation. In particular, increasing the incumbency advantage in the political contest leads to instability of the cooperative coalition and to a breakdown in cooperation.

[12] See also Appendix A.1, Appendix A.2, and Appendix A.4 for more information on asymmetric equilibria.

Figure 1: Stable Myopic-Best-Response Equilibria



(a) $\varepsilon = 0$ (b) $\varepsilon = 1$

Notes: Regions of stability of equilibria with n_C^* cooperators and $n - n_C^*$ defectors as a function the maximum benefit to cooperation b and the proportion of the group a_0 required to produce benefit $\frac{b}{2}$. Except for the case of $\varepsilon = 1$ and $n_c = 2$, these equilibria are symmetric. If $\varepsilon = 1$ and $n_c = 2$, there is an infinite family of equilibria with 2 cooperators characterized by powers $\hat{f}$ and $1 - \hat{f}$, respectively, and the same expenditure $e_C^* = \delta F(2/n)\hat{f}(1 - \hat{f})$, where $\hat{f} \in (f_{min}, 1 - f_{min})$ (for more details see Appendix A.4). Parameters corresponding to the experimental treatment $T1$ are marked by $\bullet$.

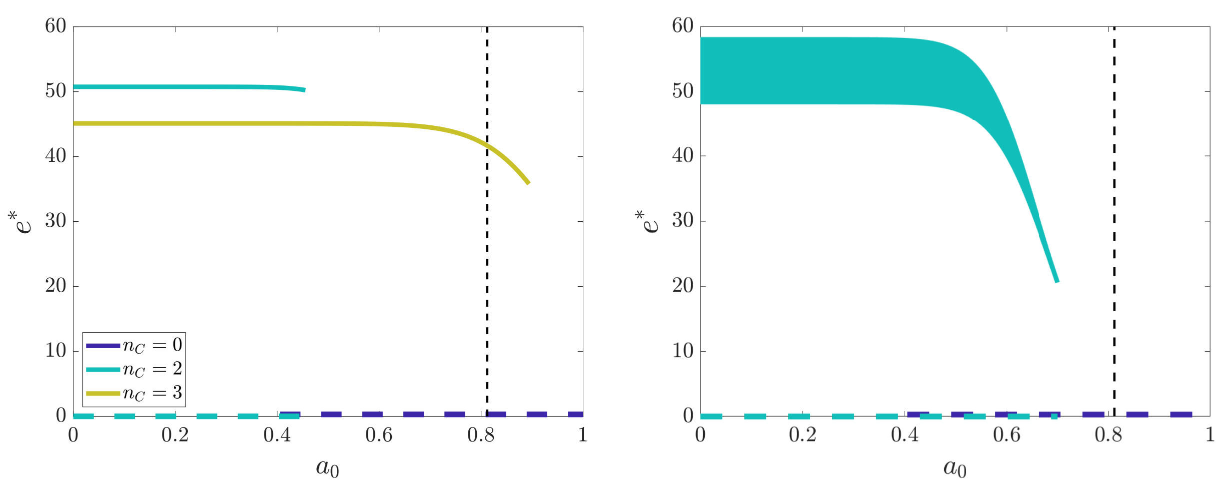
Overall, increasing the incumbency advantage in the political contest has two effects on the equilibrium results: (1) it leads to the instability of more cooperative equilibria by promoting inequality in power and expenditures among cooperators; and (2) it leads to the emergence of less cooperative equilibria. Figure 1 illustrates these theoretical findings for the case of $n = 3$ players. The figure shows parameter regions for which a particular equilibrium (denoted by the number of cooperators) exists. Below we discuss these equilibria in detail providing an intuitive explanation for their existence and stability. First, in the equilibrium with $n_C = 0$ cooperators all agents have equal powers 1/3 and zero expenditures $e_D^* = 0$ (see Proposition 1). This equilibrium exists if the individual payoff from cooperation of an agent who unilaterally switched to cooperation does not cover the cost of cooperation (i.e., if $F(1/3) < c$, see Proposition 3 in Appendix A.2). Second, in the equilibrium with $n_C = 3$ cooperators all agents have equal powers 1/3 and equal expenditures $e_C^* = \frac{2\delta}{9}F(1)$. Intuitively, this equilibrium exists if each individual payoff from cooperation greatly exceeds the cost of cooperation (i.e., if $\frac{1}{3}F(1) \geq 3c$, see Proposition 3 in Appendix A.2). However, this equilibrium becomes unstable if $\varepsilon > 0.75$ (see Proposition 2). This means that for large ε even infinitesimal differences in power and expenditures between the three cooperating agents are amplified, since more powerful agents can easily grab even more power by increasing their expenditures in the contest due to the incumbency advantage. Conversely, less powerful agents are forced to decrease their expenditures and eventually switch to defection as their power becomes sufficiently low. Third, in the symmetric equilibrium with $n_C = 2$ cooperators, the cooperators have equal powers 1/2 and equal expenditures $e_C^* = \frac{\delta}{4}F(2/3)$, while the defector has zero power and expenditures. On the one hand, the above equilibrium exists if the individual payoff from cooperation is high enough to motivate cooperators not to defect. On the other hand, the benefit from cooperation should not be very high or the incumbency advantage should be sufficiently high to restrain the defector from cooperation (see Proposition 3 in Appendix A.2 for details). Finally, note that with $\varepsilon = 1$, the symmetric equilibrium with $n_C = 2$ cooperators is part of an infinite family of asymmetric equilibria with $n_C = 2$ cooperators (see Appendix A.4 for details).

In Figure 1, we also mark the parameter combination, $T1$, that we chose to run for the experiment. Specifically, the T1 parameter combination with $\varepsilon = 1$ is predicted to have no cooperation, whereas for the same parameter combination and $\varepsilon = 0$, full cooperation (all three players) can be supported in equilibrium, along with the equilibrium with no cooperators. We summarize the above considerations with the following hypothesis:

Hypothesis 1 *Cooperation is lower in treatments with a higher incumbency advantage.*

Figure 2 summarizes theoretical predictions on the equilibrium expenditures in the contest for power. The main takeaway is that for the T1 parameter combination increasing the incumbency advantage in the political contest on average leads to a decrease in the expenditures. Specifically, we predict all agents to have zero expenditures in the contest if $\varepsilon = 1$, while with $\varepsilon = 0$, two equilibria are supported: full-defection and full-cooperation with expenditures $e^*_D = 0$ and $e^*_C = 41.69$, respectively.

Figure 2: Contest Expenditures in Equilibrium



(a) $\varepsilon = 0$ (b) $\varepsilon = 1$

Notes: The figure shows equilibrium expenditures e^* of individuals in the contest in stage 2 at equilibria with $n_C = 0, 2,$ and 3 cooperators. Solid curves show expenditures of cooperators (i.e., e^*_C), while dashed curves correspond to expenditures of defectors (i.e., e^*_D). Vertical dashed lines denote experimental treatment T1. With $\varepsilon = 1$ and $n_c = 2$, there is an infinite family of equilibria forming the green shaded region in panel (b).

3 Agent-based Simulations

The theory has several shortcomings. First, in the presence of multiple equilibria, as is the case of $\epsilon = 0$, the theory does not provide a precise prediction. For example, for the chosen parameters in the $\epsilon = 0$ treatment, $n_C^* = 0$ and $n_C^* = 3$ are two possible equilibria. Second, we carried out the theoretical analysis without taking into account behavioral considerations such as altruism (Simon, 1993; Andreoni and Miller, 2002) and fairness (Kahneman, Knetsch, and Thaler, 1986; Rabin, 1993; Fehr and Schmidt, 1999), which have been extensively shown to matter for human decisions (Falk, Fehr, and Fischbacher, 2008; Duffy and Muñoz-García, 2015). Third, and most importantly for this project, the theory does not provide a prediction regarding the difference between individual and group-decision-making processes. Finally, the theory does not provide predictions regarding the dynamics of cooperation across rounds of interactions. We look to overcome these shortcomings by using simulations with an agent-based model motivated by the individual evolutionary model of Arifovic and Ledyard (2011, 2012).

3.1 Individual Evolutionary Model

For the baseline individual-decision-maker treatment, we follow the model of Arifovic and Ledyard (2011, 2012). Specifically, we assume that when making a choice in round t, each agent has a set of rules in their memory, denoted by $A_{i,t}$. The number of rules in the set is denoted by $J = |A_{i,t}|$. Although any rule could be selected to make a choice, rules that yield higher utilities are selected with higher probability. Each rule's utility is determined based on forgone utility (i.e., the utility that the rule would have generated had it made a choice). Individual evolutionary learning has two main operators. The first operator is *experimentation* — going from round to round, agents experiment with new rules by perturbing old rules (selected with a probability ρ), using a normal distribution that has a mean of zero and a variance of σ. The second operator is *replication* — going from round to round, agents are more likely to replicate rules that generate higher forgone utilities. We follow Arifovic and Ledyard (2012) in assuming the three free parameters in the learning model ($J = 100$, $\rho = 0.033$, $\sigma = 0.1$).[13]

In addition to the learning component, Arifovic and Ledyard (2012) emphasize the role of other-regarding preferences. Specifically, the utility function takes the following form:

$$u_i = \underbrace{\mathbb{E}[\pi_i]}_{\substack{\text{Expected individual}\\ \text{payoff}}} + \underbrace{\frac{\beta_i}{n}\sum_{j\in I}\mathbb{E}[\pi_j]}_{\substack{\text{Preference for higher payoffs}\\ \text{to all agents (i.e., altruism)}}} - \underbrace{\frac{\gamma_i}{n-1}\sum_{j\neq i, j\in I} max\{0, \mathbb{E}[\pi_j] - \mathbb{E}[\pi_i]\}}_{\substack{\text{Disutilty from being}\\ \text{taken advantage of (i.e., envy)}}}, \quad (10)$$

where the behavioral components are captured by parameters β (altruism) and γ (envy).[14] Follow-

[13] As mentioned in the introduction, these parameters were estimated by Arifovic and Ledyard (2012) based on the data from Isaac and Walker (1988).

[14] Unlike experiments by Isaac and Walker (1988), in our environment subjects receive feedback regarding individual payoffs of all other subjects, therefore, we modified the fairness component to take that into account.

ing Arifovic and Ledyard (2012), we assume with probability 48% an agent is self-interested (with $\beta_i = 0$ and $\gamma_i = 0$), and with probability 52% an agents has uniformly and independently drawn β_i and γ_i from the ranges of [0,22] and [0,8], respectively. Notice that the notation in equation (10) is simplified relative to equation (4) by omitting the strategies, timing, and decision structure across stages in order to focus on the functional form of the utility. Next, we provide more details.

Our environment differs from those studied in Arifovic and Ledyard (2011, 2012) in that we have two distinct stages that occur sequentially. Thus, each subject will maintain two rule sets, $A^1_{i,t}$ and $A^2_{i,t}$. In particular, $A^1_{i,t}$ contains J probabilities of cooperation that a subject may consider in stage 1 of round t. We denote the jth rule in set $A^1_{i,t}$ by $r^{1,j}_{i,t} \in [0,1]$. At the same time, $A^2_{i,t}$ contains J expenditure proportions that the subject may consider in stage 2 of round t. We denote the jth rule in set $A^2_{i,t}$ by $r^{2,j}_{i,t} \in [0,1]$. The rules are selected to make a choice based on their forgone utilities $v^{s,j}_{i,t}$. Specifically, the forgone utilities of each rule are calculated based on equation (10) with the strategies of others taken to be the most recently observed strategies at each stage (see Appendix B for details). Then, subject i selects rule j to make a choice in stage s of round t with probability

$$\psi^{s,j}_{i,t} = \frac{v^{s,j}_{i,t} - v^{s,min}_{i,t}}{\sum_{j=1}^{J}(v^{s,j}_{i,t} - v^{s,min}_{i,t})}, \tag{11}$$

where $v^{s,min}_{i,t} = \min_{j\in\{1,\ldots,J\}}\{0, v^{s,j}_{i,t}\}$.

As mentioned above, the learning process contains two operators: experimentation and replication. First, with probability ρ, each rule is modified to introduce a new, related rule. The modification is done via adding noise drawn from a normal distribution with a mean equal to the current rule and standard deviation $\sigma = .1$. Second, the replication is carried out by the following procedure: for each slot $j \in \{1, 2, \ldots J\}$ in $A^s_{i,t}$, two rules are randomly selected from $A^s_{i,t-1}$ (with replacement). In each pair, a rule with a higher forgone utility will be chosen to fill the slot in $A^s_{i,t}$.

3.2 Agent-based Model of Group Decision

One of the contributions of this paper is to provide an agent-based model of group decision-making. To this end, we build on the IEL model described above, by adding a group-decision-making stage. Specifically, first, each agent proposes a rule for making a choice. This process is similar to the rule selection in the individual model. Second, all of the proposed rules are evaluated by each agent based on the forgone utility. Finally, each agent votes for one of the rules proposed by the members of own group. The voting takes a form of probabilistic choice based on the forgone utilities. For simplicity, we use the same proportional rule from in equation 11. The rule with the most votes is chosen to make the choice for a group (with ties broken randomly). Algorithm 1 presents the outline of steps for the group-decision-making process based on IEL agents. Notice that when $K = 1$, the algorithm implements the individual evolutionary learning paradigm of Arifovic and Ledyard (2011, 2012). For the experiment carried out in this paper, we are interested in comparing individual and group decision-making ($K = 1$ vs. $K = 2$).

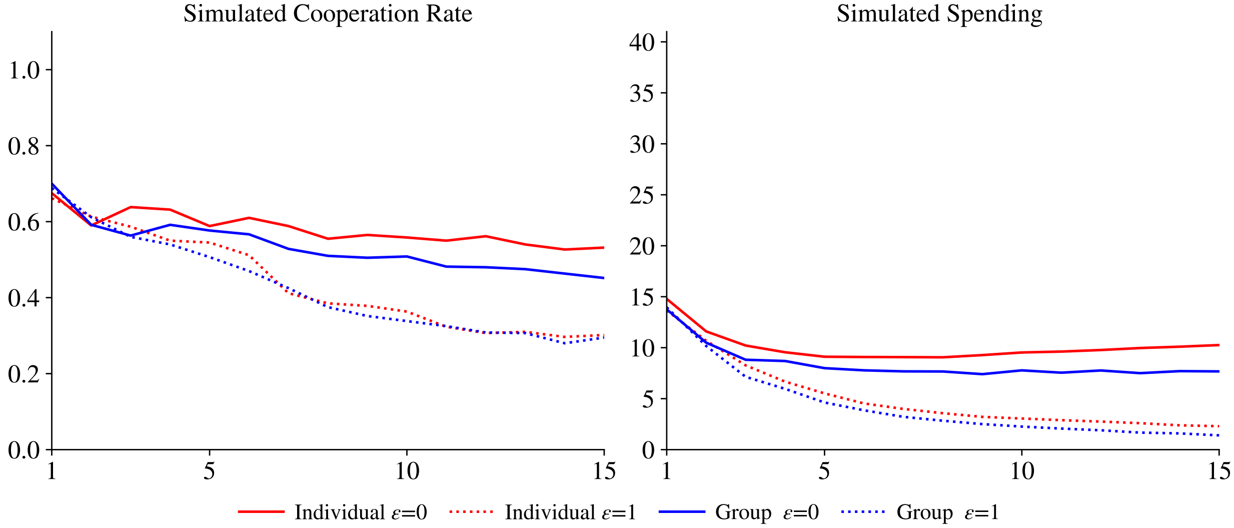
Algorithm 1 IEL and Group Decision *(group of size K)*

Initialize $i \in \{1, ..., K \times n\}$ agents
  w.p. 48%: $\beta_i = 0$ and $\gamma_i = 0$; w.p. 52%: $\beta_i \sim U[0, 22]$ and $\gamma_i \sim U[0, 8]$
  initialize $A^1_{i,0}$ and $A^2_{i,0}$ with $J = 100$ random rules: $r^{s,j}_{i,0} \sim U[0, 1]$
Randomly split agents into n groups
For each round $t \in \{1, ..., T\}$:
  For each stage $s \in \{1, 2\}$:
    For each agent $i \in \{1, ..., K \times n\}$:
      Experimentation: modify each rule $r^{s,j}_{i,t} \in A^s_{i,t-1}$ with probability ρ
      Replication: probabilistically copy good rules from $A^s_{i,t-1}$ to $A^s_{i,t}$
      Proposal: probabilistically choose a rule $\hat{r}^s_{i,t}$ from $A^s_{i,t}$
    For each group $n \in \{1, ..., n\}$:
      For each agent $k \in \{1, ..., K\}$:
        Evaluate all group members' proposals
        Vote for one rule among K proposed
      Implementation: proposal with the most votes is implemented (ties broken randomly)

3.3 Simulations

The simulations are carried out in the environment presented in section 2. Specifically, in each match, we have three decision-making units. In the individual treatment, each decision-making unit consists of one agent ($K = 1$); in group treatment, each decision-making unit consists of two agents ($K = 2$). We simulated a repeated interaction for the four treatments of interest ($\{\epsilon = 0, \epsilon = 1\} \times \{K = 1, K = 2\}$). Each treatment contains 200 independent trials of 15 rounds of play. Figure 3 presents the simulation results. The left panel shows the average cooperation rate in stage 1, whereas the right panel shows the average spending amount in stage 2.

Figure 3: IEL Simulations



Notes: Red lines indicate individual treatments ($K = 1$). Blue lines indicate group treatments ($K = 2$). Solid lines indicate no incumbency advantage ($\epsilon = 0$). Dashed lines indicate with incumbency advantage ($\epsilon = 1$).

We find cooperation rates are higher for $\epsilon = 0$ than for $\epsilon = 1$ for both the Individual and the Group treatment which is aligned with Hypothesis 1. More importantly, the cooperation rates in the Group treatment are lower than Individual treatment both when $\epsilon = 0$ and when $\epsilon = 1$. Thus, the results of the simulations provide a foundation for our second hypothesis.

Hypothesis 2 *Cooperation is lower in treatments with groups than in treatments with individuals.*

In addition to the comparative static predictions, the simulations provide predictions regarding the dynamics of cooperation. Specifically, Figure 2 shows that cooperation decreases over time across all four treatments. Thus, we rely on these results to propose our third hypothesis:

Hypothesis 3 *Cooperation within an interaction breaks down over time.*

4 Experimental Design

For our human-subject experiment, we implement a 2×2 factorial design similar to the simulations described above. Specifically, in the experiment we vary the incumbency advantage ($\epsilon = 0$ vs $\epsilon = 1$) and the decision-making unit (individual vs group). We recruited 288 subjects and ran 16 sessions at the Vernon Smith Experimental Economics Laboratory at Purdue University between February and March 2023. Table 2 presents a summary of the four treatments. Each treatment contains four sessions and 48 decision-making units. On average, subjects earned \$24.1 (including the \$5 show-up fee).

Table 2: Summary of Experiment Administration

Treatment	Administration				Demographics		
	Sessions	DM Units	Subjects	Earnings	% Male	% STEM	% US HS
GRP E0	4	48	96	23.6	53.1	66.7	64.6
				(0.3)	(5.1)	(4.8)	(4.9)
GRP E1	4	48	96	24.0	47.9	60.4	72.9
				(0.2)	(5.1)	(5.0)	(4.6)
IND E0	4	48	48	25.9	52.1	72.9	58.3
				(0.4)	(7.3)	(6.5)	(7.2)
IND E1	4	48	48	23.5	43.8	70.8	75.0
				(0.5)	(7.2)	(6.6)	(6.3)
Overall	16	192	288	24.1	49.7	66.3	68.1
				(0.2)	(3.0)	(2.8)	(2.8)

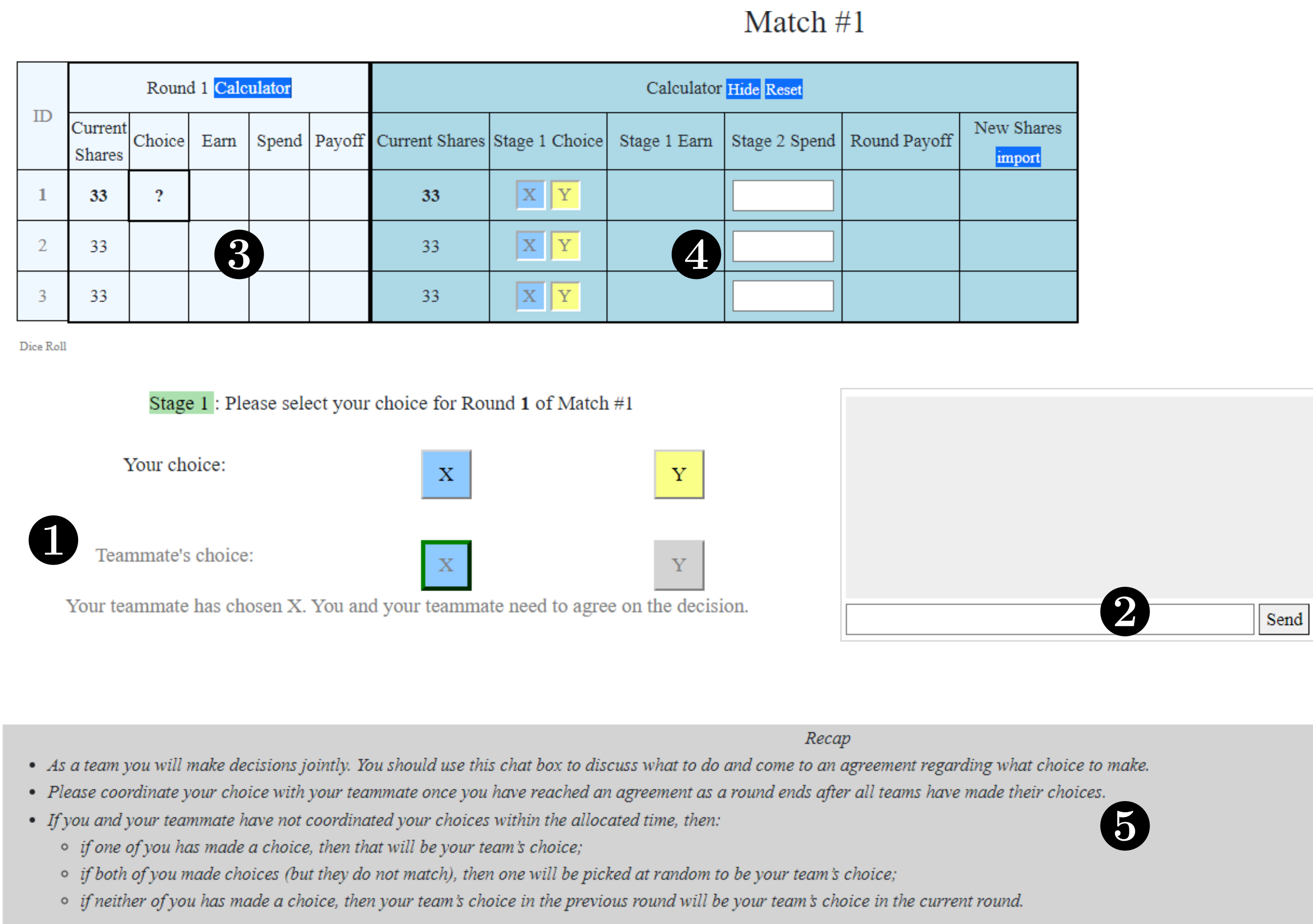
Notes: Standard errors are in parentheses. DM Units denote the number of decision-making units for each treatment. % STEM denotes proportion of participants that are in STEM majors. % US HS denotes the proportion of participants that completed high school in the US.

The experiment began with 11 matrix-reasoning questions (see Appendix E.1.1 for an example) and a demographic questionnaire. Next, subjects had 20 minutes to go through a set of interactive instructions. After the instructions, the main experiment began. Throughout the experiment, all payoffs were displayed in Experimental Currency Units (ECUs) The main part of the experiment consisted of 10 matches for the group treatments and 20 matches for the individual treatments.[15] Each match consisted of an indefinitely repeated interaction with a probability of continuation $\delta = .875$ (Roth and Murnighan, 1978). Specifically, at the end of each decision round, the computer randomly drew a number between 1 and 8. The repeated game ended if 8 was drawn and continued to at least one more round otherwise. Therefore, the expected duration of interaction was eight rounds.

Each round contained two stages: (1) collective action game and (2) contest for power. In stage 1, decision-making units simultaneously decide whether to cooperate in the production of a collective good. Figure 4 presents the decision screen for stage 1 of the Group $\epsilon = 1$ treatment. Given the complexity of the environment and the dynamic consequences of decisions, we provide a hypothetical calculator (4 in Figure 4). Using the calculator, subjects could enter a hypothetical scenario to see the resulting payoffs for the round as well as the power in the following round.

[15] This difference is motivated by the fact that group treatments proceed much slower. For the main analysis below, we report results from the first 10 matches for both group and individual treatments. In the appendix figure **??**, we report results from all 20 matches in individual treatments and confirm that behaviors have stabilized in matches 5-10.

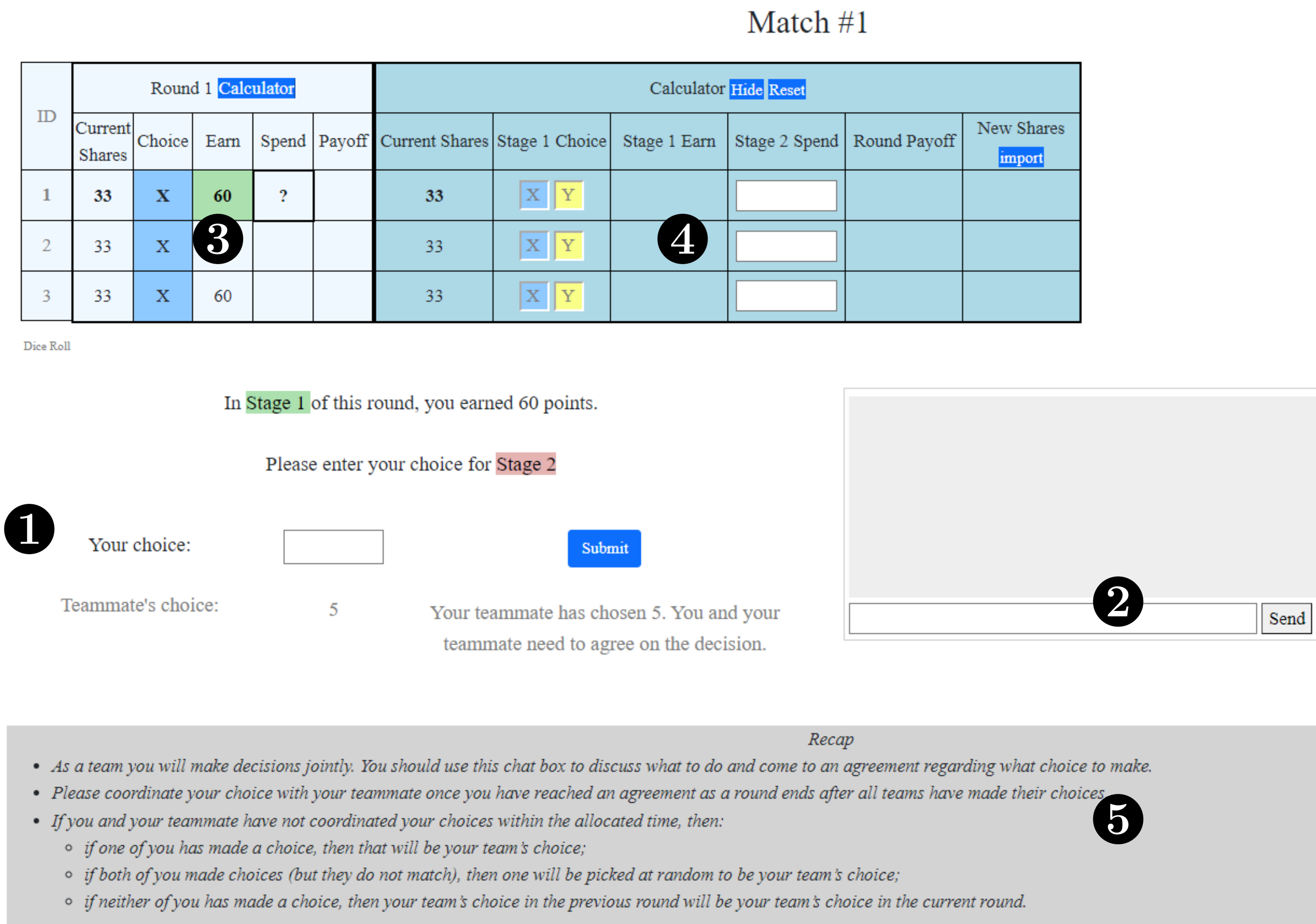
Figure 4: Stage 1 Screenshot



Notes: The screenshot shows the decision screen in the Group $\epsilon = 1$ treatment. The neutral actions X and Y correspond to D (defect) and C (cooperate), respectively. The screenshot shows (1) decision entry in the first row and the dynamically updated teammate's choice in the second row (in the individual treatment, the second row is left blank), (2) the group chat window (in individuals treatment, the chat window is left blank), (3) 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, (4) a hypothetical payoff calculator, and (5) a recap of the decision rules.

After all decision-making units make their stage 1 decisions, the experiment proceeds to stage 2. Figure 5 presents the screenshot of the stage 2 interface for the Group $\epsilon = 1$ treatment. Decision-making units need to decide how many points to spend in the contest for power. In particular, we use neutral phrases such as "shares" when referring to power (see (2) in Figure 5). The points they spend in stage 2 cannot exceed their earnings in stage 1.

Figure 5: Stage 2 Screenshot



Notes: The screenshot shows the decision screen in the Group $\epsilon = 1$ treatment. The neutral actions X and Y correspond to D (defect) and C (cooperate), respectively. The screenshot shows (1) stage 2 decision entry in the first row and the dynamically updated teammate's choice in the second row (in individual treatment, the second row is left blank), (2) the group chat window (in individuals treatment, the chat window is left blank), (3) 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, (4) a hypothetical payoff calculator, and (5) a recap of the decision rules.

4.1 Group vs. Individual Decision-Making

For group-decision-making treatments, we adopted procedures from Cooper and Kagel (2022). Specifically, at the beginning of the experiment, subjects were randomly matched into groups of two. Subjects stayed matched in the same groups throughout the experiment. To make decisions jointly, each subject entered a choice for the game. The choice was immediately displayed to the partner but was implemented only if both subjects in the group agreed within an allocated time interval. If subjects did not agree on the choice within an allocated time, we followed Cooper and

Kagel (2022) in implementing the choice (see (5) [16] in Figures 4 and 5, and Appendix E.2.7). To facilitate the decision-making process, subjects had access to the chat box for the duration of the main experiment. If the two subjects failed to reach an agreement within the allocated time, the default option was implemented (see Appendix E.2.7).[17] The time restrictions were as follows: before the first match, we allocated five minutes for groups to discuss their planned strategies for the match (which we call "prematch chat" as shown in Appendix E.3.2). After the first match, we gradually reduced the time of the pre-match chat to one minute.[18] On average, subjects spent 2.29 minutes discussing their plan prior to the first match, and 0.36 minutes discussing their plan prior to matches 5–10. After the match began, we allocated up to one minute for the group to make a choice in each stage of round 1 and 2, and up to 40 seconds in each stage of rounds 3 onward. On average, subjects in the group treatment spent 12.7 seconds to make a decision in each round of matches 5–10.

In the individual-decision-making treatments, we maintained the above procedures as much as possible. In particular, the instructions were identical except for the two pages explaining group decision-making (pages 9 and 10 in Appendix E). The stage-game interface was the same as the group treatment except that we removed the teammate's choice and the chat window. Importantly, because of the existing evidence that additional reflection may impact the decisions (e.g., Piovesan and Wengström, 2009; Rand, Greene, and Nowak, 2012; Neo, Yu, Weber, and Gonzalez, 2013; Rand, Peysakhovich, Kraft-Todd, Newman, Wurzbacher, Nowak, and Greene, 2014; Kocher, Martinsson, Myrseth, and Wollbrant, 2017), we implemented the same time restrictions. Specifically, subjects had up to five minutes before the first match to think about their plan for the match. The "pre-match" time was then reduced in the same manner as in the group treatment.

Given the complexity of the environment, we took several steps to ensure subjects understood the interface and the consequences of the cooperation and competition decisions. First, we developed an interactive interface to engage subjects throughout the instructions (see Appendix E). Second, to ensure subjects actively engaged with the interactive instructions, they were given 20 minutes to complete the instruction and 10 incentivized comprehension questions. Each comprehension question was worth $0.5 and was designed to test the understanding of different parts of the instructions. Subjects received immediate feedback once they answered the question. After the interactive instructions, we provided subjects with a hard copy of the instructions and a recap of the decisions in each stage. Third, to improve participants' understanding of how earnings in stages 1 and 2 were determined, we required each participant to go through five examples with

[16] The decision rules are recapped as: As a team you will make decisions jointly. You should use this chat box to discuss what to do and come to an agreement regarding what choice to make. Please coordinate your choice with your teammate once you have reached an agreement as a round ends after all teams have made their choices. If you and your teammate have not coordinated your choices within the allocated time, then: if one of you has made a choice, then that will be your team's choice; if both of you made choices (but they do not match), then one will be picked at random to be your team's choice; if neither of you has made a choice, then your team's choice in the previous round will be your team's choice in the current round.

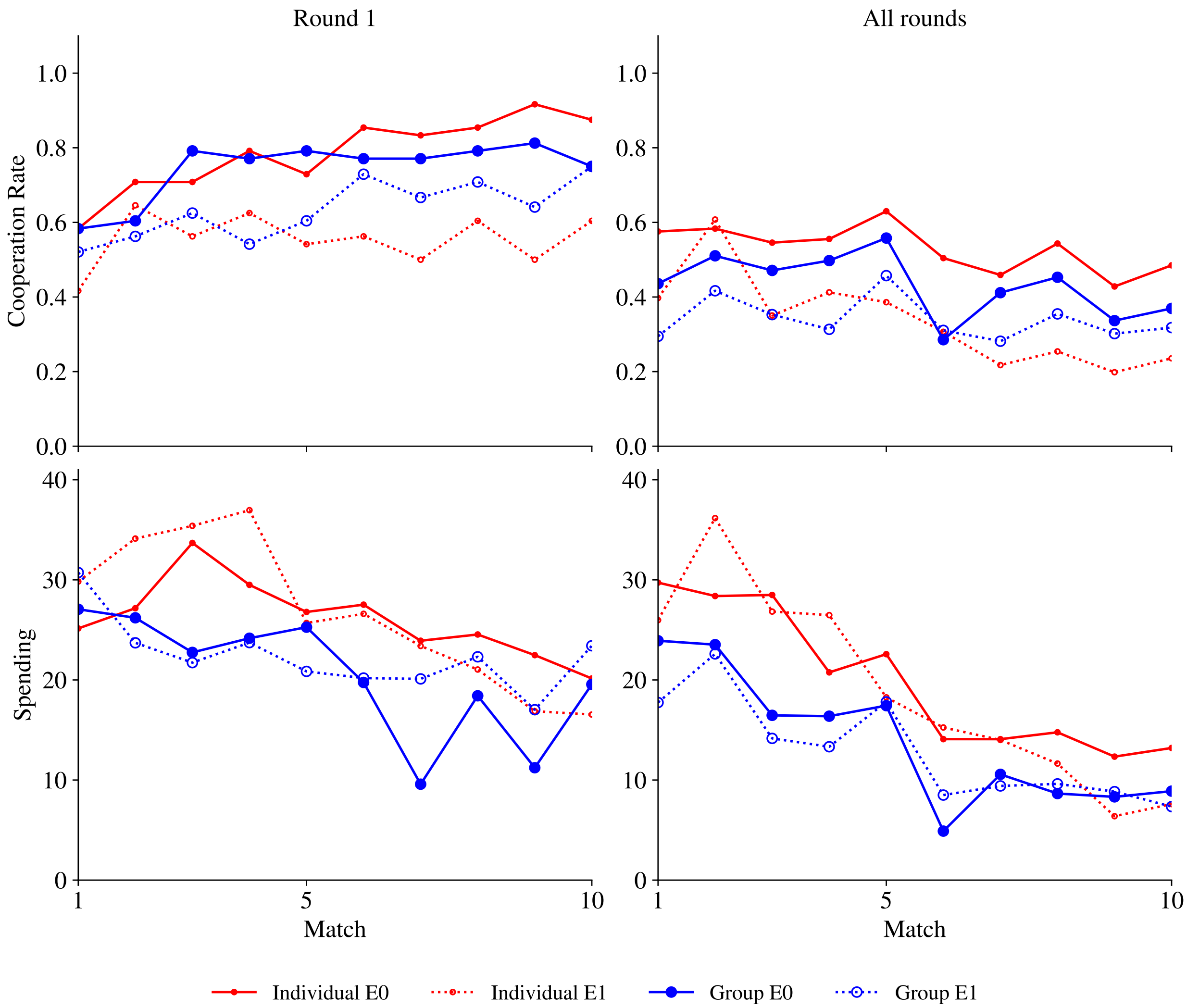
[17] In the second half of the experiment, only 2.7% of choices reached the time-out.

[18] Prematch-chat duration: match 2, 3 minutes; matches 3 to 5, 2 minutes; matches 6 and onward, 1 minute.

step-by-step calculations.[19] Lastly, we provided access to the payoff calculator for the duration of the experiment (including the waiting pages).

5 Experimental Results

Figure 6: Cooperation and Competition Across Matches



Notes: Blue color denotes the Group treatments ($K = 2$). Red color denotes the Individual treatment ($K = 1$). Solid line with filled markers denotes treatments without incumbency advantage ($\epsilon = 0$). Dashed line with empty markers denotes treatments with incumbency advantage ($\epsilon = 1$).

[19]To avoid bias, we randomly generated the power distribution and choices in those examples. In particular, for stage 1, subjects saw five randomly generated power distributions and five sets of random choices. They then saw step-by-step calculations of their earnings in stage 1. Next, in stage 2, they saw randomly generated spending and how the spending will result in the next-round power.

Figure 6 presents the average cooperation in the first round (top left panel) and in all rounds (top right panel) across matches observed in our experiment.[20] The solid lines indicate treatment $\epsilon = 1$ whereas the dashed lines indicate treatment $\epsilon = 0$. In the raw data, it is clear that for both the Individual treatment (red lines) and the Group treatment (bue lines), the average cooperation is higher when $\epsilon = 0$, which is consistent with our theoretical prediction. To formally test Hypothesis 1, we run a regression of cooperation in a round on treatment dummies and their interaction. In the regression, we include controls that capture the history of play (e.g., others' cooperation in round 1 of the previous match) and demographic characteristics (e.g., major). The results of the regression, presented in columns (1)-(3) of Table 3, show that the estimated coefficient of the dummy for $\epsilon = 1$ treatment is negative and highly significant (p-value< .01).

Result 1 *Cooperation is lower in treatments with a higher incumbency advantage.*

Figure 6 also shows stage 2 spending in the first round (bottom left panel) and in all rounds (bottom right panel) across matches observed in our experiment. In both panels, we see a clear downward trend for all treatments, which is consistent with the previous finding in Rosokha, Lyu, Tverskoi, and Gavrilets (2022), such that over time, subjects learn to spend less.[21] Although subjects in the Individual treatment tend to spend slightly more than the Group treatment for both $\epsilon = 0$ and $\epsilon = 1$ in the first 10 matches, the difference is not significant in the formal regression test as shown in table 3 when we include other control variables. The average spending amount doesn't seem to differ between $\epsilon = 0$ and $\epsilon = 1$ treatments, either (p-value is .789 for comparison between two Group treatments; p-value is .064 for the comparison between two Individual treatments).

The comparison of cooperation between the Individual and Group treatments is less clear. Focusing on all rounds, we see that the average cooperation rate in the Individual treatment is higher than Group treatment when $\epsilon = 0$, but not when $\epsilon = 1$. To delve deeper, Figure 7 shows the evolution of cooperation within match. There are two notable observations from this figure. First, the difference in cooperation between individuals and groups when $\epsilon = 0$ arises after the second round of interaction. Second, cooperation in Individual and Group treatments tends to zero when $\epsilon = 1$. Regression results in Table 3 confirm these observations. Specifically, the cooperation in rounds after round four is significantly lower for groups (p-value < .05) but only when $\epsilon = 0$.

Result 2 *Cooperation is higher by individuals than groups when $\epsilon = 0$, but not when $\epsilon = 1$.*

[20] The cooperation rates observed in Individual $\epsilon = 0$ treatment are comparable to previous experiments with similar parameters (Rosokha, Lyu, Tverskoi, and Gavrilets, 2022). Specifically, with $b = 218$, Rosokha, Lyu, Tverskoi, and Gavrilets (2022) reported average cooperation of 69.7% for the $n = 2$ treatment and 24.9% for the $n = 4$ treatment. In comparison, for $b = 232$ and $n = 3$ we find an average cooperation rate of 50.8%, which is within the expected range.

[21] For the two comparable treatments reported in Rosokha, Lyu, Tverskoi, and Gavrilets (2022), the average spending fraction over stage 1 earnings both started from around 0.4 in match 1 and dropped to 0.1 ($n = 4$) and 0.3 ($n = 2$) respectively. In comparison, the average spending fraction in the Individual $\epsilon = 0$ treatment of the current paper is 0.19.

Table 3: Cooperation and Competition

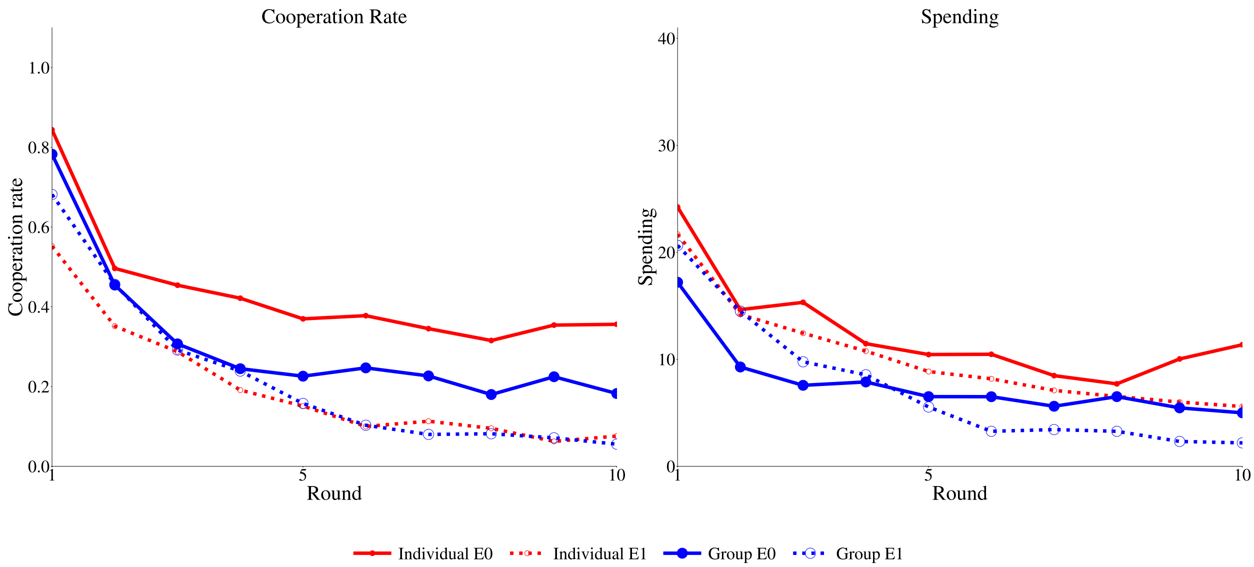
	Cooperation			Spending		
	Round 1	Round 5+	All Rounds	Round 1	Round 5+	All Rounds
	(1)	(2)	(3)	(4)	(5)	(6)
E = 1	-0.26***	-0.31***	-0.27***	5.14	1.44	2.27
	(0.07)	(0.06)	(0.05)	(5.27)	(2.32)	(2.71)
Being in a GRP	-0.07	-0.19**	-0.15*	-6.27	-2.88	-3.47
	(0.07)	(0.09)	(0.08)	(5.63)	(2.48)	(2.66)
E=1 × GRP	0.20	0.21*	0.20*	2.26	-2.79	-1.69
	(0.12)	(0.11)	(0.12)	(7.55)	(3.14)	(3.37)
Power Inequality / 100					-6.91***	-8.86***
					(1.81)	(1.37)
My power					-0.66	-1.84**
					(0.93)	(0.93)
Money at Hand				0.29***	0.21***	0.24***
				(0.05)	(0.06)	(0.04)
Own Round 1 Coop in Match 1	0.14**	0.01	0.02	-1.40	0.09	-0.57
	(0.06)	(0.02)	(0.03)	(2.38)	(0.94)	(1.18)
Others' Round 1 Coop in Match t-1	0.09***	-0.02	-0.00	4.29**	1.82*	2.10**
	(0.03)	(0.04)	(0.04)	(2.08)	(1.01)	(0.99)
Round Number / 10		-0.05*	-0.23***		-2.39***	-3.72***
		(0.03)	(0.03)		(0.81)	(0.71)
Match Number / 10	0.09	-0.02	-0.14	-12.70**	-8.60**	-9.52***
	(0.09)	(0.11)	(0.11)	(6.06)	(3.42)	(3.39)
Constant	0.64***	0.46***	0.72***	4.94	6.80	8.79**
	(0.09)	(0.16)	(0.16)	(5.28)	(5.25)	(4.25)
Observations	924	5,649	8,961	924	5,649	8,961
Number of Decision Makers	192	192	192	192	192	192

Notes: The table reports results from random-effects regressions using data across all treatments in match 6-10. Columns (1)-(3) show how the cooperation responds to the treatments. The dependent variable is 1 if subjects chose "Y"(cooperation) in stage 1, and 0 otherwise. Columns (4)-(6) show how the spending responds to the treatments. The dependent variable is subjects' spending in stage 2. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

One interesting observation from Figure 6 is that the cooperation in round 1 was increasing across matches but cooperation across all rounds was decreasing across matches. For example, the Individual $\epsilon = 0$ treatment started from 0.58 in match 1 and increased to 0.87 by match 10. Despite this increase, cooperation across all rounds actually dropped from 0.58 to 0.48. This indicates that cooperation break-down within a match is substantial. For a closer look, Figure 7 presents the evolution of cooperation and spending within a match. The figure shows a clear downward trend which we confirm with regression presented in Table 3. In particular, the coefficient on 'Round Number' is negative and highly significant (p-value < .01). We summarize these observations with the following result.

Result 3 *Cooperation breaks down across rounds.*

Figure 7: Cooperation and Competition Within a Match



Notes: The figure indicates the average cooperation rate in round 1 and all rounds for match 5-10 only. In each panel, a blue color indicates the Group treatment while a red color indicates the Individual treatment. A solid line with filled markers indicates the treatment without incumbency $\epsilon = 0$. A dashed line with empty markers indicates the treatment with incumbency $\epsilon = 1$.

6 Conclusion

In this paper, we investigate the role of the incumbency advantage in driving the breakdown of cooperation between political factions. Our approach is threefold. First, we develop the theory based on the myopic best response. Second, we run agent-based simulations using the recent model of individual evolutionary learning proposed by Arifovic and Ledyard (2012). Finally, we run controlled economics experiments. Across all three approaches we show that cooperation in the collective action is lower if the incumbency advantage in the political contest is high.

In addition to the incumbency advantage, we investigate the difference between individuals and groups. In particular, we contribute to the existing literature by proposing an extension to the individual evolutionary learning of Arifovic and Ledyard (2011, 2012) to model the group decision-making process. The computational and experimental results show that without the incumbency advantage, groups are less cooperative than individuals. However, in the environment with the incumbency advantage, cooperation for both individuals and groups breaks down to zero thus leading to no difference.

Our work is not without limitations and as such opens many exciting avenues for future research. First, we consider one specific setting for the comparison between individuals and groups.

Investigating whether the proposed model of group decision-making can reconcile some of the conflicting results in the literature (e.g., more cooperation in the prisoners' dilemma, less cooperation in the trust game) would be an important next step. Second, our results highlight that inequality in power over the division of surplus, such as those generated during elections, are important determinants of subsequent cooperation.[22] Furthermore, the incumbency advantage only amplifies this inequality and leads to a dramatic breakdown in cooperation. Future research could investigate mechanisms and institutions that could mitigate the detrimental effect of inequality. Finally, although in our environment players could communicate within groups, they could not communicate across groups. Understanding the extent to which communication across groups (as is the case with political negotiations) could improve cooperation is important.

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[22]Other studies that focus on cooperation and inequality include Camera, Deck, and Porter (2020) and Camera, Hohl, and Weder (2022). In particular, Camera, Hohl, and Weder (2022) shows that inequalities of potential payoffs don't seem to affect behaviors, but the realized unequal welfare distribution seems to undermine greater cooperation benefits.

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Appendix A Additional details on theoretical predictions

In Appendix A.1-Appendix A.3, we build a general theory for $\varepsilon \in [0,1)$. For the sake of simplicity, we assume $f_{i,t+1} = 1/n$ in formula (3) if $e_t \cdot (1-\varepsilon+\varepsilon f_t) = 0$.[23] In Appendix A.4, we discuss the special case of $\varepsilon = 1$.

Appendix A.1 Proof of Proposition 1

Here we will prove an extended version of Proposition 1.

Proposition 1 (an extended version). *Existence of myopic-best-response equilibria.*

- *A symmetric myopic-best-response equilibrium is characterized by at most two types of players: defectors and cooperators. All* $n_C \in \{0,1,..,n\}\backslash\{1\}$ *cooperators (if they exist) have the same power* $\hat{f}_C = 1/n_C$ *and spend the same non-zero expenditure* $e^*_C = \delta\left(1-\frac{1}{n_C}\right)\frac{F(n_C/n)}{n_C}$*; and all* $n-n_C$ *defectors (if they exist) have the same power* $\hat{f}_D = 0$ *and the same expenditure* $e^*_D = 0$.
- *With* $\varepsilon \in (0,1)$ *and* $n \geq 3$*, an asymmetric myopic-best-response equilibrium is characterized by at most three types of players: defectors (if they exist) and two types of cooperators. All* $n_{C1} \in \{1,..,n-1\}$ *cooperators of the first type have the same power* $\hat{f}_{C1} = \frac{\varepsilon-(2\varepsilon-1)n_{C2}}{\varepsilon(n_{C1}-n_{C2})}$ *and spend the same non-zero expenditure* $e^*_{C1} = \frac{\delta F(n_{C1}+n_{C2}/n)}{\varepsilon(n_{C1}-n_{C2})^2}\big(\varepsilon(n_{C1}-1)-(1-\varepsilon)n_{C2}\big)\big(\varepsilon-(2\varepsilon-1)n_{C2}\big)$. *All* $n_{C2} \in \{1,..,n-1\}$ *cooperators of the second type (*$n_{C1} > n_{C2}$*, and* $n_{C1}+n_{C2} \leq n$*) have the same power* $\hat{f}_{C2} = \frac{-\varepsilon+(2\varepsilon-1)n_{C1}}{\varepsilon(n_{C1}-n_{C2})}$ *and spend the same non-zero expenditure* $e^*_{C2} = \frac{\delta F(n_{C1}+n_{C2}/n)}{\varepsilon(n_{C1}-n_{C2})^2}\big(-\varepsilon(n_{C2}-1)+(1-\varepsilon)n_{C1}\big)\big(-\varepsilon+(2\varepsilon-1)n_{C1}\big)$. *All* $n-n_{C1}-n_{C2}$ *defectors (if exist) have the same power* $\hat{f}_D = 0$ *and the same expenditure* $e^*_D = 0$.

Proof. Let $F_C(\bar{a}_{-i,t}) = F\left(\frac{1+(n-1)\bar{a}_{-i,t}}{n}\right)$ is the total production when player i cooperates and $\bar{a}_{-i,t}$ is the proportion of cooperators among other players. Let $E_i(a_i,e_i) = -e_i + \delta\pi^1_i\Big((a_i,a_{-i,t}),\phi\big((e_i,e_{-i,t-1}),f_t\big)\Big)$ be expected earnings of individual i. Recall that

$$\forall i \in I: \phi_i\big((e_i,e_{-i,t-1}),f_t\big) = \begin{cases} \frac{e_i(1-\varepsilon+\varepsilon f_{i,t})}{e_i(1-\varepsilon+\varepsilon f_{i,t})+e_{-i,t-1}\cdot(1-\varepsilon+\varepsilon f_{-i,t})}, \text{ if } e_i+e_{-i,t-1}\cdot\mathbb{1}>0 \\ \frac{1}{n}, \text{ otherwise,} \end{cases} \tag{12}$$

$$\forall j \in I\backslash\{i\}: \phi_j\big((e_i,e_{-i,t-1}),f_t\big) = \begin{cases} \frac{e_{j,t-1}(1-\varepsilon+\varepsilon f_{i,t})}{e_i(1-\varepsilon+\varepsilon f_{i,t})+e_{-i,t-1}\cdot(1-\varepsilon+\varepsilon f_{-i,t})}, \text{ if } e_i+e_{-i,t-1}\cdot\mathbb{1}>0 \\ \frac{1}{n}, \text{ otherwise,} \end{cases} \tag{13}$$

To prove proposition 1, we need to consider the following lemmas:

Lemma 1 *Assume that* $a_{-i,t}\cdot e_{-i,t-1} = 0$ *and* $a_{-i,t} \neq 0$*. Then, player i to maximize her expected earnings* $E_i(a_i,e_i)$ *on the set* $\{0,1\}\times[0,\pi^1_i(a_t,f_t)]$,

- *is motivated to cooperate (i.e.,* $a_i = 1$*) and spend expenditure* $e_i = \Delta$*, where* $\Delta > 0$ *and* $\Delta \to 0$ *if* $c < F_C(\bar{a}_{-i,t})$,
- *chooses to defect with the zero expenditure, otherwise.*

[23] Although this assumption differs from what we used in the experiment setting (see footnote #9 in the main text), it does not affect our main equilibrium results, while simplifying all the proofs.

Proof. With $a_{-i,t} \cdot e_{-i,t-1} = 0$ and $a_{-i,t} \neq 0$, the expected earnings of individual i are

$$E_i(a_i, e_i) = \begin{cases} -e_i + \delta R_0, \text{ if } a_i = 0, \\ \delta\Big(R_0 - c + \frac{1}{1+a_{-i,t}\cdot\mathbb{1}} F_C(\bar{a}_{-i,t})\Big), \text{ if } a_i = 1, e_i = 0, \\ -e_i + \delta(R_0 - c + F_C(\bar{a}_{-i,t})), \text{ if } a_i = 1, e_i \neq 0. \end{cases}$$

Given the expected earnings, it is straightforward that $\text{argmax}_{e_i \in [0, \pi_i^1(a_t, f_t)]} E_i(0, e_i) = 0$ and $E_i(1, 0) < E_i(1, \Delta)$ if $\Delta \in \Big(0, \delta F_C(\bar{a}_{-i,t}) \frac{a_{-i,t}\cdot\mathbb{1}}{1+a_{-i,t}\cdot\mathbb{1}}\Big)$. With $F_C(\bar{a}_{-i,t}) \leq c$, one concludes that $\forall \Delta > 0 : E_i(0, 0) > E_i(1, \Delta)$. As a result,

$$\underset{a_i \in \{0,1\}, e_i \in [0, \pi_i^1(a_t, f_t)]}{\text{argmax}} E_i(a_i, e_i) = (0, 0).$$

With $F_C(\bar{a}_{-i,t}) > c$, one concludes that $E_i(0, 0) < E_i(1, \Delta)$ if $\Delta \in \Big(0, \delta(F_C(\bar{a}_{-i,t}) - c)\Big)$. As a result, an individual maximizing her expected earnings should choose among strategies $(1, \Delta)$, where

$$\Delta \in \Bigg(0, min\Big\{\delta F_C(\bar{a}_{-i,t}) \frac{a_{-i,t} \cdot \mathbb{1}}{1 + a_{-i,t} \cdot \mathbb{1}}, \delta(F_C(\bar{a}_{-i,t}) - c)\Big\}\Bigg).$$

Specifically, the individual should choose $\Delta > 0$ such that $\Delta \to 0$. The lemma is proved.

Lemma 2 *If $a_{-i,t} = 0$,*

$$(a_{i,t+1}, e_{i,t}) = BR_i^{a,e}(a_t, e_{t-1}, f_t) = \begin{cases} (1, 0), & \text{if } c \leq F_C(0), \\ (0, 0), & \text{otherwise.} \end{cases} \tag{14}$$

Proof. With $a_{-i,t} = 0$, $E_i(1, e_i) = -e_i + \delta(R_0 - c + F_C(0))$. Consequently, one concludes that

$$argmax_{e_i \in [0, \pi_i^1(a_t, f_t)]} E_i(1, e_i) = 0.$$

Moreover, $\text{argmax}_{e_i \in [0, \pi_i^1(a_t, f_t)]} E_i(0, e_i) = 0$. Then, $BR^{a,e}(a_t, e_{t-1}, f_t) = 1$ if $E_i(1, 0) \geq E_i(0, 0)$ and $BR^{a,e}(a_t, e_{t-1}, f_t) = 0$, otherwise, which is equivalent to the statement of the lemma.

Lemma 3 *Assume that $a_{-i,t} \cdot e_{-i,t-1} \neq 0$. Then,*

$$\pi_i^1\Big((a_i, a_{-i,t}), \phi\big((e_i, e_{-i,t-1}), f_t\big)\Big) = \begin{cases} R_0, & \text{if } a_i = 0, \\ R_0 - c + \frac{e_i(1-\varepsilon+\varepsilon f_{i,t})}{e_i(1-\varepsilon+\varepsilon f_{i,t}) + S_{-i,t}} F_C(\bar{a}_{-i,t}), & \text{otherwise,} \end{cases} \tag{15}$$

where $S_{-i,t} = \sum_{j \in I\backslash\{i\}} a_{j,t} e_{j,t-1}(1 - \varepsilon + \varepsilon f_{j,t})$.

Proof. The proof is straightforward. Since $a_{-i,t} \cdot e_{-i,t-1} \neq 0$, there exists individual $j \in I\backslash\{i\}$ such that $a_{j,t} \neq 0$ and $e_{-i,t-1} \neq 0$. As a result, $e_i + e_{-i,t-1} \cdot \mathbb{1} > 0$, and according to formula 13, $\phi_j\big((e_i, e_{-i,t-1}), f_t\big) \neq 0$. This means that $\pi_i^1\Big((a_i, a_{-i,t}), \phi\big((e_i, e_{-i,t-1}), f_t\big)\Big)$ is defined by formula 2 in the main text. Combining together formulas 12, 13, and 2, we get 15. The lemma is proved.

Lemma 4 *Let $\sqrt{\delta F_C(\bar{a}_{-i,t})(1 - \varepsilon + \varepsilon f_{i,t}) S_{-i,t}} - S_{-i,t} \leq \pi_i^1(a_t, f_t)(1 - \varepsilon + \varepsilon f_{i,t})$, and $a_{-i,t} \cdot e_{-i,t-1} \neq 0$. Then,*

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

$$= \begin{cases} \left(1, \frac{1}{1-\varepsilon+\varepsilon f_{i,t}}\left(\sqrt{\delta F_C(\bar{a}_{-i,t})(1-\varepsilon+\varepsilon f_{i,t})S_{-i,t}} - S_{-i,t}\right)\right), & \textit{if } \sqrt{S_{-i,t}} < \sqrt{\delta(1-\varepsilon+\varepsilon f_{i,t})}(\sqrt{F_C(\bar{a}_{-i,t})} - \sqrt{c}), \\ (0,0), & \textit{otherwise.} \end{cases} \tag{16}$$

Proof. First, note that $\operatorname{argmax}_{e_i \in [0, \pi_i^1(a_t, f_t)]} E_i(0, e_i) = 0$, and according to formula 15

$$\operatorname*{argmax}_{e_i \in [0, \pi_i^1(a_t, f_t)]} E_i(1, e_i) =$$

$$\begin{cases} \frac{1}{1-\varepsilon+\varepsilon f_{i,t}}\left(\sqrt{\delta F_C(\bar{a}_{-i,t})(1-\varepsilon+\varepsilon f_{i,t})S_{-i,t}} - S_{-i,t}\right), & \text{if } S_{-i,t} < \delta F_C(\bar{a}_{-i,t})(1-\varepsilon+\varepsilon f_{i,t}), \\ 0, \text{otherwise.} \end{cases}$$

Since $E_i(0,0) > E_i(1,0)$, one concludes that $BR_i^{a,e}(a_t, e_{t-1}, f_t) = (1, e_i^{\#})$ if $S_{-i,t} < \delta F_C(\bar{a}_{-i,t})(1-\varepsilon+\varepsilon f_{i,t})$ and $E_i(0,0) \le E_i(1, e_i^{\#})$, where $e_i^{\#} = \frac{1}{1-\varepsilon+\varepsilon f_{i,t}}\left(\sqrt{\delta F_C(\bar{a}_{-i,t})(1-\varepsilon+\varepsilon f_{i,t})S_{-i,t}} - S_{-i,t}\right)$. Otherwise, $BR_i^{a,e}(a_t, e_{t-1}, f_t) = (0,0)$. A straightforward algebraic manipulations show that this is equivalent to the statement of the lemma.

Now we can prove proposition 1. Consider an equilibrium with $n_C \in \{0, 1, .., n\}$ cooperators, and $n - n_C$ defectors. Assume that $n_C < n$, then, as follows from Lemmas 1-3, each defector has an effort $e_D^* = 0$.

Assume that $n_C = 1$. Let player i is the cooperator. Then, $a_{-i}^* = 0$, and according to Lemma 2, $e_i^* = 0$, and $F_C(\bar{a}_{-i,t}) = F_C(0) = F(1/n) \ge c$. Then, consider a defector $j \in I \backslash \{i\}$. Note, that $a_{-j}^* \cdot e_{-j}^* = 0$ and $a_{-j}^* \ne 0$. As a result, according to Lemma 1, j is motivated to defect if $c \ge F_C(\bar{a}_{-j,t}) = F_C(1/n) = F(2/n)$, which leads to a contradiction $c \le F(1/n) < F(2/n) \le c$ since F is a monotonically increasing function on $(0, +\infty)$. Consequently, a state with $n_C^* = 1$ cooperator is not an equilibrium in the model.

Assume that $n_C > 1$. Let i is a cooperator. Then, (1) $a_{-i}^* e_{-i}^* \ne 0$, and (2) $\sqrt{\delta F_C(\bar{a}_{-i}^*)(1-\varepsilon+\varepsilon\hat{f}_i)S_{-i}^*} - S_{-i}^* \le \pi_i^1(a^*, \hat{f})(1-\varepsilon+\varepsilon\hat{f}_i)$. First, we prove statement (1). Indeed, assume that $a_{-i}^* e_{-i}^* = 0$. Since $n_C > 1$, one concludes that $a_{-i}^* \ne 0$, i.e. there exists $j \in I \backslash \{i\}$ with $a_j^* = 1$. Moreover, since $a_j^* e_j^* = 0$ by the assumption, it follows that $e_j^* = 0$. Furthermore, according to Lemma 1, i is motivated to make an infinitely small but non-zero effort, which implies $a_{-j}^* \cdot e_{-j}^* \ne 0$. Consequently, we can apply Lemma 4 to individual j which implies that $(a_j^*, e_j^*) = (1, 0)$ cannot be the best response choice of j which is a contradiction.

Second, we prove statement (2). Indeed, assume that $\sqrt{\delta F_C(\bar{a}_{-i}^*)(1-\varepsilon+\varepsilon\hat{f}_i)S_{-i}^*} - S_{-i}^* \le \pi_i^1(a^*, \hat{f})(1 - \varepsilon + \varepsilon\hat{f}_i)$. Then, $e_i^* = \pi_i^1(a^*, \hat{f})$. As a result, $E_i(1, e_i^*) = (\delta - 1)\pi_i^1(a^*, \hat{f}) < 0 < \delta R_0 = E(0,0)$, which is a contradiction.

As a result of (1) and (2), we can apply Lemma 4 to two cooperators, i and j. Specifically, it means that $e_i^*, e_j^*, \hat{f}_i, \hat{f}_j, S_{-i}^*, S_{-j}^* > 0$ and

$$\sqrt{\delta F(n_C/n)} = \frac{S_{-i}^* + e_i^*(1-\varepsilon+\varepsilon\hat{f}_i)}{\sqrt{S_{-i}^*(1-\varepsilon+\varepsilon\hat{f}_i)}} = \frac{S_{-j}^* + e_j^*(1-\varepsilon+\varepsilon\hat{f}_j)}{\sqrt{S_{-j}^*(1-\varepsilon+\varepsilon\hat{f}_j)}}. \tag{17}$$

From equation 7 and since for each defector k, $\hat{f}_k = 0$, one shows that

$$\hat{f}_i = \frac{e_i^*(1-\varepsilon+\varepsilon\hat{f}_i)}{e_i^*(1-\varepsilon+\varepsilon\hat{f}_i) + S_{-i}^*} \Rightarrow S_{-i}^* = \frac{e_i^*(1-\varepsilon+\varepsilon\hat{f}_i)(1-\hat{f}_i)}{\hat{f}_i}. \tag{18}$$

Plugging equation 18 into 17 one concludes that

$$\delta F(n_C/n) = \frac{e_i^*}{\hat{f}_i(1-\hat{f}_i)} = \frac{e_j^*}{\hat{f}_j(1-\hat{f}_j)} \Rightarrow \frac{e_i^*\hat{f}_j}{e_j^*\hat{f}_i} = \frac{1-\hat{f}_i}{1-\hat{f}_j}. \tag{19}$$

As follows from equation 7,

$$\frac{\hat{f}_i}{\hat{f}_j} = \frac{e_i^*(1-\varepsilon+\varepsilon\hat{f}_i)}{e_j^*(1-\varepsilon+\varepsilon\hat{f}_j)} \Rightarrow \frac{e_i^*\hat{f}_j}{e_j^*\hat{f}_i} = \frac{1-\varepsilon+\varepsilon\hat{f}_j}{1-\varepsilon+\varepsilon\hat{f}_i}. \tag{20}$$

Combining equations 19 and 20, one observes:

$$\frac{1-\hat{f}_i}{1-\hat{f}_j} = \frac{1-\varepsilon+\varepsilon\hat{f}_j}{1-\varepsilon+\varepsilon\hat{f}_i} \Rightarrow (\hat{f}_i-\hat{f}_j)[\varepsilon(\hat{f}_i+\hat{f}_j)+1-2\varepsilon] = 0, \tag{21}$$

which means that either $\hat{f}_i = \hat{f}_j$ or $\hat{f}_i + \hat{f}_j = 2 - 1/\varepsilon$. Now we can show that there are no more than two distinct types of cooperators at an equilibrium. To do this, assume that there are three cooperators i, j, k with different powers $\hat{f}_i, \hat{f}_j, \hat{f}_k$ ($\hat{f}_i \neq \hat{f}_j$, $\hat{f}_i \neq \hat{f}_k$, and $\hat{f}_j \neq \hat{f}_k$). Then, $2 - 1/\varepsilon - \hat{f}_i = \hat{f}_j = \hat{f}_k$, which is a contradiction. As a result, either all cooperators have the same power $\hat{f}_C = 1/n_C$ or there are two types of cooperators with non-zero powers $\hat{f}_{C1}$ and $\hat{f}_{C2}$ such that $\hat{f}_{C1} \neq \hat{f}_{C2}$ and $\hat{f}_{C1} + \hat{f}_{C2} = 2 - 1/\varepsilon$.

To finish the proof, we need to calculate the characteristics of equilibria. As follows from formula 19,

$$e_C^* = \delta\Big(1 - \frac{1}{n_C^*}\Big)\frac{F(n_C^*/n)}{n_C^*} \tag{22}$$

in a symmetric equilibrium with $n_C > 1$ cooperators. For each asymmetric equilibrium, we have:

$$\begin{cases} \hat{f}_{C1} + \hat{f}_{C2} = 2 - 1/\varepsilon, \\ n_{C1}\hat{f}_{C1} + n_{C2}\hat{f}_{C2} = 1. \end{cases}$$

Solving the above system, one ends up with the corresponding formulas for $\hat{f}_{C1}$ and $\hat{f}_{C2}$. Applying formula 19, one also observes the corresponding formulas for e_{C1}^* and e_{C2}^*. The proposition is proved.

Appendix A.2 Results on the existence of equilibria

Proposition 3 ***Existence of symmetric equilibria.***

- *The symmetric equilibrium with all defectors exists if* $F(1/n) < c$.
- *The symmetric equilibrium with all cooperators exists if* $\frac{F(1)}{n} \geq cn$.
- *A symmetric equilibrium with* $n_C \in I\backslash\{0, 1, n\}$ *cooperators exists if two conditions hold:*

$$\frac{F(n_C/n)}{n_C} \geq cn_C, \text{ and} \tag{23}$$

$$\frac{\varepsilon}{1-\varepsilon} > \begin{cases} \frac{\delta}{e_C^*}\left(\sqrt{F(n_C+1/n)} - \sqrt{c}\right)^2 - n_C, & \text{if } F(n_C+1/n) < \frac{1}{c}\Big(c + \frac{R_0}{\delta}\Big)^2, \\ \frac{R_0}{e_C^*}\Big(\frac{F(n_C+1/n)}{c+R0/\delta} - 1\Big) - n_C, & \text{otherwise.} \end{cases} \tag{24}$$

Proof. Consider a state with $n_C \in I\backslash\{1\}$ cooperators and $n - n_C$ defectors such that each defector has zero power and spend the zero expenditure, while each cooperator has power $1/n_C$ and spend expenditure e_C^* defined by formula 22. Overall, to check existence, we need to check condition 6 in Definition 1 (note that condition 7 is automatically satisfied for the above state). Namely, for each defector (if exists), we should check that $(0,0)$ is the best response strategy to the strategies of others for given powers of all players. Likewise, for each cooperator (if exists) we should check that $(1, e_C^*)$ is the best rsponse strategy to the strategies of others for given powers of all players.

- Let $n_C = 0$. Then, according to Lemma 2, for each defector i: $(0,0) = BR_i^{a,e}(a^*, e^*, \hat{f})$ if $c > F(1/n)$.
- Let $n_C = n$. Then, according to Lemma 4, for each cooperator i: $(1, e_C^*) = BR_i^{a,e}(a^*, e^*, \hat{f})$ if

$$\sqrt{S_{-i}^*} \leq \sqrt{\delta(1-\varepsilon+\varepsilon\hat{f}_i)}(\sqrt{F_C(\bar{a}_{-i}^*)} - \sqrt{c}),$$

  which transforms to $\sqrt{(n-1)e_C^*(1-\varepsilon+\varepsilon/n)} \leq \sqrt{\delta(1-\varepsilon+\varepsilon/n)}(\sqrt{F(1)} - \sqrt{c})$, which, in turn, is equivalent to $\frac{F(1)}{n} \geq cn$.
- Let $n_C \in I\backslash\{0,1,n\}$. Then, according to Lemma 4, for each cooperator we should have

$$\sqrt{(n_C-1)e_C^*(1-\varepsilon+\varepsilon/n_C)} \leq \sqrt{\delta(1-\varepsilon+\varepsilon/n_C)}(\sqrt{F(n_C/n)} - \sqrt{c}),$$

  which transforms to $\frac{F(n_C/n)}{n_C} \geq cn_C$. To check whether a defector is not motivated to cooperate, we should take into account the fact that their expenditures cannot exceed their current payoff R_0. As a result, Lemma 4 cannot be employed. Instead, we should explicitly consider their expected earnings E and show

$$\forall e \in [0, R_0] : E(1,e) \leq E(0,0) \Leftrightarrow$$

$$\Leftrightarrow \forall e \in [0, R_0] : -e + \delta\left(R_0 - c + \frac{e(1-\varepsilon)}{e(1-\varepsilon) + e_C^*[(1-\varepsilon)n_C + \varepsilon]} \cdot F(n_C + 1/n)\right) \leq \delta R_0 \Leftrightarrow$$

$$\Leftrightarrow \forall e \in [0, R_0] : L(e) = e^2 + (B + D - A)e + BD \geq 0,$$

  where $A = \delta F(n_C + 1/n)$, $B = e_C^*[(1-\varepsilon)n_C + \varepsilon]$, and $D = \delta c$. Let us consider the opposite expression: we need to find parameter values such that

$$\exists e \in [0, R_0] : L(e) < 0.$$

  Since $L(0) = BD > 0$ and $\forall e : L''(e) > 0$, the above condition is equivalent to the system of 3 conditions:

$$\begin{cases} x > 0 \text{ (i.e., } L'(0) < 0 \Rightarrow \text{all roots of } L(e) = 0 \text{ (if exist) are positive)}, \\ x^2 - 4BD \geq 0 \text{ (i.e., } L(e) = 0 \text{ has real roots)}, \\ 2R_0 \geq x - \sqrt{x^2 - 4BD} \text{ (i.e., the smallest root is less than or equal to } R_0), \end{cases}$$

  where $x = A - B - D$. The above system of inequalities transforms to

$$\begin{cases} x \geq 2\sqrt{BD}, \text{ if } R_0 \geq \sqrt{BD}, \\ x \geq \frac{BD}{R_0} + R_0, \text{ otherwise.} \end{cases}$$

Substituting the expression for x, we obtain

$$\begin{cases} B \leq \left(\sqrt{A} - \sqrt{D}\right)^2, \text{ if } A < \frac{(D+R_0)^2}{D}, \\ B \leq \frac{(A-D-R_0)R_0}{D+R_0}, \text{ otherwise }. \end{cases}$$

Taking the opposite expression and plugging in the expressions for A, B, and D, we obtain the required condition 24. The proposition is proved.

Note that in an equilibrium with $1 < n_C < n$ cooperators, the decisions of at least one agent (defector) in stage 1 are actually constrained by their current payoff only if $F(n_C + 1) > \frac{1}{c}\left(c + \frac{R_0}{\delta}\right)$ (see condition 24), which implies

$$b > c + R_0\left(2 + \frac{R_0}{c}\right).$$

Intuitively, this means that incentives of a defector to cooperate are actually limited by their current payoff (i.e., R_0) if the maximum benefit to cooperation is very high relative to the endowment (or alternatively, the endowment is very small compared to the maximum benefit to cooperation).

Proposition 4 ***Existence of asymmetric equilibria.*** *An asymmetric equilibrium with $n_C \in \{3, .., n\}$ cooperators such that $n_{C1} > 0$ of them are of the first type, and $n_{C2} > 0$ of them are of the second type ($n_{C1} + n_{C2} = n_C$, $n_{C1} < n_{C2}$) exists if*

- $$k \leq \frac{1}{n_C} \text{ and } \varepsilon \in \left[\frac{1}{2 - k + \frac{kn_{C2}-1}{n_{C1}}}, \frac{n_C}{2(n_C - 1)}\right) \cup \left(\frac{n_C}{2(n_C - 1)}, \frac{1}{2 - k + \frac{kn_{C1}-1}{n_{C2}}}\right], \tag{25}$$

  where $k = \sqrt{\frac{c}{F(n_C/n)}}$, and

- $$\frac{\varepsilon}{1-\varepsilon}\hat{f}_{C1}\hat{f}_{C2} > \begin{cases} \frac{\left(\sqrt{F(n_C+1/n)}-\sqrt{c}\right)^2}{F(n_C/n)} - 1, \text{ if } F(n_C + 1/n) < \frac{1}{c}\left(c + \frac{R_0}{\delta}\right)^2, \\ \frac{R_0}{\delta F(n_C/n)}\left(\frac{F(n_C+1/n)}{c+R0/\delta} - 1\right) - 1, \text{ otherwise.} \end{cases} \tag{26}$$

Proof.

- First, we need to ensure that $\hat{f}_{C1}, \hat{f}_{C2} \geq 0$ and $\hat{f}_{C1} \neq \hat{f}_{C2}$, which (According to Proposition 1) implies

  $$\varepsilon \in \left[\frac{n_{C1}}{2n_{C1} - 1}, \frac{n_C}{2(n_C - 1)}\right) \cup \left(\frac{n_C}{2(n_C - 1)}, \frac{n_{C2}}{2n_{C2} - 1}\right]. \tag{27}$$

- For each cooperator i of the first type, we should check that $(1, e^*_{C1})$ is the best response strategy to the strategies of others for given powers of all players. Then, according to Lemma 4,

  $$\sqrt{S^*_{-i}} \leq \sqrt{\delta(1 - \varepsilon + \varepsilon\hat{f}_{C1})}\left(\sqrt{F(n_C/n)} - \sqrt{c}\right),$$

  which (employing equation 18) is equivalent to

  $$\sqrt{\frac{e^*_i(1 - \hat{f}_{C1})}{\hat{f}_{C1}}} \leq \sqrt{\delta}\left(\sqrt{F(n_C/n)} - \sqrt{c}\right).$$

According to equation 19, the above inequality can be transformed to

$$\hat{f}_{C1} \geq k.$$

- Likewise, for each cooperator of the second type, we should check that $(1, e^*_{C2})$ is the best response strategy to the strategies of others for given powers of all players, which is equivalent to $\hat{f}_{C2} \geq k$. Combining together conditions $\hat{f}_{C1}, \hat{f}_{C2} \geq k$ and condition 27, one obtains condition 25.
- Let $n_C < n$. Then, there exists defector d. To check whether the defector is not motivated to cooperate, we should take into account the fact that their expenditures cannot exceed their current payoff R_0. As a result, Lemma 4 cannot be employed. Instead, we should explicitly consider their expected earnings E and show

$$\forall e \in [0, R_0] : E(1, e) \leq E(0, 0) \Leftrightarrow$$

$$\Leftrightarrow \forall e \in [0, R_0] : -e + \delta\left(R_0 - c + \frac{e(1-\varepsilon)}{e(1-\varepsilon) + S_{-d}} \cdot F(n_C + 1/n)\right) \leq \delta R_0.$$

Following the arguments used to prove Proposition 3, we show that the above condition is equivalent to

$$\frac{S_{-d}}{1-\varepsilon} > \begin{cases} \delta\left(\sqrt{F(n_C+1/n)} - \sqrt{c}\right)^2, \text{ if } F(n_C+1/n) < \frac{1}{c}\left(c + \frac{R_0}{\delta}\right)^2, \\ R_0\left(\frac{F(n_C+1)}{c + R_0/\delta} - 1\right) \text{ otherwise }. \end{cases} \tag{28}$$

Sequentially employing conditions 18, 19, and the fact that $(1 - \hat{f}_{C1})(1 - \varepsilon + \varepsilon \hat{f}_{C1}) = 1 - \varepsilon + \varepsilon \hat{f}_{C1}(2 - 1/\varepsilon - \hat{f}_{C1}) = 1 - \varepsilon + \varepsilon \hat{f}_{C1}\hat{f}_{C2}$, we get

$$S_{-d} = \frac{e^*_{C1}(1 - \varepsilon + \varepsilon \hat{f}_{C1})}{\hat{f}_{C1}} = \delta F(n_C/n)(1 - \hat{f}_{C1})(1 - \varepsilon + \varepsilon \hat{f}_{C1}) = \delta F(n_C/n)(1 - \varepsilon + \varepsilon \hat{f}_{C1}\hat{f}_{C2}).$$

Plugging in the above expression for S_{-d} to condition 28, we obtain condition 26. The proposition is proved.

Appendix A.3 Proof of Proposition 2

Here we will prove an extended version of Proposition 2.

Proposition 2 (an extended version). *Stability of symmetric myopic-best-response equilibria. The symmetric equilibrium with $n_C = 0$ cooperators is stable. Consider a symmetric myopic-best-response equilibrium with $n_C \in \{2, .., n\}$ cooperators.*

- *If $\varepsilon < \frac{n_C}{2(n_C-1)}$ and $n_C \leq 3$, the equilibrium is stable to small perturbations in expenditures and powers.*
- *if $\varepsilon > \frac{n_C}{2(n_C-1)}$ or $n_C \geq 5$, the equilibrium is unstable.* [24]

Proof. First, note that the stability of the symmetric equilibrium with $n_C \geq 2$ cooperators among n players is equivalent to the stability of the symmetric equilibrium with n_C cooperators among n_C players $I_C = \{1, .., n_C\}$. Second, note that without loss of generality we can postulate

$$\psi_i(e_{t-1}, f_t) = \frac{1}{1 - \varepsilon + \varepsilon f_{i,t}}\left(\sqrt{\delta F_C(\bar{a}_{-i,t})(1 - \varepsilon + \varepsilon f_{i,t})S_{-i,t}} - S_{-i,t}\right), \forall i \in I_C,$$

[24] **Remark 1.** *Numerical simulations show that with $n_C = 4$, the equilibrium is stable if $\varepsilon < 2/3$ and unstable if $\varepsilon > 2/3$.*

where $S_{-i,t} = \sum_{j \in I_C \setminus \{i\}} e_{j,t-1}(1-\varepsilon+\varepsilon f_{j,t})$. Let $\forall i \in I_C$: $\Psi_i(e_{t-1}, \tilde{f}_t) = \psi_i\big(e_{t-1}, (f_{1,t}, .., f_{n_C-1,t}, 1 - f_{1,t} - ... - f_{n_C-1,t})\big)$, and $\Phi_i(e_t, \tilde{f}_t) = \phi_i\big(e_t, (f_{1,t}, .., f_{n_C-1,t}, 1 - f_{1,t} - ... - f_{n_C-1,t})\big)$, where $\tilde{f}_t = (f_{1,t}, .., f_{n_C-1,t})$. Then, instead of the system 8-9, we can check stability of the system

$$e_{i,t} = \Psi_i(e_{t-1}, \tilde{f}_t), \forall i \in I_C, \tag{29}$$

$$f_{i,t+1} = \Phi_i(e_t, \tilde{f}_t), \forall i \in I_C \setminus \{n_C\}, \tag{30}$$

which can be rewritten as an autonomous non-linear system of $2n_C - 1$ difference equations of the form

$$f_{i,t+1} = H_i(e_{t-1}, \tilde{f}_t), \forall i \in I_C \setminus \{n_C\}, \tag{31}$$

$$e_{i,t} = \Psi_i(e_{t-1}, \tilde{f}_t), \forall i \in I_C, \tag{32}$$

where $\forall i \in I_C : H_i(e_{t-1}, \tilde{f}_t) = \Phi_i(\Psi(e_{t-1}, \tilde{f}_t), \tilde{f}_t)$, $\Psi(e_{t-1}, \tilde{f}_t) = (\Psi_1(e_{t-1}, \tilde{f}_t), .., \Psi_{n_C}(e_{t-1}, \tilde{f}_t))$. The Jacobian matrix of this system calculated at the equilibrium point is a block matrix of the form

$$J = \begin{pmatrix} \frac{\partial H}{\partial f} & \frac{\partial H}{\partial e} \\ \frac{\partial \Psi}{\partial f} & \frac{\partial \Psi}{\partial e} \end{pmatrix}, \tag{33}$$

where $\frac{\partial H}{\partial f}$ is $(n-1) \times (n-1)$ matrix with elements $\left(\frac{\partial H}{\partial f}\right)_{i,j} = \left(\frac{\partial H_i(e_{t-1}, \tilde{f}_t)}{\partial f_{j,t}}\right)\Big|_{(e^*, f^*)}$, $i, j \in I_c \setminus \{n_C\}$; $\frac{\partial H}{\partial e}$ is $(n-1) \times n$ matrix with elements $\left(\frac{\partial H_i(e_{t-1}, \tilde{f}_t)}{\partial e_{j,t-1}}\right)\Big|_{(e^*, f^*)}$, $i \in I_c \setminus \{n_C\}, j \in I_C$; $\frac{\partial \Psi}{\partial f}$ is $n \times (n-1)$ matrix with elements $\left(\frac{\partial \Psi_i(e_{t-1}, \tilde{f}_t)}{\partial f_{j,t}}\right)\Big|_{(e^*, f^*)}$, $i \in I_C$, $j \in I_c \setminus \{n_C\}$; and $\frac{\partial \Psi}{\partial e}$ is $n \times n$ matrix with elements $\left(\frac{\partial \Psi_i(e_{t-1}, \tilde{f}_t)}{\partial e_{j,t-1}}\right)\Big|_{(e^*, f^*)}$, $i, j \in I_c$, where $f^* = (\hat{f}_1, ..., \hat{f}_{n_C-1})$.

Let $\alpha = \frac{\varepsilon e^*_C n_C}{1-\varepsilon+\varepsilon/n_C}$, $\beta = -\frac{(n-2)}{2(n-1)}$, and $\gamma = \frac{1}{n_C^2 e^*_C}$. Then, straightforward calculations show that:

$$\left(\frac{\partial \Psi}{\partial f}\right)_{i,j} = \begin{cases} -\alpha\beta, & \text{if } i = j, \\ \alpha\beta, & \text{if } i = n_C, \\ 0, & \text{otherwise}, \end{cases}$$

$$\left(\frac{\partial \Psi}{\partial e}\right)_{i,j} = \begin{cases} 0, & \text{if } i = j, \\ \beta, & \text{otherwise}. \end{cases}$$

To derive $\left(\frac{\partial H}{\partial f}\right)_{i,j}$ and $\left(\frac{\partial H}{\partial e}\right)_{i,j}$, one should calculate some auxiliary derivatives:

$$\left(\frac{\partial \Phi}{\partial \Psi}\right)_{i,j} = \left(\frac{\partial \Phi_i(e_t, \tilde{f}_t)}{\partial e_t}\right)\Big|_{(e^*, f^*)} = \begin{cases} (n_C - 1)\gamma, & \text{if } i = j, \\ -\gamma, & \text{otherwise}, \end{cases}$$

$$\left(\frac{\partial \Phi}{\partial f}\right)_{i,j} = \left(\frac{\partial \Phi_i(e_t, \tilde{f}_t)}{\partial f_t}\right)\Big|_{(e^*, f^*)} = \begin{cases} \alpha\gamma, & \text{if } i = j, \\ 0, & \text{otherwise}. \end{cases}$$

Then,

$$\left(\frac{\partial H}{\partial f}\right)_{i,i} = \underbrace{\left(\frac{\partial \Phi}{\partial f}\right)_{i,i}}_{=\alpha\gamma} + \underbrace{\left(\frac{\partial \Phi}{\partial \Psi}\right)_{i,i}}_{=(n_C-1)\gamma} \underbrace{\left(\frac{\partial \Psi}{\partial f}\right)_{i,i}}_{=-\alpha\beta} + \underbrace{\left(\frac{\partial \Phi}{\partial \Psi}\right)_{i,n_C}}_{=-\gamma} \underbrace{\left(\frac{\partial \Psi}{\partial f}\right)_{n_C,i}}_{=\alpha\beta} + \sum_{j=I_C\setminus\{i,n_C\}} \left(\frac{\partial \Phi}{\partial \Psi}\right)_{i,j} \underbrace{\left(\frac{\partial \Psi}{\partial f}\right)_{j,i}}_{=0} =$$

$$= \alpha\gamma(1 - n_C\beta), \forall i \in I_C\setminus\{n_C\}.$$

Similar algebraic manipulations allows to calculate all elements of matrices $\frac{\partial H}{\partial f}$ and $\frac{\partial H}{\partial e}$, so that:

$$\left(\frac{\partial H}{\partial f}\right)_{i,j} = \begin{cases} \alpha\gamma(1 - n_C\beta), \text{ if } i = j, \\ 0, \text{ otherwise,} \end{cases}$$

$$\left(\frac{\partial H}{\partial e}\right)_{i,j} = \begin{cases} -\beta\gamma(n_C - 1), \text{ if } i = j, \\ \beta\gamma, \text{ otherwise.} \end{cases}$$

To examine stability of the equilibrium, one should find eigenvalues of the Jacobian J, i.e., solve equation $det(J - \lambda I_{2n_C-1}) = 0$, where I_{2n_C-1} is $(2n_C - 1) \times (2n_C - 1)$ identity matrix. Given that J is a block matrix, and $\lambda \neq \alpha\gamma(1 - n_C\beta)$,

$$det(J - \lambda I_{2n_C-1}) = 0 \leftrightarrow det(\Omega) = 0, \tag{34}$$

where $\Omega = \left(\frac{\partial H}{\partial f} - \lambda I_{n_C-1}\right) - \frac{\partial H}{\partial e} \cdot \left(\frac{\partial \Psi}{\partial e} - \lambda I_{n_C}\right)^{-1} \cdot \frac{\partial \Psi}{\partial f}$. The elements $(\Omega)_{i,j}$ of matrix Ω are

$$(\Omega)_{i,j} = \begin{cases} -\alpha\beta^2\gamma\frac{(n_C-1)}{\alpha\gamma(1-n_C\beta)-\lambda} - \lambda, \text{ if } i = j, \\ \alpha\beta^2\gamma\frac{1}{\alpha\gamma(1-n_C\beta)-\lambda} + \beta, \text{ otherwise.} \end{cases}$$

According to Tverskoi, Senthilnathan, and Gavrilets (2021), the equation $det(\Omega) = 0$ is equivalent to either $\lambda = (n_C - 1)\beta = -\frac{n_C-2}{2}$ or $\lambda = -\beta - \alpha\beta^2\gamma\frac{n_C}{\alpha\gamma(1-n_C\beta)-\lambda}$. The latter one leads to the quadratic equation on λ:

$$\lambda^2 + (\beta + n_c\beta\alpha\gamma - \alpha\gamma)\lambda - \beta\alpha\gamma = 0. \tag{35}$$

As a result, the spectrum of the Jacobian consists of three elements: $\lambda_1 = -\frac{n_C-2}{2}$, λ_2, and λ_3, where λ_2 and λ_3 are the solutions to equation 35. To unsure stability, one can check that λ_1, λ_2, and λ_3 lie inside the unit disk. In particular, it means $n_C < 4$ and (Eladyi, 2000):

$$\begin{cases} 1 + (\beta + n_C\beta\alpha\gamma - \alpha\gamma) - \beta\alpha\gamma > 0, \\ 1 - (\beta + n_C\beta\alpha\gamma - \alpha\gamma) - \beta\alpha\gamma > 0, \\ 1 + \beta\alpha\gamma > 0, \end{cases}$$

which is equivalent to $\varepsilon < \frac{n_C}{2(n_C-1)}$. The proposition is proved.

Appendix A.4 The special case of $\varepsilon = 1$

With $\varepsilon = 1$, all previous results on the existence and stability of the above symmetric and asymmetric equilibria are valid. However, there is an additional family of asymmetric equilibria observed only for $\varepsilon = 1$.

Proposition 5. *With $\varepsilon = 1$, there is a family of asymmetric equilibria with 2 cooperators and $n - 2$*

defectors. All defectors (if they exist) have the same power $\hat{f}_D = 0$ *and the same expenditure* $e^*_D = 0$. *Cooperators have powers* $\hat{f}_C$ *and* $1 - \hat{f}_C$*, respectively, and the same expenditure* $e^*_C = \delta F(2/n)\hat{f}_C(1-\hat{f}_C)$*, where* $\hat{f}_C \neq 0.5$ *and* $\hat{f}_C \in \left[\sqrt{\frac{c}{F(2/n)}}, 1 - \sqrt{\frac{c}{F(2/n)}}\right]$*. These equilibria exist if* $c < \frac{F(2/n)}{4}$.

Proof. Following the arguments used to prove Proposition 1, it is straightforward to show that in an asymmetric equilibrium with two cooperators, all defectors (if they exist) have the same power $\hat{f}_D = 0$ and the same expenditure $e^*_D = 0$, while cooperators have powers $\hat{f}_C$ and $1 - \hat{f}_C$, respectively, and the same expenditure $e^*_C = \delta F(2/n)\hat{f}_C(1-\hat{f}_C)$, where $\hat{f}_C \in (0,1)$. To check the existence, we need to show that: (1) for each defector (if exists) $(0,0)$ is the best rsponse strategy to the strategies of others for given powers of all players; and (2) for the two cooperators, $(1, e^*_C)$ is the best rsponse strategy to the strategies of others for given powers of all players.

First, note that condition (1) is satisfied for all values of the model parameters (this can be verified using Lemma 3). To check condition (2), we employ Lemma 4. Namely, the following condition must be satisfied for cooperator i:

$$\sqrt{S^*_{-i}} < \sqrt{\delta \hat{f}_i}\left(\sqrt{F(2/n)} - \sqrt{c}\right),$$

which transforms to two conditions for cooperators 1 and 2 with powers $\hat{f}_C$ and $1 - \hat{f}_C$, respectively:

$$\sqrt{e^*_C(1-\hat{f}_C)} < \sqrt{\delta \hat{f}_C}\left(\sqrt{F(2/n)} - \sqrt{c}\right)$$

and

$$\sqrt{e^*_C \hat{f}_C} < \sqrt{\delta(1-\hat{f}_C)}\left(\sqrt{F(2/n)} - \sqrt{c}\right),$$

which yields

$$\hat{f}_C \in \left[\sqrt{\frac{c}{F(2/n)}}, 1 - \sqrt{\frac{c}{F(2/n)}}\right]$$

and

$$c < \frac{F(2/n)}{4}.$$

The proposition is proved. Note that together with the symmetric equilibrium with $n_C = 2$ cooperators, the above asymmetric equilibria constitute a family of equilibria with 2 cooperators that exist if $c < \frac{F(2/n)}{4}$.

Proposition 6. *An asymmetric equilibrium with* $n_C = 2$ *cooperators is unstable to small perturbations in expenditures and powers if* $\hat{f}_C \notin \left[\frac{1}{2} - \frac{1}{2\sqrt{2}}, \frac{1}{2} + \frac{1}{2\sqrt{2}}\right]$.

Proof. To check the stability of an asymmetric equilibrium, we follow the arguments used to prove Proposition 2. Specifically, we consider the system of 3 difference equations 29-30. The corresponding Jacobian is

$$J = \begin{pmatrix} 1 + 2A^2CD & BDA & BCA \\ -\frac{C}{B}A & 0 & CA \\ -\frac{D}{B}A & -DA & 0, \end{pmatrix} \tag{36}$$

where $A = \hat{f}_C - \frac{1}{2}$, $B = \frac{1}{\delta F(2/n)}$, $C = \frac{1}{\hat{f}_C}$, and $D = \frac{1}{1-\hat{f}_C}$. To examine stability of an asymmetric equilibrium, one should find eigenvalues of the Jacobian J, i.e., solve equation $det(J - \lambda I_3)$, where I_3 is 3×3 identity matrix. Given that $\lambda \neq 1 + 2A^2CD$,

$$det(J - \lambda I_3) = 0 \leftrightarrow 1 + 2A^2CD - \lambda - \begin{pmatrix} BDA & BCA \end{pmatrix} \cdot \begin{pmatrix} -\lambda & CA \\ -DA & -\lambda \end{pmatrix}^{-1} \cdot \begin{pmatrix} -\frac{C}{B}A \\ -\frac{D}{B}A \end{pmatrix} = 0. \tag{37}$$

The above expression can be simplified so we end up with the equation

$$\lambda^3 - (2k+1)\lambda^2 + 3k\lambda - k = 0, \tag{38}$$

where $k = A^2CD$. This equation is equivalent to

$$(\lambda - 1)(\lambda^2 - 2k\lambda + k) = 0.$$

At least one root of this equation is outside the unit disk if

$$k > 1,$$

which gives us the condition on $\hat{f}_C$:

$$\hat{f}_C \notin \left[\frac{1}{2} - \frac{1}{2\sqrt{2}}, \frac{1}{2} + \frac{1}{2\sqrt{2}}\right].$$

The proposition is proved.

Remark 2. Numerical simulations show that an asymmetric equilibrium with $n_C = 2$ cooperators is stable to small perturbations in expenditures and powers if $\hat{f}_C \in \left(\frac{1}{2} - \frac{1}{2\sqrt{2}}, \frac{1}{2} + \frac{1}{2\sqrt{2}}\right)$.

Appendix B Additional details on IEL application

In this Appendix, we provide more detailed information about the IEL. Specifically, we discuss how to calculate the forgone utilities in each stage.

In stage 1 of round t, agents know the stage choices of others in the previous round $(a_{-i,t-1}, e_{-i,t-1})$, the current power distribution f_t, and calculate the expected payoffs for each $r^{1,j}_{i,t-1} \in A^1_{i,t-1}$ as follows:

$$\mathbb{E}[\pi^{1,j}_{i,t-1}] = [r^{1,j}_{i,t-1}\pi^1(1, a_{-i,t-1}, f_t) + (1 - r^{1,j}_{i,t-1})\pi^1(0, a_{-i,t-1}, f_t)] - e_{i,t-1} \tag{39}$$

, where $e_{i,t-1}$ is agent i's stage 2 choice in the previous round. The forgone utility for each rule is:

$$v^{1,j}_{i,t} = \mathbb{E}[\pi^{1,j}_{i,t-1}] + \frac{\beta_i}{n}\sum_{k\in I}\mathbb{E}[\pi^{1,j}_{k,t-1}] - \frac{\gamma_i}{n-1}\sum_{k\neq i, k\in I} max\{0, \mathbb{E}[\pi^{1,j}_{k,t-1}] - \mathbb{E}[\pi^{1,j}_{i,t-1}]\} \tag{40}$$

In sage 2 of round t, agents have decided their stage 1 cooperation probability $r^1_{i,t}$, know others' stage 1 choice in round t $(a_{-i,t})$, and assume that others will spend the same amount $(e_{-i,t-1})$ in this round. To ensure that the round earning is non-negative, we time the spending with $\pi^{1,min}$ ($\pi^{1,min} = R_0 - c = 40$, the lowest possible stage 1 earning in our experiment). The spending rule $r^{2,j}_{i,t-1} \in A^2_{i,t-1}$ doesn't only change the earning in the current round t, but will also change the next round power distribution and the future earning. Thus, the expected payoff for each stage 2 rule is defined as:

$$\mathbb{E}[\pi^{2,j}_{i,t-1}] = -r^{2,j}_{i,t-1}\pi^{1,min} + \delta[r^1_{i,t}\pi^1(1, a_{-i,t}, f_{t+1}) + (1 - r^1_{i,t})\pi^1(0, a_{-i,t}, f_{t+1})] \tag{41}$$

where the next round power distribution becomes $f_{i,t+1}(r^{2,j}_{i,t-1}) = \frac{r^{2,j}_{i,t-1}\pi^{1,min}(1-\epsilon+\epsilon f_{i,t})}{e_{t-1}(1-\epsilon+\epsilon f_t)}$, and $e_{t-1} = (r^{2,j}_{i,t-1}\pi^{1,min}, e_{-i,t-1})$. The forgone utility for each rule is:

$$v^{2,j}_{i,t} = \mathbb{E}[\pi^{2,j}_{i,t-1}] + \frac{\beta_i}{n}\sum_{k\in I}\mathbb{E}[\pi^{2,j}_{k,t-1}] - \frac{\gamma_i}{n-1}\sum_{k\neq i, k\in I} max\{0, \mathbb{E}[\pi^{2,j}_{k,t-1}] - \mathbb{E}[\pi^{2,j}_{i,t-1}]\} \tag{42}$$

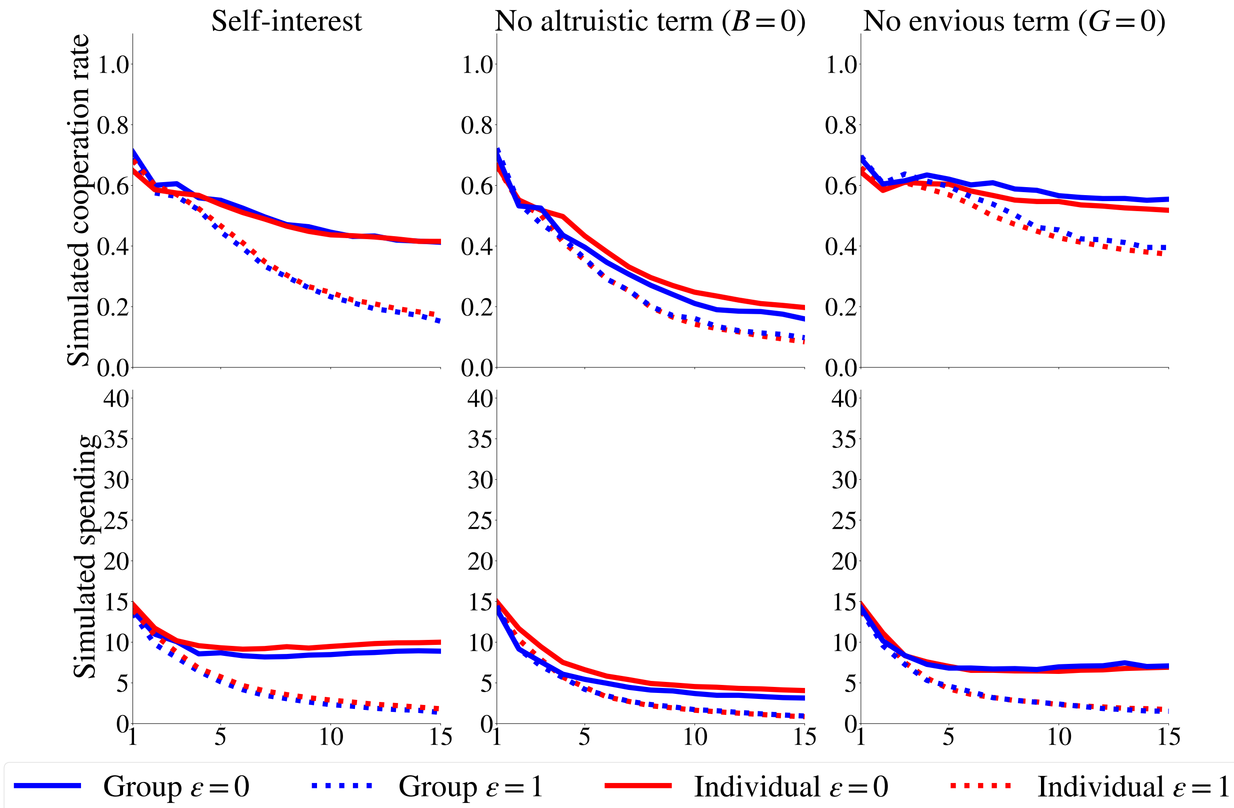
In round 1 stage 1, without the history of others' choices, each agent assumes that others will use the same rule as the one he considers and calculate the expected utilities accordingly.

Appendix C Robustness Checks for IEL Simulation

Appendix C.1 Varying Other-regarding Preferences

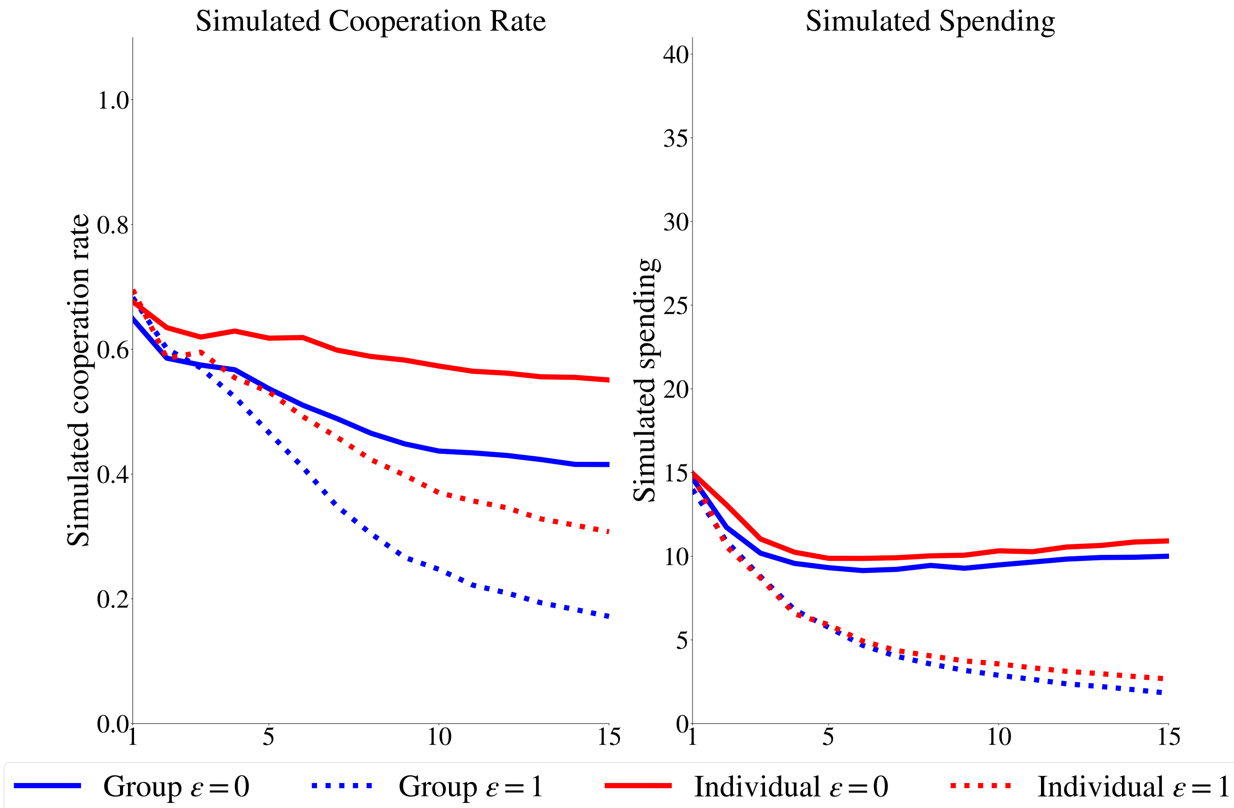
Other-regarding preferences seem to play an important role in driving the cooperation difference observed between individuals and groups when $\epsilon = 0$. In figure C-2, we present simulation results varying the other-regarding preferences. Each line represents the average simulated results of 200 independent trials of 15 rounds of play. We start by completely removing the other-regarding preferences and assuming that all agents only care about their individual expected payoffs. The results, as shown in the left column, suggest no difference in cooperation rate between individuals and groups when $\epsilon = 0$. This inconsistency confirms that other-regarding preferences drive the observed cooperation differences between groups and individuals. Next, we separately remove the altruistic term (second term in equation 10) and the envious term (second term in equation 10) to check which part of the other-regarding preference plays a larger role in driving the difference. In the middle column, when the other-regarding agents are only "envious", the simulated results consistently show that individuals are more cooperative than groups. In addition, the cooperation rate declines rapidly even in $\epsilon = 0$ case. In the right column, when the other-regarding agents are only "altruistic", the simulated results are no longer consistent with the laboratory findings since groups are simulated to be more cooperative than individuals. Combining these results, the envious term seems to be more important in driving the behavioral differences between groups and individuals. Previous studies about parochial altruism indicate that people are inclined to behave more aggressively against other groups (Bernhard, Fischbacher, and Fehr, 2006; Yamagishi and Mifune, 2016; Abbink, Brandts, Herrmann, and Orzen, 2010, 2012; Song and Houser, 2021; Eckel, Fatas, and Kass, 2022). It is thus possible that when subjects make decisions in groups, they end up incurring more disutility from earning less than other groups, which drives the groups to act less cooperatively than individuals.

Figure C-1: Simulated Results Vary Other-regarding Preference



Notes: Red lines indicate individual treatments ($K = 1$). Blue lines indicate group treatments ($K = 2$). Solid lines indicate no incumbency advantage ($\epsilon = 0$). Dashed lines indicate with incumbency advantage ($\epsilon = 1$). The top panels present the average simulated cooperation rate of 200 independent simulations. The bottom panels present the average simulated spending of 200 independent simulations. In the left column, agents are modeled as self-interested without other-regarding preferences. Their utility functions only contain the expected individual payoffs (the first component of equation 10). In the middle column, agents with other-regarding preferences are modeled as caring about their individual expected payoffs and incurring a disutility from being taken advantage of. In the simulation, $\beta_i = 0$ for all i, γ is uniformly and independently drawn from the range of [0,8]. In the right column, agents are modeled as caring about their individual expected payoffs and preferring higher payoffs to all agents. In the simulation, $\gamma_i = 0$ for all i, β is uniformly and independently drawn from the range of [0,22].

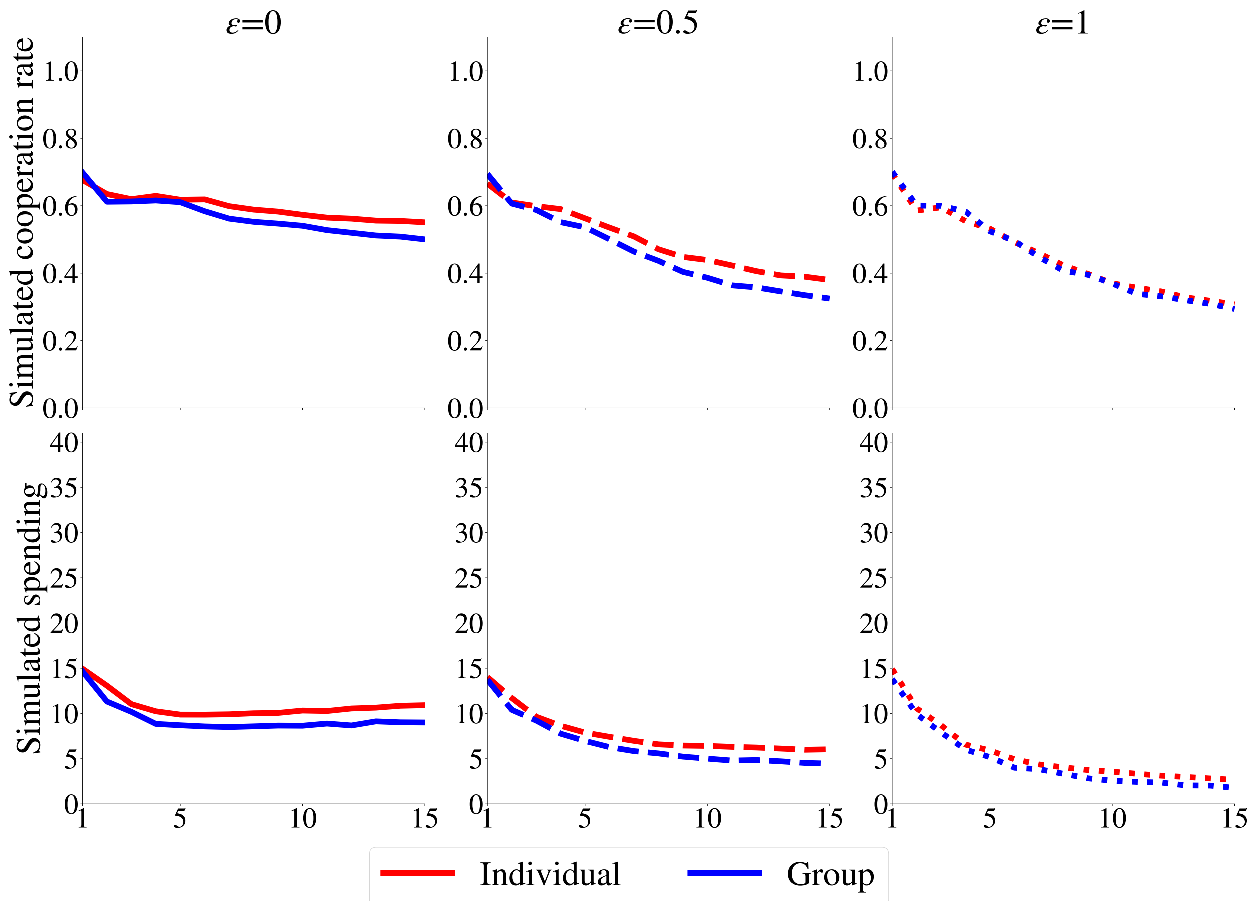
Figure C-2: Simulated Results Modeling Groups as Self-interested Agents



Notes: Red lines indicate individual treatments ($K = 1$). Blue lines indicate group treatments ($K = 2$). Solid lines indicate no incumbency advantage ($\epsilon = 0$). Dashed lines indicate with incumbency advantage ($\epsilon = 1$). The top panels present the average simulated cooperation rate of 200 independent simulations. The bottom panels present the average simulated spending of 200 independent simulations. In the left column, agents are modeled as self-interested without other-regarding preferences. Their utility functions only contain the expected individual payoffs (the first component of equation 10). In the middle column, agents with other-regarding preferences are modeled as caring about their individual expected payoffs and incurring a disutility from being taken advantage of. In the simulation, $\beta_i = 0$ for all i, γ is uniformly and independently drawn from the range of [0,8]. In the right column, agents are modeled as caring about their individual expected payoffs and preferring higher payoffs to all agents. In the simulation, $\gamma_i = 0$ for all i, β is uniformly and independently drawn from the range of [0,22].

Appendix C.2 Varying ϵ

Figure C-3: Simulated Results Vary Incumbency Parameter ϵ



Notes: Red lines indicate individual treatments ($K = 1$). Blue lines indicate group treatments ($K = 2$). Solid lines indicate no incumbency advantage ($\epsilon = 0$). Dashed lines indicate with incumbency advantage ($\epsilon = 1$). The top panels present the average simulated cooperation rate of 200 independent simulations. The bottom panels present the average simulated spending of 200 independent simulations.

Appendix D Additional Tables and Figures

Table D-1: Supergame Lengths

Supergame Number:	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**M10:**	**M20:**
Realization #0:	7	4	18	7	1	6	2	17	11	8	7	1	24	6	14	23	7	5	3	3	8.1	8.7
Realization #1:	11	4	13	11	4	17	10	10	9	5	2	4	7	11	18	6	3	8	11	6	9.4	8.5
Realization #2:	17	3	1	7	3	25	11	3	8	2	8	20	4	11	8	2	2	3	19	12	8.0	8.45
Realization #3:	1	6	5	1	15	3	14	2	12	19	3	9	1	21	7	4	8	3	16	2	7.8	7.6

Table D-2: Average Cooperation Rate across Treatments

	All Rounds			Round 1		
	all Match	Match 1-5	Match 6-10	all Match	Match 1-5	Match 6-10
GRP E0	43.5	49.5	37.1	74.4	70.8	78.1
	(2.69)	(3.63)	(3.87)	(2.03)	(2.87)	(2.83)
GRP E1	34.1	36.7	31.4	63.2	57.1	69.9
	(2.44)	(3.17)	(3.74)	(2.34)	(3.03)	(3.45)
IND E0	50.8	57.8	48.4	84.8	70.4	86.7
	(1.75)	(3.54)	(3.18)	(1.27)	(3.41)	(2.02)
IND E1	33.0	43.1	24.2	62.0	55.8	55.4
	(1.49)	(2.98)	(2.43)	(1.58)	(3.18)	(3.35)

Notes: "all Match" means match 1-20 for the Individual treatment and match 1-10 for the Group treatment. Standard errors (in parentheses) are calculated by taking one group in one match as a unit of observation.

Table D-3: Average Spending Proportion across Treatments

	All Rounds			Round 1		
	Match 1-5	Match 6-10	all Match	Match 1-5	Match 6-10	all Match
GRP E0	26.1	10.7	18.6	35.3	19.6	27.6
	(1.11)	(0.76)	(0.72)	(1.49)	(1.44)	(1.07)
IND E0	33.9	17.8	18.8	37.3	26.0	24.1
	(1.79)	(1.44)	(0.78)	(2.17)	(2.11)	(1.05)
GRP E1	26.8	10.7	19.1	38.5	25.8	32.5
	(1.21)	(0.74)	(0.77)	(1.55)	(1.28)	(1.04)
IND E1	42.5	18.2	21.0	51.3	31.5	31.0
	(1.98)	(1.58)	(0.91)	(2.29)	(2.27)	(1.17)

Notes: "all Match" means match 1-20 for the Individual treatment and match 1-10 for the Group treatment. Standard errors (in parentheses) are calculated by taking one group in one match as a unit of observation.

Appendix E Experimental Instructions (E1 Group)

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 E.1 Part 1

Part 1

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

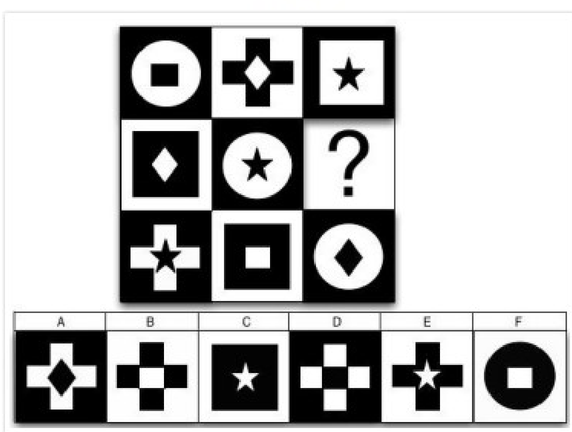
The top right-hand corner of the screen will display the time remaining.

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.

Appendix E.1.1 Task: ICAR Example

Sample item:



Appendix E.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 E.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 E.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 choose 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 E.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 E.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**	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 E.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 E.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 E.2.7 Team Decision

These two pages are specific to the group treatment.

Team's Decision (9/10)

You and your teammate will make decisions jointly. To facilitate this, there will be a chat box on your screen to send and receive messages between the two of you. You should use this chat box to discuss your strategy and come to an agreement regarding what choice to make.

To make a choice in stage 1, you and your teammate will need to click on the relevant button. Once you and your teammate have clicked on the same choice, it will become binding.

To make a choice in stage 2, you will need to enter a number into the entry box. Once you and your partner have entered the same choice, it will become binding.

Timing of Making a Decision (10/10)

At the beginning of each match you will have some time to discuss what to do and to coordinate your choices. In round 1 and round 2 of each match you will have up to 1 minute to make your choices. From round 3, you will have up to 40 seconds to do the same.

If you and your teammate have not coordinated your choices within the allocated time, then:

- if one of you has made a choice, then that will be your team's choice;
- if both of you made choices (but they do not match), then one will be picked at random to be your team's choice;
- if neither of you has made a choice, then your team's choice in the previous round will be your team's choice in the current round.

Please don't plan on using any of these options in making your choices as a round ends after all teams have made their choices, so these options are just designed to deal with "sleepy" teammates.

Note, in sending messages back and forth between you and your teammate, we request you follow two simple rules:

- Be civil to each other and do not use profanity.
- Do not identify yourself.

The chat box is intended for you to use to discuss and coordinate your choices and should be used that way.

Appendix E.3 Main Experiment

Appendix E.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 E.3.2 Prematch Chat

New Match

Time left: **4:57**

ID	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				
2	33					33	X Y				
3	33					33	X Y				

Dice Roll

You have up to 5 minutes to discuss with your teammate what to do during this match.

You can use this time to discuss your Stage 1 and Stage 2 decisions.

When you are ready, please click "Next".

Next

Send

Appendix E.3.3 Stage 1 Decision Page

Match #1

Time left: **0:53**

ID	Round 1 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				
2	33					33	X Y				
3	33					33	X Y				

Dice Roll

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

Your choice: X Y

Teammate's choice: X Y

Your teammate has chosen X. You and your teammate need to agree on the decision.

Send

Recap

- *As a team you will make decisions jointly. You should use this chat box to discuss what to do and come to an agreement regarding what choice to make.*
- *Please coordinate your choice with your teammate once you have reached an agreement as a round ends after all teams have made their choices.*
- *If you and your teammate have not coordinated your choices within the allocated time, then:*

Appendix E.3.4 Stage 2 Decision Page