# Unity Through Rivalry: How Competition Mitigates Social Dilemmas*

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**Abstract**

We study whether competition between groups that yields no material rewards fosters within-group cooperation. In a laboratory experiment, pairs of subjects played an indefinitely repeated Prisoner's Dilemma either in isolation or in a tournament against another pair, where winning conferred no monetary payoff. The competitive environment increased cooperation, and the effect strengthened over time as subjects gained experience. Exploiting the binary action space of the repeated game, we estimate participants' strategies and find that the tournament reallocates play away from strategies that start with defection toward strategies that start with cooperation. This reallocation results in a shift from Always Defect to the least risky cooperative strategy, Grim. We complement the experiment with a simple tournament-based model that shows how non-monetary competition can shift equilibrium selection toward cooperative strategies.

**Key words:** *Competition; Cooperation; Prisoner's Dilemma; Repeated game.*

**JEL code:** C73, C92, D81.

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# 1 Introduction

Theoretical and empirical work shows that cooperation among group members is crucial to the performance of a wide range of institutions (e.g., Alchian & Demsetz, 1972; Fehr & Gächter, 2000; Hamilton, Nickerson, & Owan, 2003; Holmstrom, 1982; Ostrom, 1990). However, the conflict between selfish and cooperative choices endures in many social and economic interactions, presenting a trade-off between individual and collective interests.

Experimental research has documented that intergroup competition represents a valuable intervention for mitigating this social dilemma and promoting cooperation, but it is typically implemented in conjunction with financial incentives. This confounding makes it difficult to identify the effect of competition from that of monetary rewards. At the same time, many real-world interventions in firms, schools, and the public sector introduce competition among groups without altering monetary incentives, for example through public rankings that compare departments, units, or branches. Therefore, understanding whether competition, in the absence of material rewards, can foster cooperation remains of critical importance for both experimentalists and organizations seeking to enhance cooperation through cost-effective instruments.

In this paper, we investigate whether intergroup competition promotes within-group cooperation in the absence of material incentives. Our goal is not only to document changes in average cooperation but also to identify how competition reshapes strategic behavior. To this end, we run a laboratory experiment in which pairs of subjects play an indefinitely repeated Prisoner's Dilemma (PD) under parameters that allow cooperation to be sustained in equilibrium. We compare a baseline to a treatment that introduces a tournament between pairs while holding stage-game payoffs fixed. Participants' earnings depend only on outcomes in their own game, and winning the tournament yields no monetary reward. Thus, this design cleanly identifies the effect of a non-monetary intergroup tournament while holding material payoffs fixed.

We find that first-round (all-rounds) cooperation increases on average by $\approx 42\%$ ($\approx 15\%$) in the tournament compared to the control condition, and this effect unfolds and becomes significant as subjects gain experience. The result is driven by a shift in strategy adoption. In the baseline, the most common strategy followed by subjects prescribes unconditional defection, Always Defect. By contrast, in the treatment, a substantial share of subjects adopt Grim, the least risky cooperative strategy. The competitive environment appears to foster a cooperative norm under which players mutually cooperate, and deviations are met with harsh punishment. These differences reveal that the non-monetary tournament alters behavior along dimensions not visible in aggregate cooperation rates. By exploiting the binary and history-dependent structure of the repeated PD, our design, along with the strategy estimation, offers a key methodological contribution to the study of intergroup competition and cooperation.

Intergroup competition is pervasive in organizational, academic, and social contexts, and experimental evidence consistently finds that it enhances cooperation within groups. However, most existing studies pair competition with monetary rewards (e.g., Abbink, Brandts, Herrmann, & Orzen, 2010; Y.-Y. Chen, 2020; Markussen, Reuben, & Tyran, 2014; Puurtinen & Mappes, 2009; Reuben & Tyran, 2010), making it difficult to disentangle competition from the direct effects of material incentives.[1] Moreover, the literature has primarily relied on public goods games (e.g., Augenblick & Cunha, 2015; Burton-Chellew, Ross-Gillespie, & West, 2010), where cooperation is proxied by average contributions, a coarse metric that offers limited insight into the underlying strategies that sustain cooperation. Relatively little is known about whether a competitive environment without monetary stakes fosters cooperation, or how such competition affects the behavioral patterns that lie behind similar aggregate cooperation rates. This paper aims to address both questions.

As a first contribution, we show that a non-monetary tournament fosters within-group cooperation. This contrasts with much of the experimental literature, in which competitive environments are typically paired with monetary rewards and are therefore intertwined with material incentive effects. To the best of our knowledge, only a limited number of experimental studies have investigated the impact of non-monetary intergroup competition on cooperative behavior (Böhm & Rockenbach, 2013; Cárdenas & Mantilla, 2015; Tan & Bolle, 2007). All these studies employ public goods games. Cárdenas and Mantilla (2015) and Tan and Bolle (2007) report that cooperation levels are higher when competition is associated with material rewards. Tan and Bolle (2007) additionally demonstrates that mere provision of relative-performance feedback exerts a positive effect on cooperation, though only in one-shot interactions. Furthermore, Böhm and Rockenbach (2013) provides evidence that intergroup comparison alone substantially increases cooperation compared to conditions in which only intragroup feedback is provided. While these studies share important elements with our setting, our design combines three features that have not been studied jointly: (i) it includes a control condition without relative information, allowing us to identify the effect of a non-monetary competitive environment; (ii) it employs an indefinitely repeated Prisoner's Dilemma rather than a public goods game; and (iii) it implements indefinite repetition. Thus, we isolate a competitive environment from material incentives and, exploiting the PD's binary, history-dependent structure, uncover individual strategies.

Therefore, our second contribution is that we capture how competition changes strategic behavior by employing the indefinitely repeated PD. This methodological choice is particularly advantageous, as its binary decision framework (*Cooperate* or *Defect*) clearly

[1] A related body of research explores the role of non-monetary incentives such as relative performance information (Schnieder, 2022). However, it focuses on individual effort, performance, and sabotage. In contrast, our paper focuses on cooperation.

represents participants' intentions. The decision to cooperate unequivocally provides a round-by-round indicator of cooperative behavior. By contrast, in public goods games, the broader choice set available to participants introduces potential ambiguity in interpreting individual contributions. For instance, a positive contribution below the group's average may be interpreted as free riding relative to peers, even though it is cooperative relative to a non-cooperative benchmark. Our use of the repeated PD thus offers a clean mapping from observed actions to cooperation and, together with strategy estimation, allows us to recover the dynamic rules sustaining cooperation rather than only aggregate levels. Estimating strategies from actual choices is not a trivial task for two main reasons. First, the number of possible strategies is virtually infinite (Fudenberg & Maskin, 1986). Second, while each choice is conditional on a specific history, we only observe one actual choice and not what subjects would have done at other decision stages. Our approach involves the use of a finite mixture model to estimate the proportion of participants in each treatment who employ a specific strategy. This widely used method provides insights into the decision-making processes that drive cooperation, offering a more nuanced understanding than studies that use different designs and focus on aggregate outcomes.

We complement the experiment with a theoretical analysis in which we develop a simple tournament-based model that rationalizes the observed reallocation of strategies. The model shows how introducing an intergroup tournament effectively lowers the discount-factor thresholds under which cooperation and Grim strategies can be sustained in equilibrium. We posit that players receive hedonic utility from winning the tournament, a parsimonious assumption about the utility function that applies to agents who are otherwise purely self-interested. Although other mechanisms, such as group identity or social framing (Bacharach, 1999; Ellingsen, Johannesson, Mollerstrom, & Munkhammar, 2012), can likewise foster cooperation, the objective of our framework is to demonstrate that the tournament itself can generate the observed shift toward cooperative trigger strategies, in line with the experimental evidence, and that this effect does not depend critically on any particular specification of the utility function. In doing so, we contribute to the theoretical literature on intergroup competition and repeated interaction, which has typically relied on either group-contingent social preferences, identity-based utilities, or material incentives (Cason, Lau, & Mui, 2019; Cheikbossian, 2012; B. Chen, Li, & Liu, 2026). Identity-based and social-preference approaches effectively modify the Prisoner's Dilemma payoff matrix by allowing others' material payoffs to enter utility, while contest models change material incentives by awarding additional monetary payoffs for winning. In contrast, our model leaves the stage-game monetary payoffs of the Prisoner's Dilemma unchanged and instead introduces a small non-monetary reward at the level of the intergroup contest. Formally, we treat the probability of winning the tournament as an increasing function of a pair's expected total payoffs for any fixed distribution of opponents' strategies. The resulting analysis is therefore partial-equilibrium but sufficient for our purpose, as it shows how, for a given competitive environment, the tournament shifts the relative sustainability and risk-dominance of Grim versus Always Defect, thereby rationalizing the observed reallocation of strategies.

Our findings show that an intergroup tournament, without monetary incentives, can be a cost-effective means of fostering cooperation in environments where individual and collective interests collide. In our setting, introducing a simple tournament between groups, while leaving material payoffs unchanged, increases cooperation and shifts play toward more self-enforcing cooperative paths. This result is consistent with a mechanism in which a modest hedonic value of winning can substitute for high-powered financial incentives. Thus, we show that such tournaments can be particularly attractive for organizations that face budgetary or equity constraints, yet seek to enhance welfare in settings where cooperation is socially beneficial. At the same time, our design abstracts from potential negative externalities of competition, such as sabotage. Thus, our conclusions may not extend to contexts where groups can directly influence rival groups.

The remainder of this paper is organized as follows: Section 2 introduces the game and describes the experimental design; Section 3 reports the results; Section 4 presents the theoretical analysis of the game; and Section 5 concludes. An appendix provides supplementary material that enhances and extends the content presented in the main body of the paper.

# 2 Methods

## 2.1 Experimental Design

This study implements a between-subjects design in which pairs of subjects play an indefinitely repeated PD game. The game is based on one of the treatments from Dal Bó and Fréchette (2011), with the individual payoff matrix of the stage game represented in Table 1. The parameters of the stage game are such that cooperative behavior can be supported in a subgame perfect equilibrium (SPE), but not in a risk-dominant equilibrium (RD). Thus, while cooperation is theoretically feasible in equilibrium, it is difficult to maintain in practice, consistent with the findings of Dal Bó and Fréchette (2011), who report overall cooperation rates of only about 20%. For the remainder of this paper, we will use the term round to refer to the stage where subjects make decisions. Players can choose between two actions at each round: *Cooperate* or *Defect*.[2] At the end of the round, there is a fixed and known probability $\delta = 0.75$ (continuation probability) that the game will continue, and the participant will play with the same partner in the next round. We refer to the series of consecutive rounds played with the same partner as a supergame.

[2] To prevent unintended framing effects, the actions in the experiment were labeled as Action 1 and Action 2, respectively.

| | *Cooperate* | *Defect* |
|---|---|---|
| *Cooperate* | $32, 32$ | $12, 50$ |
| *Defect* | $50, 12$ | $25, 25$ |

**Table 1** Payoffs of the stage game represented in Experimental Currency Units (ECU).

At the end of each round, every player receives feedback about the action taken by their partner and the resulting outcome. A history box summarizing the actions and payoffs of both players in previous rounds is displayed on the screen and stored until the end of the supergame. When a supergame ends, new pairs are randomly formed, and a new supergame with the same rules begins. The participants have 50 minutes to play, and their earnings are computed as the cumulative sum of the individual payoffs of each round they played. We refer to the subjects who play using this set of rules as the *Control* group.

**Tournament** In the treatment group (henceforth *Tournament*), the rules of the game are identical to those of *Control*, with a single exception: the two players are competing with another pair of subjects. At the beginning of each supergame, two pairs (now teams) are randomly matched. The pair that accumulates more points (the sum of both players' individual payoffs) by the end of the supergame is declared the winner. Because cooperation always yields more points to the pair, the more the two subjects cooperate, the greater their likelihood of winning the tournament. The outcome of the competition (win, loss, or tie) is displayed at the end of each supergame, but no information is given regarding the points achieved by the other pair. It is essential to note that winning the competition does not result in an additional monetary payoff, and participants are explicitly informed of this. If additional economic incentives were provided to the winners, it would not be possible to disentangle the effects of competition and monetary prizes, as the additional monetary rewards would virtually increase the stage-game payoff associated with cooperation.

This design disentangles non-monetary competition from material incentives. It studies a practically relevant tournament environment in which intergroup rivalry is embedded in team-based comparison and outcome feedback, as is often the case in organizational settings. Accordingly, the estimated treatment effect captures the effect of introducing this non-monetary tournament environment as a whole.

## 2.2 Experimental Procedure

We recruited 94 participants (46 in the control group and 48 in the treatment group) from the subjects' pool of the University of Côte d'Azur (Nice, France) using ORSEE (Greiner, 2015). The subject pool included students from various disciplines. The experiment was programmed using zTree (Fischbacher, 2007) and conducted at the Laboratoire d'Économie Expérimentale de Nice (LEEN) in September 2020. The payoffs are expressed in Experimental Currency Units (ECU), and at the end of the experiment, participants were paid €0.50 for 100 ECU earned during the experiment. The average payment was €21.42, including a €5 show-up fee, and the experimental sessions lasted, on average, 75 minutes. We conducted a total of six sessions evenly distributed across treatments, and each participant played in one of the two treatments only. At the end of the experiment, participants completed a brief questionnaire in which they self-reported their socio-demographics, generalized trust, and risk aversion.[3] Table C.1 in Appendix C shows that treatment randomization is balanced with respect to variables elicited in the final questionnaire.

# 3 Results

The primary objective of this study is to show that introducing a competitive environment that bears no additional economic rewards is sufficient to foster cooperation. The first part of this section reports evidence on the treatment effect, while in the second part, we provide results on the strategy estimation.[4]

## 3.1 Treatment effect

The left panel of Figure 1 shows cooperation rates in the first round of each supergame, a standard practice in the repeated-games literature. First-round choices are comparable across supergames with random lengths, avoid complications from history-dependent behavior in later rounds, and cleanly measure the willingness to start cooperating (see Dal Bó & Fréchette, 2011, 2018, for an in-depth discussion). Our data show a sizable treatment effect: average first-round cooperation rates are 38.74% and 54.92% in *Control* and *Tournament*, respectively. Introducing a competitive environment thus increased first-round cooperation by 16.18 percentage points ($p = 0.033$).[5] The figure shows that the treatment effect emerges and increases in magnitude as subjects gain experience. Consistent with this, first-round cooperation in *Control* declines significantly over supergames ($p = 0.007$), whereas in the tournament we do not detect any systematic time trend ($p = 0.885$). This difference in time trends across experimental conditions is weakly significant ($p =$

[3]See the questionnaire in Appendix B.

[4]In one session of *Control*, we encountered a problem as subjects continued playing the game even after the 50-minute mark. For this reason, in that session, we only use observations that were played up to supergame 29 (the maximum supergame number played in other sessions). This ensures a similar number of total decisions across sessions and treatments, allowing for a fair comparison. Cooperation in those "extra" supergames further decreased over time, thus not undermining our results.

[5]Throughout the paper, if not otherwise stated, statistical significance is assessed by estimating average marginal effects from mixed-effects probit models with standard errors clustered at the participant level where cooperation is regressed against the relevant variables.

0.073). In the right panel of Figure 1, we plot cooperation rates using all rounds within each supergame. Even though we do not detect systematic differences in supergame length across treatments (Mann-Whitney U test: $p = 0.173$), these all-round comparisons should be interpreted with caution, as later-round actions are strongly history-dependent and yield multiple non-independent observations per supergame. As expected, treatment differences are attenuated once later rounds are included. Although the figure suggests higher cooperation in the *Tournament* condition toward the end of the experiment, the overall differences are not statistically significant when all rounds are considered. Overall cooperation rates are 31.36% in *Control* and 36.17% in *Tournament*, with no significant difference in levels ($p = 0.157$) or in time trends across treatments ($p = 0.353$).

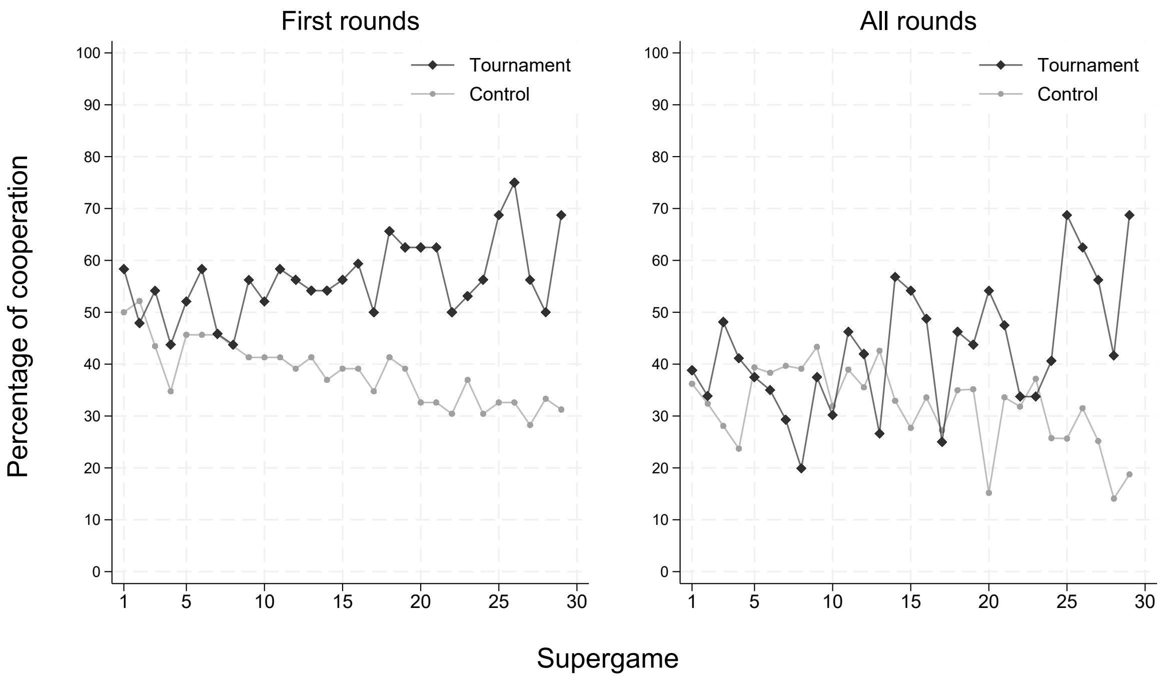


**Figure 1** Percentage of cooperation by supergame. The left panel shows cooperation rates in the first rounds of each supergame. The right panel uses all observations. To improve readability, confidence intervals are omitted here. The corresponding figure with confidence intervals is reported in Appendix E.

Table 2 reports mean cooperation rates by treatment, separately for first rounds (left panel) and all rounds (right panel). Within each panel, columns Q1-Q4 isolate choices from the first, second, third, and fourth quartiles of the overall sequence of decisions, respectively. This aligns observations by their position in the overall sequence of play, rather than by supergame number, which can vary in length. The bottom rows display the treatment difference and the associated p-value for each comparison. The estimates indicate that the effect of competition on cooperation is consistently positive, negligible in the early stages of the experiment, but sizable and statistically significant in the final quartiles, where subjects have gained experience and behavior is likely to have stabilized. The treatment difference in the last quartile of decisions is more than 21 percentage points (+61%) in the first rounds and almost 10 (+34%) when all rounds are considered.[6]

| | First rounds | | | | | All rounds | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | **All** | **Q1** | **Q2** | **Q3** | **Q4** | **All** | **Q1** | **Q2** | **Q3** | **Q4** |
| **Control** | 38.74 | 47.02 | 40.10 | 36.56 | 35.71 | 31.36 | 32.79 | 32.43 | 31.14 | 29.26 |
| **Tournament** | 54.92 | 51.56 | 54.02 | 56.25 | 57.42 | 36.17 | 37.84 | 33.24 | 33.81 | 39.10 |
| **diff** | 16.18 | 4.54 | 13.92 | 19.69 | 21.71 | 4.81 | 5.05 | 0.81 | 2.67 | 9.84 |
| **p-value** | 0.033 | 0.513 | 0.302 | 0.075 | 0.003 | 0.157 | 0.403 | 0.489 | 0.436 | 0.027 |

**Table 2** Percentage of cooperation in first rounds (left panel) and all rounds (right panel). Q1-Q4 shows cooperation rates in each quartile of the decision distribution.

The evidence presented so far highlights a sizable treatment effect that develops over time and consolidates in the last parts of the experiment. However, average treatment effects may conceal systematic changes in the composition of outcomes. In Figure 2 we display the distribution of stage-game outcomes by treatment, separately for first rounds (left column) and all rounds (right column), and for the full sample (top row) versus only the last quartile of decisions (bottom row). In every panel, the *Tournament* condition features a higher fraction of mutual cooperation (C,C) and a lower fraction of mutual defection (D,D) than the *Control* condition. The differences are especially pronounced in the last quartile of decisions (bottom row). Pair-level probit estimates indicate that the treatment significantly increases the probability of mutual cooperation in all panels except the top-right one, where the estimated effect is positive but not statistically significant at any conventional level (top-left panel: $p = 0.002$; top-right panel: $p = 0.403$; bottom-left panel: $p = 0.000$; bottom-right panel: $p = 0.006$).[7]

The pattern in Figure 2 suggests that the competition between groups primarily shifts mass from mutual defection toward mutual cooperation. Across panels, the fraction of *D,D* outcomes is systematically lower in *Tournament* than in *Control*, while the share of mixed outcomes *C,D* or *D,C* remains relatively stable. This suggests that the treatment does not merely induce one-sided deviations from defection, but rather fosters coordinated moves toward mutual cooperation.

The evidence presented so far shows that competition increases cooperation and shifts realized outcomes away from mutual defection and toward mutual cooperation, especially in the later stages of the experiment. This naturally raises the question of which underlying strategies account for this pattern. To address this issue, we move

[6]Table C.2 in Appendix C reports descriptive statistics for each experimental session separately.

[7]Statistical significance is assessed using average marginal effects from probit specifications estimated at the pair level, with standard errors clustered at the session level.

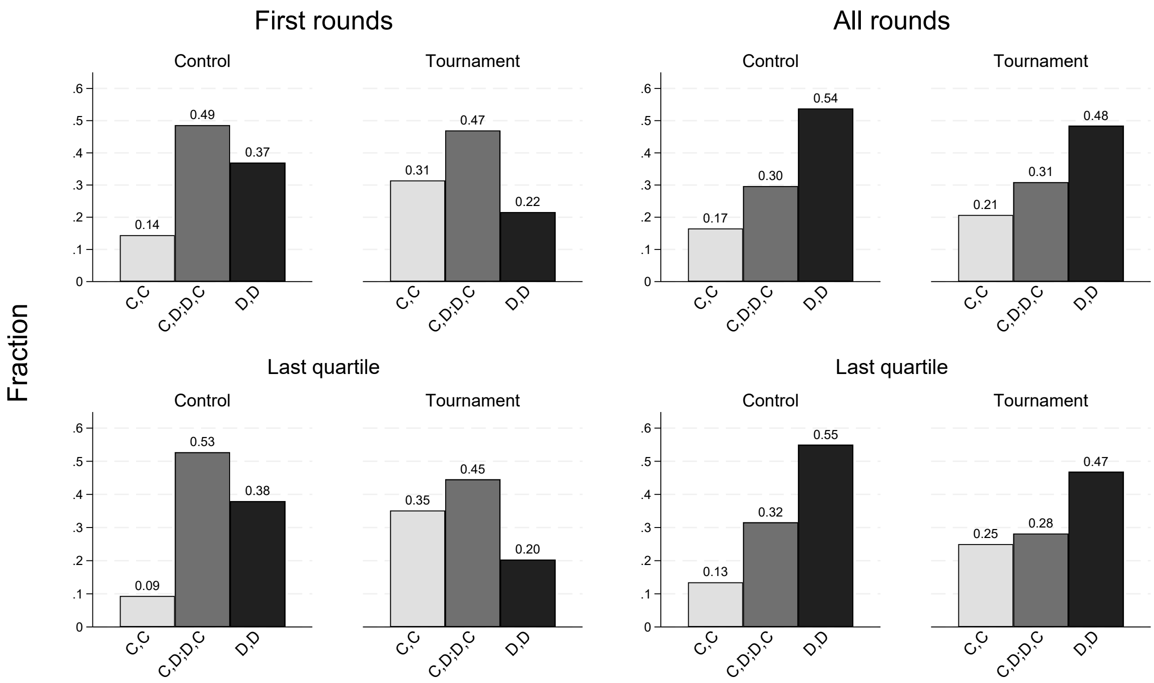


**Figure 2** Outcomes by treatment. Pictures in the left column show the fraction of outcomes for only the first rounds of each supergame. The pictures in the second column use all rounds of every supergame. The first row uses choices from the entire experimental session, while the bottom row only uses decisions from the last quartile. The outcome in each round can be either mutual cooperation (C,C), one cooperates and the other defects (C,D or D,C), or mutual defection (D,D). To improve readability, confidence intervals are omitted here. The corresponding figure with confidence intervals is reported in Appendix E.

beyond average cooperation rates and estimate a finite-mixture model to estimate how the tournament reshapes the distribution of strategies.

## 3.2 Strategies

This section exploits the dependency of choices between and within supergames by estimating the strategies that participants used in the experiment via finite mixture models. This practice was pioneered by Dal Bó and Fréchette (2011) and later adopted and refined in subsequent experimental work (e.g., Aoyagi, Bhaskar, & Fréchette, 2019; Arechar, Dreber, Fudenberg, & Rand, 2017; Bigoni, Casari, Skrzypacz, & Spagnolo, 2015; Breitmoser, 2015; Camera, Casari, & Bigoni, 2012; Dal Bó & Fréchette, 2018; Dvorak, 2023; Fréchette & Yuksel, 2017; Fudenberg, Rand, & Dreber, 2012; Jones, 2014; Romero & Rosokha, 2023; Vespa, 2020).

We estimate strategies with a finite mixture model following Dvorak (2023).[8] We start from a rich set of candidate strategies and assume that each individual is a latent type who follows one of these strategies, subject to random trembles.[9] Given the observed action histories, we estimate the model by maximum likelihood and obtain, for each treatment, an estimated distribution over strategy types and an error rate. Because the space of possible strategies is virtually infinite, we restrict our attention to strategies that previous work has identified as relevant in indefinitely repeated games (Aoyagi, Fréchette, & Yuksel, 2024; Dal Bó & Fréchette, 2011, 2018; Fudenberg et al., 2012; Romero & Rosokha, 2023), which yields an initial set of 17 pure strategies.[10] Following the literature, we focus this part of the analysis on later supergames (20-29), where behavior is likely to have stabilized, as suggested by the evidence provided above. When this was not possible, we attempted to maintain a balanced distribution of later decisions (interactions) across treatments. In practice, in both *Control* and *Tournament*, approximately the last quarter of decisions is used for estimation.[11] Finally, because an overly rich candidate set can induce instability in the classification of observationally similar types (e.g., Grim vs Always Cooperate), we use the Bayesian Information Criterion (BIC) to select, from the initial set, a parsimonious subset of strategies to estimate.

The surviving strategies are: always defect (AD); Tit-for-Tat (TFT), that starts cooperating and then mimics the opponent's choice in the previous round; Suspicious Tit-for-Tat

[8] Please refer to the paper for details on the estimation procedure.

[9] Aligning with the literature, we assume a common probability of mistakes within each treatment rather than strategy-specific trembles. In Table D.2 in the appendix, we provide estimates using the selected set of strategies presented in the main analysis, relaxing this assumption. Our main conclusions do not vary.

[10] In Appendix D we describe the full set of candidate strategies, and in Table D.1 we provide estimates using this initial set. Our main conclusions remain unchanged.

[11] In Appendix D.2, we report results from a robustness check in which strategies are estimated using all available observations (supergames 1-29). The resulting estimates are qualitatively similar to those reported in the main analysis and do not alter our main conclusions.

(STFT), that starts defecting and then plays as TFT; Grim that cooperates until a defection from the opponent, then defects forever; Grim2 and Grim3 that are lenient version of Grim where defection is triggered by 2 or 3 consecutive defections of the opponent respectively; and T2 and T3 cooperate for 2 and 3 rounds respectively, and then defects forever. We then estimate a joint finite-mixture model allowing for treatment-specific mixture weights and trembles. Results are reported in Table 3.

| | *Control* | *Tournament* |
|---|---|---|
| AD | 0.380*** (0.078) | 0.233*** (0.066) |
| TFT | 0.159*** (0.061) | 0.197*** (0.064) |
| STFT | 0.337*** (0.077) | 0.196*** (0.062) |
| Grim | 0.062 (0.043) | 0.193*** (0.066) |
| Grim2 | 0.033 (0.031) | 0.061 (0.047) |
| Grim3 | | 0.077 (0.049) |
| T2 | | 0.043 (0.033) |
| T3 | 0.030 (0.029) | |
| $\beta$ | 0.892 (0.018) | 0.882 (0.017) |
| LL | -1077.367 | |
| BIC | 2227.427 | |

**Table 3** Estimated shares of strategies selected by the Bayesian Information Criterion (BIC). Shares with an estimated value of zero are not displayed to improve readability. Standard errors are bootstrapped from 10,000 resamples and reported in parentheses. The statistical significance of each share is assessed based on the estimated distribution of the parameter. $\beta$ is implied by the estimated tremble and represents the probability that subjects follow what is prescribed by the strategies. The log-likelihood (LL) and the Bayesian Information Criterion (BIC) of the joint model fit are displayed in the last two rows. $^{*}$ $p < 0.10$, $^{**}$ $p < 0.05$, $^{***}$ $p < 0.01$

The table shows a clear composition shift under the *Tournament* treatment. Relative to *Control*, the competitive environment is associated with a pronounced reallocation of mass away from strategies that start by defecting toward trigger-type punishment, as Grim is relevant only in the *Tournament* condition and equal to 0.19. The parameter $\beta$, which is implied by the estimated tremble, is similar across treatments ($\beta_C = 0.892$, $\beta_T = 0.882$), indicating that the treatment effect operates through strategy composition rather than decision noise.

Taken together, these estimates indicate that the non-monetary tournament does not simply raise cooperation, but it changes how cooperation is sustained. In the *Control* condition, a large share of subjects rely on AD and STFT, both of which start by defecting, with STFT allowing for some recovery after a deviation. Under *Tournament*, their combined weight falls, while the share of Grim, and to a lesser extent, TFT, increases. Grim is less forgiving than STFT, as any defection permanently triggers punishment. Thus, the rise in cooperation documented above is not driven by greater leniency after deviations, but by a shift toward strategies that begin with cooperation and impose stricter sanctions when cooperation is broken, consistent with the idea that the tournament strengthens a social norm to cooperate. In this sense, the competitive environment both enhances initial cooperation and reallocates probability mass toward trigger strategies that make cooperative play more sustainable, in line with the mechanism formalized in Section 4, where the tournament shifts equilibrium selection toward cooperative trigger strategies.

# 4 Theoretical Framework

The results presented in the previous section indicate that non-monetary tournaments increase cooperation and alter the distribution of strategies: fewer participants choose Always Defect, while a substantial share adopts the trigger strategy Grim. In this section, we provide a theoretical analysis of the game used in the experiment. Specifically, we investigate how a tournament with non-monetary incentives affects the equilibria of the game by introducing competition between pairs of players who play an infinitely repeated Prisoner's Dilemma. The pair that achieves the highest cumulative sum of aggregate payoffs (points) wins the tournament. Because cooperation yields more points, cooperating increases the odds of winning. No additional monetary payoffs are awarded to the winners.

Intuitively, the tournament introduces an additional incentive to cooperate. This extra incentive modifies the strategic environment and lowers the thresholds under which cooperative trigger strategies are viable. In particular, we derive conditions under which the tournament reduces both the subgame-perfect and the risk-dominance thresholds. The model therefore predicts a reallocation of play away from Always Defect toward the least risky cooperative strategy, Grim, a pattern that closely matches what we observe in the data.

To obtain these results, we model the incentives introduced by the tournament as hedonic utility from winning. This choice is guided by two considerations. First, it is parsimonious, as we simply posit that players enjoy winning the tournament and that cooperation increases the likelihood of doing so. Second, the specification keeps agents selfish with respect to material payoffs and does not require the presence or activation of other-regarding preferences. We acknowledge that comparable predictions might also be obtained with models that introduce other-regarding preferences through group identity (Y. Chen & Li, 2009) or social framing (Tversky & Kahneman, 1981). For instance, B. Chen et al. (2026) derive theoretical predictions similar to ours by leveraging on group identity.

The aim of this section, as well as of this paper, is not to test the specific hypothesis that players derive hedonic utility from winning. Rather, we use a simple tournament-based model to characterize how an intergroup competition without material prizes can change equilibrium selection in the repeated Prisoner's Dilemma and to provide a theoretical benchmark consistent with the observed shift from Always Defect to Grim.

## 4.1 The Model

In what follows, we analyze the game described in the previous section, an infinitely repeated PD. To ease the exposition, we perform a normalization of the payoff matrix as shown in Table 4.[12] To ensure that mutual cooperation generates a higher combined outcome, it is required that $2 > 1+g-\ell$. Otherwise, alternating between $(Cooperate, Defect)$ and $(Defect, Cooperate)$ would generate higher payoffs for both players. This condition, which is satisfied in our experimental design, ensures that the benefits of cooperation outweigh the potential gains from alternating between cooperation and defection.

| | *Cooperate* | *Defect* |
|---|---|---|
| *Cooperate* | $1$ | $-\ell$ |
| *Defect* | $1+g$ | $0$ |

**Table 4** Row Player's Payoffs of the stage game.

The first step is to derive, from the stage-game payoffs, the two critical discount factors that will be used throughout the analysis. To fix notation, let AD denote the strategy that prescribes $D$ after every history (Always Defect). Let Grim denote the trigger strategy with two continuation paths: $\mathrm{G_C}$, the cooperative path, prescribes $C$ as long as no defection has occurred; $\mathrm{G_D}$, the defection path, is reached after the first defection and prescribes $D$ forever thereafter. Hence, $\mathrm{G_C}$ and $\mathrm{G_D}$ are not two different strategies, but the two continuation paths of the same Grim strategy.
The threshold $\delta^{SPE}$ is obtained from the standard one-shot deviation condition for Grim. In particular, starting from the cooperative path $\mathrm{G_C}$, one checks whether a player prefers to keep playing $C$ rather than deviate once. Since any deviation triggers the punishment path $\mathrm{G_D}$ forever, cooperation is sustainable if the continuation payoff from remaining on $\mathrm{G_C}$ is at least as large as the current gain from deviation plus the continuation payoff on $\mathrm{G_D}$. This yields

$$\delta^{SPE} = \frac{g}{1+g}.$$

We also compute the threshold $\delta^{RD}$ for cooperation to be risk-dominant. Following Blonski and Spagnolo (2015), risk dominance in the repeated game is studied through the auxiliary $2 \times 2$ game whose actions are the two equilibrium points of the supergame, namely AD and Grim.[13] The corresponding threshold is obtained by comparing the Nash products

[12]We performed the same normalization as in Dal Bó and Fréchette (2018). For our game, the game's parameters are set to: $g = \frac{18}{7}$ and $\ell = \frac{13}{7}$. In the experiment, the continuation probability is set to $\delta = 0,75$.

[13]Harsanyi and Selten (1988) define risk dominance for $2 \times 2$ games. In repeated games, the concept

associated with the two equilibria in this auxiliary game, that is, the products of the players' losses from unilateral deviations. This gives

$$\delta^{RD} = \frac{g + \ell}{1 + g + \ell}.$$

In what follows, we will therefore use AD to denote the Always Defect strategy, and $\mathrm{G_C}$ and $\mathrm{G_D}$ to denote the cooperative and punishment paths of Grim, respectively.

**The Tournament.** In the tournament setting, two pairs of players, referred to as teams, engage in an infinitely repeated PD game. Each player is aware of the presence of the opposing team. The objective of the tournament is for a team to achieve the highest number of *points* (aggregate sum of both players' individual payoffs). Winning the tournament does not provide any additional material payoff. Furthermore, the actions taken by one team do not directly affect the payoffs of the other team, and vice versa.

Assume that each player experiences a non-negative hedonic utility, denoted as $W \geq 0$, when their team wins the tournament.[14] This utility is in addition to the monetary payoffs normally obtained from the game.

In our setting, the probability that a team wins the tournament, following strategy $s$, is denoted by $\mathbb{P}(\text{win} \mid s)$. It depends on the total number of *points* the team expects to accumulate under the strategy profile $s$. Since the tournament rule is that the team with the highest score wins, this probability increases with the expected *points* scored by the team following the prescribed strategy. As a result, when choosing a strategy, players must weigh not only the immediate payoffs from their actions, but also how these actions affect their team's chances of winning, and thus the additional utility $W$ they derive from victory. Given the structure of the stage-game payoffs, with $2 > 1 + g - \ell > 0$, it follows that $\mathrm{G_C}$ yields the highest expected score, followed by $\mathrm{G_D}$ and then AD. Consequently $\mathbb{P}(\text{win} \mid \mathrm{G_C}) \geq \mathbb{P}(\text{win} \mid \mathrm{G_D}) \geq \mathbb{P}(\text{win} \mid \mathrm{AD})$.

This ranking suffices to establish our main results; no additional assumptions on the functional form of $\mathbb{P}(\text{win} \mid s)$ are required. Although the probability of victory depends on the strategies chosen by both teams, a given team cannot control its opponent's behavior. Accordingly, we treat $\mathbb{P}(\text{win} \mid s)$ as parametrically fixed from each team's viewpoint and analyze how a team's own strategy affects its expected outcome. In this sense, the results are derived in partial equilibrium. Solving for a general equilibrium that simultaneously determines both teams' strategies would demand stronger assumptions about belief formation and strategic interdependence; in our opinion such an extension is unnecessary here, because the ordinal ranking of strategies, together with the monotonic relationship

can be extended by considering an auxiliary $2 \times 2$ game whose actions are equilibrium strategies; see Blonski and Spagnolo (2015).

[14]In our framework, ties yield no additional tournament utility.

between *points* and winning, is sufficient to show how the tournament incentives lower the threshold for cooperation.

To prove that the tournament lowers the threshold $\delta^{SPE}$ necessary for cooperation, we follow the steps of Nash reversion and incorporate into the payoff of each strategy the value of winning the tournament, $W$, weighted by the probability of winning given the strategy played. This leads us to the first result:

**Proposition 1.** *Let $W \geq 0$ be the utility given by winning the tournament, then the minimum discount factor necessary to have cooperation as part of an SPE in the presence of a tournament, $\delta^{SPE^*}$, is lower than $\delta^{SPE}$ in the absence of the tournament. Moreover $\delta^{SPE^*}$ is equal to:*

$$\delta^{SPE^*} = \frac{g - W\big(\mathbb{P}(win \mid \mathrm{G_C}) - \mathbb{P}(win \mid \mathrm{G_D})\big)}{1 + g - W\big(\mathbb{P}(win \mid \mathrm{G_C}) - \mathbb{P}(win \mid \mathrm{G_D})\big)} \leq \frac{g}{1+g} = \delta^{SPE}.$$

Here, $\mathbb{P}(\text{win} \mid \mathrm{G_C})$ denotes the probability of winning the tournament when both players remain on the cooperative path, whereas $\mathbb{P}(\text{win} \mid \mathrm{G_D})$ denotes the probability of winning along the grim punishment path following a one-shot deviation (see Appendix A). Since the cooperative path yields weakly higher team points than the punishment path, $\mathbb{P}(\text{win} \mid \mathrm{G_C}) - \mathbb{P}(\text{win} \mid \mathrm{G_D}) \geq 0$, so that $\delta^{SPE^*} \leq \delta^{SPE}$.

This first result shows that the tournament lowers the critical discount factor required to sustain cooperation in an SPE. Thus, even without altering the stage-game payoffs, competition makes cooperation easier to sustain.

To prove that the tournament lowers the threshold for a risk-dominant equilibrium $\delta^{RD}$, we follow Blonski and Spagnolo (2015). To determine when cooperation is risk-dominant, we focus exclusively on two equilibria in pure actions: the Grim strategy , which is the least risky among cooperative equilibria, and always defect (AD).[15] By following the steps outlined in Blonski and Spagnolo (2015), we derive the following result:

**Proposition 2.** *Let $W \geq 0$ be the utility given by winning the tournament, then the minimum discount factor necessary to have cooperation as part of a risk-dominant strategy in the presence of a tournament, $\delta^{RD^*}$, is lower than $\delta^{RD}$ in the absence of the tournament. Moreover, $\delta^{RD^*}$ is equal to:*

$$\delta^{RD^*} = \frac{g + \ell - W\big(\mathbb{P}(win \mid \mathrm{G_C}) - \mathbb{P}(win \mid \mathrm{AD})\big)}{1 + g + \ell - W\big(\mathbb{P}(win \mid \mathrm{G_C}) - \mathbb{P}(win \mid \mathrm{AD})\big)} \leq \frac{g+\ell}{1+g+\ell} = \delta^{RD}.$$

This second result is particularly relevant in our setting because the parameters used in the experiment allow cooperation to be sustained in an SPE, but not to be risk-dominant. Specifically, $\delta^{SPE} = 0.72$ is lower than the experimental continuation

[15] Proof in Blonski and Spagnolo (2015).

probability, $\delta = 0.75$, whereas $\delta^{RD} \simeq 0.82$ is higher. Proposition 2 shows that the tournament lowers this risk-dominance threshold. Hence, players who attach sufficient utility to winning may switch from Always Defect to Grim in *Tournament*, consistent with the strategy estimates reported in Section 3.2. The detailed proofs for both propositions are provided in Appendix A.

# 5 Conclusions

In this study, we provide evidence that a tournament, which introduces competition between groups, can substantially increase cooperation in strategic environments, even when it does not confer material rewards to the winners. The experimental results show higher cooperation rates in the tournament than in the control condition, with the effect strengthening as participants gain experience. We also uncover how the competitive environment shapes strategic behavior, promoting a shift away from strategies that prescribe starting with defection toward the least risky cooperative strategy, Grim. This insight relies on the features of the Prisoner's Dilemma game, which represents a key methodological innovation compared to the existing literature.

To interpret these patterns, we develop a simple tournament-based model of the infinitely repeated Prisoner's Dilemma. The model shows that introducing a tournament between pairs can lower both the subgame-perfect and risk-dominance discount-factor thresholds for Grim relative to Always Defect, even when the stage-game payoffs are left unchanged. It thus predicts the observed empirical reallocation from Always Defect to Grim and provides a tractable benchmark for how non-monetary competition can change equilibrium selection in repeated interactions.

These findings highlight the effectiveness of non-monetary tournaments in fostering cooperation and underline the added value of our methodological approach. The use of the indefinitely repeated Prisoner's Dilemma enabled us to estimate the strategies employed by participants and to connect the experimental evidence to a tractable theoretical framework. Taken together, the empirical and theoretical analyses provide a coherent account of how structuring interaction as a tournament between groups can discipline and coordinate behavior, shifting play toward cooperative trigger strategies even in the absence of material prizes.

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# Appendix for "The Enemy of My Enemy: How Competition Mitigates Social Dilemmas"

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## A Proofs

**Proof of Proposition 1** In order to prove Proposition 1, we follow the proof of Nash reversion, and we add to each strategy the value of winning the tournament, $W \geq 0$, weighted by the probability of winning given the strategy played. We compare the continuation values from period $t^*$ onward between (i) continuing with cooperation, $\mathrm{G_C}$, and (ii) deviating once at $t^*$ and then following the grim punishment path $\mathrm{G_D}$. Therefore, the equation becomes the following:

$$\sum_{\tau=0}^{\infty} \delta^{\tau} \cdot 1 + W\mathbb{P}(\text{win} \mid \mathrm{G_C}) \geq 1 + g + \sum_{\tau=1}^{\infty} \delta^{\tau} \cdot 0 + W\mathbb{P}(\text{win} \mid \mathrm{G_D})$$

where $\tau = t - t^*$, $\mathrm{G_C}$ is the continuation path in which both players keep cooperating, while $\mathrm{G_D}$ is the punishment path triggered by a one-shot deviation at time $t^*$, after which both players play Defect forever. Since $2 > 1 + g - \ell$, the path $\mathrm{G_C}$ yields higher team points than the path $\mathrm{G_D}$, thus $\mathbb{P}(\text{win} \mid \mathrm{G_C}) - \mathbb{P}(\text{win} \mid \mathrm{G_D}) \geq 0$.

Rearranging the formula, we obtain:

$$\delta^{SPE^*} = \frac{g - W\Big(\mathbb{P}(\text{win} \mid \mathrm{G_C}) - \mathbb{P}(\text{win} \mid \mathrm{G_D})\Big)}{1 + g - W\Big(\mathbb{P}(\text{win} \mid \mathrm{G_C}) - \mathbb{P}(\text{win} \mid \mathrm{G_D})\Big)} \leq \frac{g}{1+g}.$$

□

**Proof of Proposition 2** In order to prove proposition 2, we follow Blonski and Spagnolo (2015). To assess when coordination is risk-dominant, we focus only on two equilibria in pure actions: the grim trigger strategy (Grim), which is the least risky among cooperative equilibria (proof in Blonski & Spagnolo, 2015), and always defect (AD). We build an auxiliary $2 \times 2$ game using only these two equilibrium points. According to Harsanyi and Selten (1988), risk dominance in $2 \times 2$ games can be determined by comparing the Nash products of the two equilibria, namely the products of the players' losses from unilateral deviations. We evaluate all continuation payoffs from period $t^*$ onward. Using the same normalization as above, we can write the disincentives $u_i$ for Grim and $v_i$ for AD as:

$$u_i = \sum_{\tau=0}^{\infty} \delta^\tau \cdot 1 - \Big(1 + g + \sum_{\tau=1}^{\infty} \delta^\tau \cdot 0\Big) \geq 0$$

$$v_i = \sum_{\tau=0}^{\infty} \delta^\tau \cdot 0 - \Big(-\ell + \sum_{\tau=1}^{\infty} \delta^\tau \cdot 0\Big) \geq 0.$$

The grim trigger strategy Grim is risk dominated by AD if $v_1 v_2 \geq u_1 u_2$:

$$\ell^2 - \Big(\frac{1}{1-\delta} - (1+g)\Big)^2 \geq 0.$$

From these relations, we find that the threshold for $\delta$ below which Grim is risk-dominated is the following:

$$\delta^{RD} = \frac{g+\ell}{1+g+\ell}.$$

Similarly to proposition 1, we add the weighted value of winning the tournament. Therefore, the relations become:

$$u_i = \sum_{\tau=0}^{\infty} \delta^\tau \cdot 1 + W\mathbb{P}(\text{win} \mid \text{G}_\text{C}) - \Big(1 + g + \sum_{\tau=1}^{\infty} \delta^\tau \cdot 0 + W\mathbb{P}(\text{win} \mid \text{G}_\text{D})\Big) \geq 0$$

$$v_i = \sum_{\tau=0}^{\infty} \delta^\tau \cdot 0 + W\mathbb{P}(\text{win} \mid \text{AD}) - \Big(-\ell + \sum_{\tau=1}^{\infty} \delta^\tau \cdot 0 + W\mathbb{P}(\text{win} \mid \text{G}_\text{D})\Big) \geq 0.$$

Using the same procedures as before, we obtain,

$$\Big(\ell + W\Big(\mathbb{P}(\text{win} \mid \text{AD}) - \mathbb{P}(\text{win} \mid \text{G}_\text{D})\Big)\Big)^2 - \Big(\frac{1}{1-\delta} - (1+g) + W\Big(\mathbb{P}(\text{win} \mid \text{G}_\text{C}) - \mathbb{P}(\text{win} \mid \text{G}_\text{D})\Big)\Big)^2 \geq 0$$

and by rearranging the formula, we obtain:

$$\delta^{RD^*} = \frac{g + \ell - W\Big(\mathbb{P}(\text{win} \mid \text{G}_\text{C}) - \mathbb{P}(\text{win} \mid \text{AD})\Big)}{1 + g + \ell - W\Big(\mathbb{P}(\text{win} \mid \text{G}_\text{C}) - \mathbb{P}(\text{win} \mid \text{AD})\Big)} \leq \frac{g+\ell}{1+g+\ell}.$$

□

# B Instructions

## B.1 Control Treatment

### Welcome

You are about to participate in a session on decision-making, and you will be paid for your participation with cash vouchers, privately, at the end of the session. What you earn depends partly on your decisions, partly on the decisions of others, and partly on chance.

**General Instructions**

1. In this experiment, you will be asked to make decisions in several rounds. You will be randomly paired with another person for a sequence of rounds. Each sequence of rounds is referred to as a match.

2. The length of a match is randomly determined. After each round, there is a 75% probability that the match will continue for at least another round. This probability is always the same regardless of the round. So, for instance, if you are in round 2, the probability there will be a third round is 75%, and if you are in round 9, the probability there will be another round is also 75%.

3. At the beginning of a new match, you will be randomly paired with another person for a new match.

4. The choices and the payoffs (expressed in points) in each round are as follows:

| | The other's choice | |
|---|---|---|
| Your choice | **1** | **2** |
| **1** | (32 , 32) | (12 , 50) |
| **2** | (50 , 12) | (25 , 25) |

The first entry in each cell represents your payoff, while the second entry represents the payoff of the person you are matched with.
For example, if:

- You select **1** and the other selects **1**, you each make 32.
- You select **1** and the other selects **2**, you make 12 while the other makes 50.
- You select **1** and the other selects **2**, you make 50 while the other makes 12.
- You select **2** and the other selects **2**, you each make 25.

5. At the end of the 50 min, you will be paid 0.005€ (half of a euro cent) for every point you scored individually in every round played during the whole experiment.

6. Are there any questions?

## B.2 Tournament treatment

All the framing introduced in the instructions for the treatment that does not appear in control is indicated in italics.

**Welcome**

You are about to participate in a session on *a tournament*, and you will be paid for your participation with cash vouchers, privately at the end of the session. What you earn depends partly on your decisions, partly on the decisions of others, and partly on chance.

**General Instructions**

1. In this experiment, you will be asked to make decisions in several rounds. You will be randomly paired with *a teammate* for a sequence of rounds. Each sequence of rounds is referred to as a match.

2. *During each match, your team will compete against one adversary team randomly chosen between the other teams in this experiment. The team that earns more points at the end of the match will be declared the winner.*

3. The length of a match is randomly determined. After each round, there is a 75% probability that the match will continue for at least another round. This probability is always the same regardless of the round. So, for instance, if you are in round 2, the probability there will be a third round is 75%, and if you are in round 9, the probability there will be another round is also 75%. *The match will end for both teams at the same time.*

4. At the beginning of a new match, you will be randomly paired with another *teammate, and you will play against a new adversary team.*

5. The choices and the payoffs (expressed in points) in each round are as follows:

*Teammate's choice*

| Your choice | **1** | **2** |
|---|---|---|
| **1** | (32 , 32) | (12 , 50) |
| **2** | (50 , 12) | (25 , 25) |

The first entry in each cell represents your payoff, while the second entry represents the payoff of your *teammate*. *The sum of your payoff and your teammate's payoff in each round during the whole match will determine your total team's points in the match.*
For example, if:

- You select **1** and the *teammate* selects **1**, you each make 32. *The team's points in the round will be equal to 64.*
- You select **1** and the *teammate* selects **2**, you make 12 while the *teammate* makes 50. *The team's points in the round will be equal to 62.*
- You select **2** and the *teammate* selects **1**, you make 50 while the *teammate* makes 12. *The team's points in the round will be equal to 62.*
- You select **2** and the *teammate* selects **2**, you each make 25. *The team's points in the round will be equal to 50.*

*If the total points of your team are higher than the total points of the adversary team, your team wins the match, otherwise, your team loses.*

6. At the end of the 50 min, you will be paid 0.005€ (half of a euro cent) for every point you scored individually in every round played during the whole experiment. ***Note that you will not earn any additional money for winning a match.***

7. Are there any questions?

## B.3 Questionnaire

### Socio-Demographics

- How old are you?

- What is your gender? ☐ Male ☐ Female

- What is your occupation?
  ☐ Student
  ☐ Employee
  ☐ Unemployed
  ☐ Retired
  ☐ Other

- What is your field of study?
  ☐ Economics and management
  ☐ Social Sciences
  ☐ Arts and Humanities
  ☐ Engineering Sciences
  ☐ Medical studies
  ☐ Other

- How much prior experience do you have with LEEN?

### Psychological questions

- From 0 to 10, how much do you trust people in general, where 0 indicates "better not trust none" and 10 means "better completely trust"?

  0 1 2 3 4 5 6 7 8 9 10

- For a scale from 0 to 10, how do you evaluate your behavior in front of risk: you are a person who avoids risk (1), or do you love risk (10)?

  0 1 2 3 4 5 6 7 8 9 10

# C Sample

Table C.1 reports the results of OLS regressions of *Tournament* on the relevant variable elicited in the questionnaire. The estimates show the treatment assignment was balanced with respect to all these variables. Table C.2 reports descriptive statistics at the session level.

| | Age | Female | Student | Economic background | Lab experience | Risk | Trust |
|---|---|---|---|---|---|---|---|
| *Tournament* | -1.042 | -0.111 | 0.049 | 0.155 | 0.063 | 0.011 | -0.096 |
| | (1.05) | (0.10) | (0.07) | (0.10) | (0.57) | (0.41) | (0.38) |
| Constant | 24.5*** | 0.674*** | 0.826*** | 0.283*** | 2.978*** | 5.739*** | 5.804*** |
| | (0.75) | (0.07) | (0.05) | (0.07) | (0.41) | (0.29) | (0.27) |
| Participants | 94 | 94 | 94 | 94 | 94 | 94 | 94 |
| R-squared | 0.011 | 0.013 | 0.005 | 0.026 | 0.000 | 0.000 | 0.001 |

**Table C.1** Balancing test. Standard errors in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

| | Control | | | Tournament | | |
|---|---|---|---|---|---|---|
| | $S_1$ | $S_2$ | $S_3$ | $S_1$ | $S_2$ | $S_3$ |
| Supergames | 27 | 28 | 29 | 29 | 14 | 23 |
| Duration (rounds) | 3.96 | 3.86 | 4.14 | 3.55 | 7.29 | 4.96 |
| | (3.47) | (2.86) | (4.49) | (2.69) | (5.37) | (3.65) |
| First-round cooperation (%) | 37.5 | 31.89 | 45.69 | 60.34 | 34.82 | 60.33 |
| | (9.01) | (10.56) | (7.85) | (9.34) | (15.45) | (8.13) |
| Cooperation (%) | 35.28 | 22.73 | 42.21 | 52.21 | 27.77 | 46.24 |
| | (7.01) | (8.82) | (8.84) | (12.06) | (15.57) | (13.30) |

**Table C.2** Summary statistics by session. Standard deviations in parentheses.

# D Strategy Estimation

The following are the 17 strategies we consider in our initial set of strategies. Always Defect (AD), Always Cooperate (AC), Grim, Tit for Tat (TFT), 2TFT defects if opponent defected in either of the last 2 rounds, Win Stay Lose Shift (WSLS), T2-T8 are threshold strategies that cooperate until round 2-8 and then defects forever, suspicious Tit for Tat (STFT) is equal to TFT with the only difference being it starts by defecting, Grim2-3 are lenient version of Grim that defect forever if the partner defects in 2-3 consecutive rounds, and Tit for Two Tat (TF2T), a lenient version of TFT that retaliates only after an opponent has defected twice in a row.

## D.1 Decisions from supergames 20-29

| | *Control* | *Tournament* |
|---|---|---|
| AD | 0.378*** (0.078) | 0.233*** (0.065) |
| AC | | |
| TFT | 0.130** (0.056) | 0.197*** (0.064) |
| STFT | 0.323*** (0.076) | 0.196*** (0.062) |
| Grim | 0.052 (0.038) | 0.191*** (0.065) |
| Grim2 | | 0.053 (0.041) |
| Grim3 | | 0.052 (0.044) |
| TF2T | 0.025 (0.026) | 0.035 (0.042) |
| 2TFT | 0.031 (0.032) | |
| WSLS | | |
| T2 | | 0.043 (0.032) |
| T3 | 0.022 (0.021) | |
| T4 | 0.022 (0.022) | |
| T5 | | |
| T6 | 0.017 (0.021) | |
| T7 | | |
| T8 | | |
| $\beta$ | 0.896 (0.017) | 0.883 (0.017) |
| LL | -1072.591 | |
| BIC | 2299.653 | |

**Table D.1** Estimated shares of strategies from the full initial set. Shares with an estimated value of zero are not displayed to improve readability. Standard errors are bootstrapped from 10,000 resamples and reported in parentheses. The statistical significance of each share is assessed based on the estimated distribution of the parameter. $\beta$ is implied by the estimated tremble and represents the probability that subjects follow what is prescribed by the strategies. The log-likelihood (LL) and the Bayesian Information Criterion (BIC) of the joint model fit are displayed in the last two rows. $^{*}$ $p < 0.10$, $^{**}$ $p < 0.05$, $^{***}$ $p < 0.01$

| | Shares | | $\beta$ | |
|---|---|---|---|---|
| | *Control* | *Tournament* | *Control* | *Tournament* |
| AD | 0.305*** (0.069) | 0.194** (0.091) | 0.988 (0.006) | 0.909 (0.026) |
| TFT | 0.103** (0.050) | 0.155*** (0.079) | 0.936 (0.054) | 0.955 (0.056) |
| STFT | 0.432*** (0.078) | 0.195*** (0.101) | 0.812 (0.024) | 0.879 (0.055) |
| Grim | 0.059 (0.039) | 0.209** (0.087) | 0.98 (0.054) | 0.91 (0.030) |
| Grim2 | 0.022 (0.022) | 0.041 (0.029) | 0.000 (0.147) | 0.000 (0.065) |
| Grim3 | | 0.089* (0.064) | | 0.836 (0.062) |
| T2 | 0.031 (0.030) | 0.021 (0.029) | 0.398 (0.078) | 0.000 (0.229) |
| T3 | 0.047 (0.034) | 0.095* (0.058) | 0.727 (0.119) | 0.556 (0.190) |
| LL | -990.3886 | | | |
| BIC | 2117.076 | | | |

**Table D.2** Estimated shares of strategies selected by the Bayesian Information Criterion (BIC) with different trembles per strategy. Shares with an estimated value of zero are not displayed to improve readability. Standard errors are bootstrapped from 10,000 resamples and reported in parentheses. The statistical significance of each share is assessed based on the estimated distribution of the parameter. $\beta$ is implied by the estimated tremble and represents the probability that subjects follow what is prescribed by the strategies. The log-likelihood (LL) and the Bayesian Information Criterion (BIC) of the joint model fit are displayed in the last two rows. $^{*}$ $p < 0.10$, $^{**}$ $p < 0.05$, $^{***}$ $p < 0.01$

## D.2 Decisions from all supergames

| | *Control* | *Tournament* |
|---|---|---|
| AD | 0.382*** (0.075) | 0.228*** (0.063) |
| TFT | 0.240*** (0.064) | 0.197*** (0.061) |
| STFT | 0.241*** (0.067) | 0.184*** (0.059) |
| Grim | 0.111** (0.051) | 0.300*** (0.068) |
| Grim2 | 0.026 (0.026) | 0.021 (0.021) |
| 2TFT | | 0.049 (0.034) |
| T8 | | 0.021 (0.021) |
| $\beta$ | 0.844 (0.016) | 0.838 (0.014) |
| LL | -4623.455 | |
| BIC | 9310.516 | |

**Table D.3** Estimated shares of strategies selected by the Bayesian Information Criterion (BIC) using all available decisions. Shares with an estimated value of zero are not displayed to improve readability. Standard errors are bootstrapped from 10,000 resamples and reported in parentheses. The statistical significance of each share is assessed based on the estimated distribution of the parameter. $\beta$ is implied by the estimated tremble and represents the probability that subjects follow what is prescribed by the strategies. The log-likelihood (LL) and the Bayesian Information Criterion (BIC) of the joint model fit are displayed in the last two rows. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

| | *Control* | *Tournament* |
|---|---|---|
| AD | 0.382*** (0.075) | 0.229*** (0.064) |
| AC | | |
| TFT | 0.240*** (0.065) | 0.172*** (0.058) |
| STFT | 0.242*** (0.066) | 0.185*** (0.060) |
| Grim | 0.095** (0.047) | 0.273*** (0.068) |
| Grim2 | 0.023 (0.022) | 0.021 (0.021) |
| Grim3 | | |
| TF2T | | 0.023 (0.024) |
| twoTFT | | 0.05 (0.035) |
| WSLS | | |
| T2 | | 0.027 (0.027) |
| T3 | 0.019 (0.021) | |
| T4 | | |
| T5 | | |
| T6 | | |
| T7 | | |
| T8 | | 0.021 (0.021) |
| $\beta$ | 0.844 (0.016) | 0.84 (0.014) |
| LL | -4617.302 | |
| BIC | 9389.077 | |

**Table D.4** Estimated shares from the full set of strategies using all available decisions. Shares with an estimated value of zero are not displayed to improve readability. Standard errors are bootstrapped from 10,000 resamples and reported in parentheses. The statistical significance of each share is assessed based on the estimated distribution of the parameter. $\beta$ is implied by the estimated tremble and represents the probability that subjects follow what is prescribed by the strategies. The log-likelihood (LL) and the Bayesian Information Criterion (BIC) of the joint model fit are displayed in the last two rows. $^{*}$ $p < 0.10$, $^{**}$ $p < 0.05$, $^{***}$ $p < 0.01$

# E Additional Figures

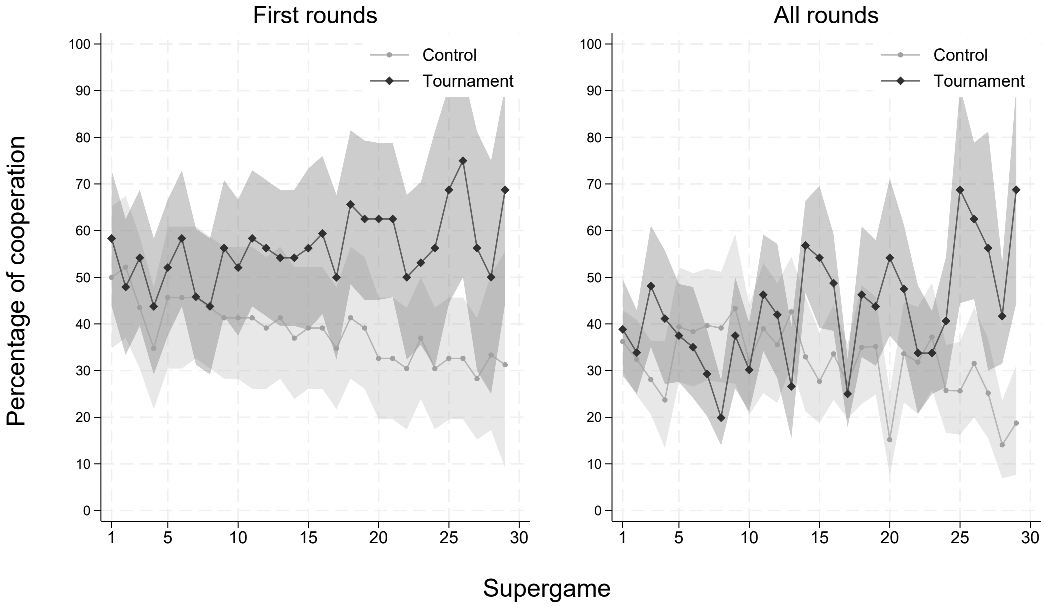


**Figure E.1** Replication of Figure 1 with confidence intervals. Note: shaded areas report 95% subject-level block-bootstrap confidence intervals, based on 10,000 replications.

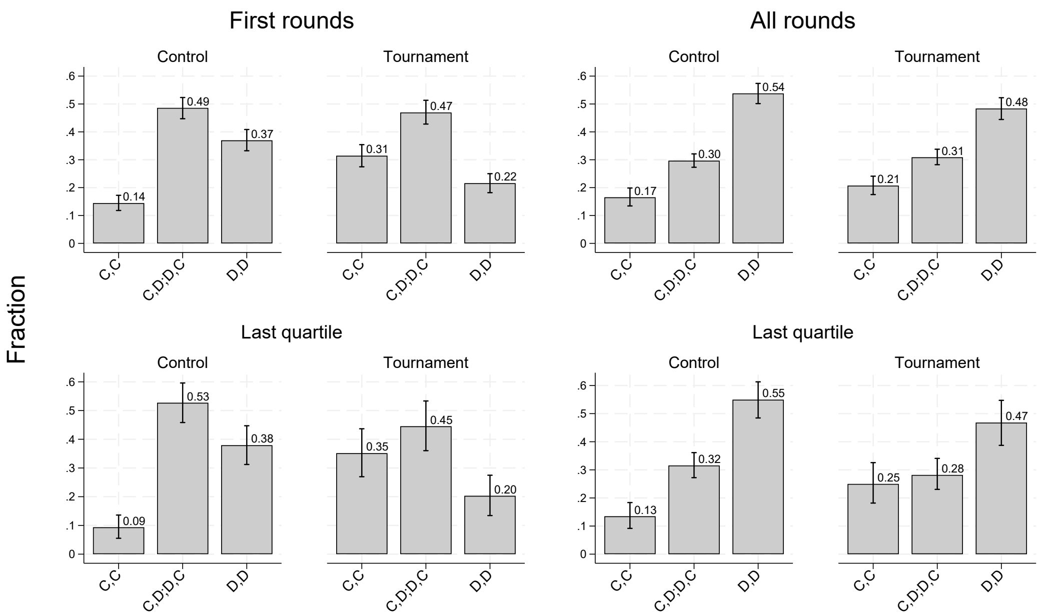


**Figure E.2** Replication of Figure 2 with confidence intervals. Note: vertical bars report 95% pair-level block-bootstrap confidence intervals, based on 10,000 replications.