The Enemy of My Enemy: How Competition Mitigates Social Dilemmas*

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Abstract

We study whether competition between groups fosters within-group cooperation, even when it yields no material rewards. In a laboratory experiment, pairs of subjects played an indefinitely repeated Prisoner's Dilemma game either in isolation or in a tournament against another pair. Winning conferred no monetary payoff. Competition increased cooperation, and the effect strengthened over time as subjects gained experience. By exploiting the binary action space of the repeated game, we estimate the participants' strategies and find that competition reallocates play away from strategies that start with defection toward strategies that start with cooperation. This reallocation results from a shift from Always Defect to the least risky cooperative strategy, Grim, showing that non-monetary competition relocates equilibrium selection toward cooperative trigger 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. Uncovering the factors and conditions that promote cooperative behavior over selfish decisions remains of critical importance. A prominent mechanism proposed to foster cooperation is intergroup competition, which is pervasive in practice but typically combined with financial incentives. This confounding makes it difficult to identify the effect of competition per se, as opposed to that of monetary rewards.

In this paper, we investigate whether intergroup competition promotes within-group cooperation in the absence of material incentives. To this end, we run a laboratory experiment in which pairs of subjects play an indefinitely repeated Prisoner's Dilemma game (PD). 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 competition absent material prizes.

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. The most common strategy followed by subjects in the baseline prescribes unconditional defection. By contrast, in the treatment, a substantial share of subjects adopt Grim, the least risky cooperative strategy. Competition appears to foster a cooperative norm under which players mutually cooperate, and deviations are met with harsh punishment. These differences reveal that competition alone alters behavior along dimensions not visible in aggregate cooperation rates. By exploiting the binary and history-dependent structure of the repeated PD, our design and strategy-mixture estimation offer a key methodological contribution to the study of 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,

[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.

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 operates in an indefinitely repeated Prisoner's Dilemma with its binary action space. This paper aims to address both questions.

As a first contribution, we show that intergroup competition, absent material incentives, fosters within-group cooperation. This result is important because much of the experimental literature employs monetary rewards, confounding competition per se with direct incentive effects. To the best of our knowledge, Cárdenas and Mantilla (2015) and Tan and Bolle (2007) are the only two papers that study the effect of intergroup competition on cooperation, both of which report higher cooperation when winning is materially incentivized. Tan and Bolle (2007) also finds a positive effect of relative-performance feedback. Our design differs in three respects: (i) it employs an indefinitely repeated Prisoner's Dilemma rather than a public goods game; (ii) it includes a condition without relative information as opposed to Cárdenas and Mantilla (2015), allowing for the identification of competition per se; and (iii) it implements indefinite repetition, thus avoiding endgame effects. Therefore, we isolate competition from material incentives and, exploiting the PD's binary, history-dependent structure, uncover individual strategies.

Our second contribution is that we capture the tension between individual and collective interest by employing the indefinitely repeated PD. This methodological choice is particularly advantageous, as its binary decision framework (*Cooperate* or *Defect*) clearly 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 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.

Although the experiment is not designed to discriminate among mechanisms, we complement it with a simple theoretical framework that rationalizes our empirical results. The model introduces a hedonic utility from winning an intergroup tournament, which, without altering monetary payoffs, raises the continuation value of cooperation for otherwise self-interested players. The resulting implications align with the empirical reallocation of strategies that we observe. We acknowledge that other channels, such as enhanced group identity or framing, may also contribute to this result. However, distinguishing among them is beyond the scope of this study. Unlike other theories that assume social preferences or "team reasoning" (e.g., Ellingsen, Johannesson, Mollerstrom, & Munkhammar, 2012; Bacharach, 1999), our explanation does not rely on other-regarding motives and applies to purely self-interested agents.

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.

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. 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.

	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

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

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 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.

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] See the questionnaire in Appendix B.

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 strategies 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 ($p = 0.038$).[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 ($p = 0.014$), 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 ($p = 0.066$). 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: $p = 0.1727$), 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 ($p = 0.163$) or in time trends across treatments ($p = 0.326$).

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,

[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 from mixed-effects probit models with standard errors clustered at the participant level where cooperation is regressed against the relevant variables.

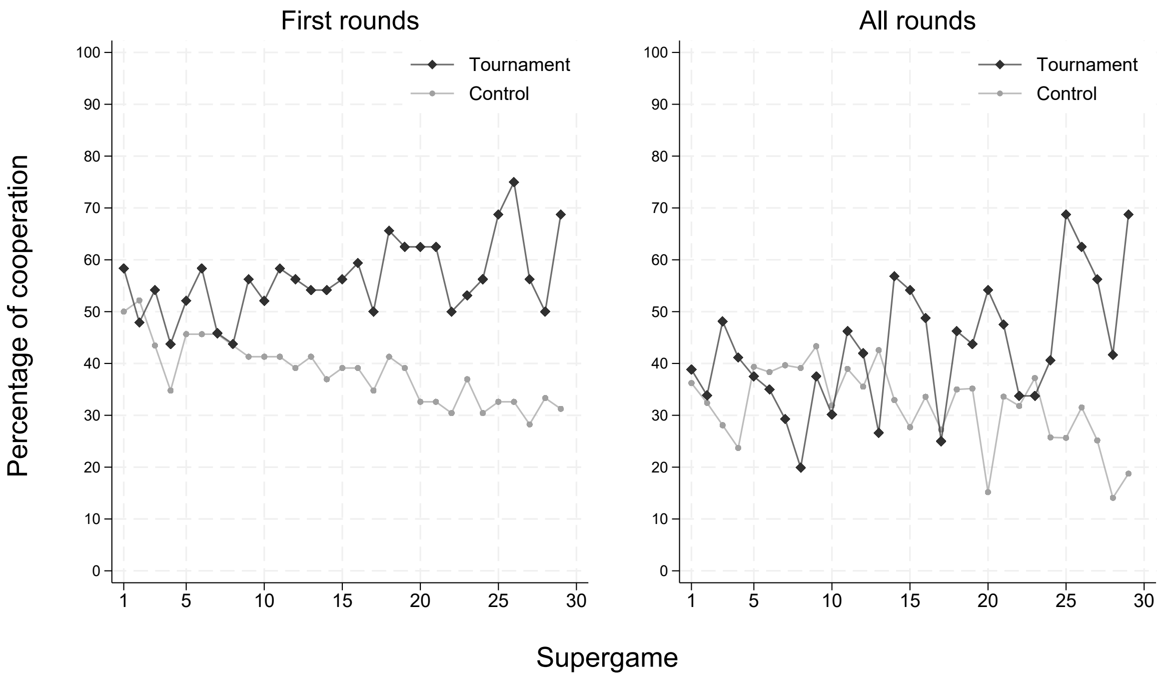

Figure 1 Percentage of cooperation by supergame. The left panel shows cooperation rates in the first rounds of each supergame. The right panel uses all observations.

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.

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

	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. Statistical significance is assessed by estimating average marginal effects from a mixed-effects probit model with standard errors clustered at the participant level, where cooperation is regressed against the treatment dummy, the quartile dummies, as well as their interactions.

panel: $p = 0.000$; bottom-right panel: $p = 0.006$).[6]

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.

In Figure 3, we visually investigate the role of previous outcome realizations on cooperation. The figure reports the probability of cooperation conditional on the previous realized outcome within a dyad, excluding first rounds so that comparisons reflect within-relationship dynamics rather than initial beliefs. We acknowledge that this represents a naive analysis of the mechanisms underlying the treatment effect, as it overlooks the within- and between-pair histories of choices. However, we believe it provides important visual evidence that motivates our strategy estimation presented in the next section. Figure 3 shows a more pronounced pattern consistent with grim-like behavior and lenient cooperative strategies in *Tournament*: higher cooperation rates after *C,C* and *D,C*, and lower cooperation rates after *C,D*, and *D,D*. These conditional histories visually show that competition increases cooperation after mutual cooperation, while leaving responses to deviations at least as punitive as those in *Control*. This pattern is consistent with a focal cooperative standard that prescribes playing C to remain on the path and is reinforced by strict deterrence, which punishes deviations from it. However, conditional frequencies cannot tell whether this operates through a reallocation across decision rules or changes in error rates within rules. This motivates the structural analysis we provide in Section 3.2, where we estimate a finite mixture model to quantify how competition

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

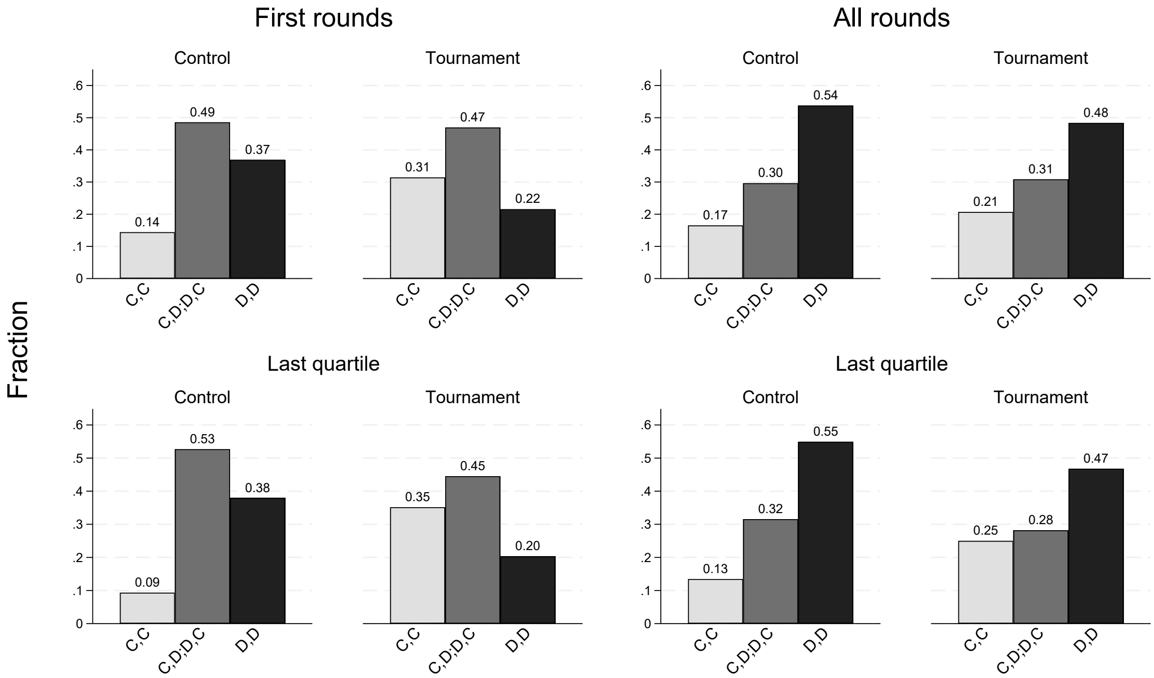

Figure 2 Outcomes by treatment. Pictures in the left column show the fraction of outcomes for only the first rounds of each supergame. The pictures in the second column use all rounds of every supergame. The first row uses choices from the entire experimental session, while the bottom row only uses decisions 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).

reshapes the strategy mix.

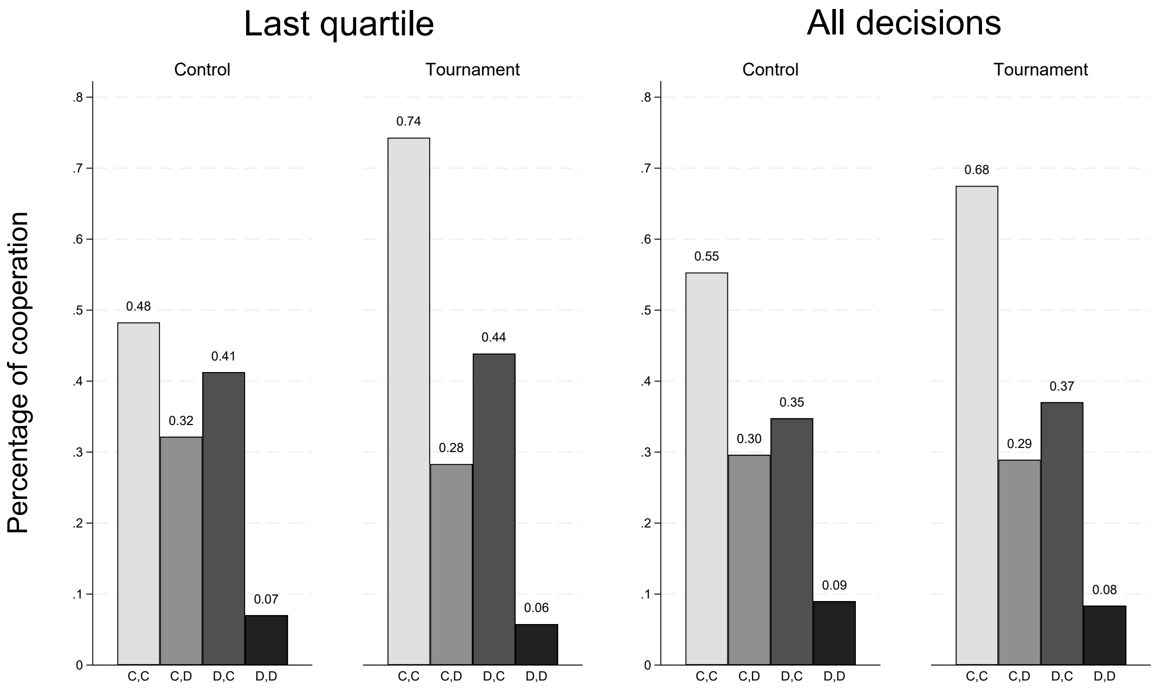

Figure 3 Percentage of cooperation conditional on the previous outcome. Only within supergame histories are considered. Hence, the first round of each supergame is excluded.

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).[7] 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.[8] Given the observed action histories, we estimate the model by maximum likelihood and obtain, for each treatment,

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

[8]Aligning with the literature, we assume a common probability of mistakes within each treatment rather than strategy-specific trembles. In Table D.2, we provide results from an estimation of the selected set of strategies presented in the main analysis, relaxing this assumption. Our main conclusions remain unchanged.

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.[9] 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.[10] Finally, because an overly rich candidate set can induce instability in the classification of observationally similar types, we use the Bayesian Information Criterion (BIC) to select 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 (STFT), that starts defecting and then plays as TFT; Grim that cooperates until a defection from the opponent, then defects forever; Grim 2-3 that are lenient version of Grim where defection is triggered by 2-3 consecutive defections of the opponent; and T2-3 cooperate for 2-3 rounds and then defect forever. We then refit the model on the selected set of strategies to estimate treatment-specific shares and trembles. Results are reported in Table 3.

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 β, 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. The larger weight on trigger-type enforcement and less on unconditional defection aligns with the evidence presented before and motivates the theoretical account in Section 4, where a small non-monetary utility from winning makes cooperative trigger strategies easier to sustain and select.

Taken together, our estimates indicate that intergroup competition enhances initial cooperation and reallocates probability mass toward trigger strategies that promote enforcement, thereby strengthening cooperation and serving as a coordination device.

[9] In Appendix D we describe the full set of candidate strategies and provide model estimates of the full set in Table D.1. Our main conclusions do not change even when considering the full set.

[10] 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.

	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)	
β	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 removed 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 parameter distribution. β represents the implied probability that the population in each treatment follows the considered set of strategies. The log-likelihood (LL) and the Bayesian Information Criterion (BIC) of the estimated model are displayed in the last two rows. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

4 Theoretical Framework

The results presented in the previous section indicate that intergroup competition increases cooperation and alters the distribution of strategies: fewer participants choose Always Defect, while a relevant 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 competition can affect the equilibria of the game by introducing a tournament between pairs of players that are playing an infinitely repeated Prisoner's Dilemma. The pair that achieves the highest cumulative sum of aggregate payoffs (points) wins the tournament. Because cooperation leads to more points, cooperating increases the odds of winning. No additional monetary payoffs are awarded to the winners. We assume that players experience hedonic utility when winning the tournament. This additional incentive modifies the strategic environment and lowers the threshold under which cooperation can be supported in equilibrium. In particular, the model predicts a shift from Always Defect to the least risky cooperative strategy, Grim, which is precisely what we observe in the data.

Apart from hedonic utility, other theories like group identity (Y. Chen & Li, 2009) and social framing (Tversky & Kahneman, 1981) might represent concurrent candidates in explaining our results. However, these theories typically require the assumption that one's utility depends on the partner's payoff, and thus tend to predict greater leniency following deviations (i.e., more forgiveness off the path) and more weight on forgiving strategies.

However, this is not what we find empirically. While such forces may contribute to higher initial cooperation, the pattern of on-path compliance, along with tougher deterrence, is more in line with our theoretical framework, where subjects are purely self-interested.

4.1 The Model

In what follows, we analyze the game described in the previous section, an indefinitely repeated PD. To ease the exposition, we perform a normalization of the payoff matrix as shown in Table 4.[11] To ensure that mutual cooperation generates a higher combined outcome, it is required that $2 > 1 + g - \ell > 0$. 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 compute, from the game parameters, the thresholds δ^{SPE} and δ^{RD}. To sustain cooperation in a subgame perfect equilibrium (SPE), players must be sufficiently forward-looking, meaning that the discount factor δ^{SPE} must be large enough. Specifically, cooperation can be sustained if the discount factor satisfies the following condition:

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

We can also determine the minimum value of δ required for cooperation to be part of a risk-dominant equilibrium.[12] This condition is met when:

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

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

[11] We performed the same normalization as in Dal Bó and Fréchette (2018). For our game, the game's parameters are set to: $g = \frac{25}{7}$ and $\ell = \frac{13}{7}$, while the continuation probability is set to $\delta = 0,75$.

[12] Harsanyi and Selten (1988) define risk dominance for 2×2 games. It is possible to extend the concept of risk dominance to repeated games using auxiliary 2×2 games that implement specific equilibrium strategies. For more reference, see Blonski and Spagnolo (2015).

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 assigns a non-negative hedonic utility, denoted as $W \geq 0$, when their team wins the tournament. 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, denoted $\mathbb{P}(win|s)$, 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. In the following, we focus on three benchmark strategies: Always Cooperate (AC), Grim (G), and Always Defect (AD). Given the structure of the stage-game payoffs, with $2 > 1 + g - \ell > 0$, it follows that AC yields the highest expected score, followed by G and then AD. Consequently $\mathbb{P}(win|\text{AC}) \geq \mathbb{P}(win|\text{G})) \geq \mathbb{P}(win|\text{AD})$.

This ranking suffices to establish our main results; no additional assumptions on the functional form of $\mathbb{P}(win|s)$ 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 $\mathbb{P}(win|s)$ 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 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 δ^{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 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, δ^{SPE^*}, is lower than δ^{SPE} in the absence of the tournament. Moreover δ^{SPE^*}*

is equal to:

$$\delta^{SPE^*} = \frac{g - W\big(\mathbb{P}(win|AC) - \mathbb{P}(win|G)\big)}{1 + g - W\big(\mathbb{P}(win|AC) - \mathbb{P}(win|G)\big)} \leq \frac{g}{1+g} = \delta^{SPE}.$$

This first result demonstrates that the tournament reduces the threshold for cooperation to be sustained in an SPE. This implies that competition can enhance cooperation, even without altering the stage game's payoffs.

To prove that the tournament lowers the threshold for a risk-dominant equilibrium δ^{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).[13] By following the steps outlined in Blonski and Spagnolo (2015), we derive the following result:

Proposition 2. *Let W 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, δ^{RD^*}, is lower than δ^{RD} in the absence of the tournament. Moreover, δ^{RD^*} is equal to:*

$$\delta^{RD^*} = \frac{g + l - W\big(\mathbb{P}(win|AC) - \mathbb{P}(win|AD)\big)}{1 + g + l - W\big(\mathbb{P}(win|AC) - \mathbb{P}(win|AD)\big)} \leq \frac{g+l}{1+g+l} = \delta^{RD}.$$

This second result is particularly relevant in our setting because, in our game, the parameters are such that cooperation can be sustained in an SPE, but it is not risk dominant. The game parameters used in our experiment are such that cooperation can be sustained in equilibrium, as the derived δ^{SPE} is 0.72, which is lower than the continuation probability of $\delta = 0.75$. However, cooperation is not risk-dominant, as indicated by the fact that $\delta^{RD} = 0.84$ is higher than the continuation probability. As Proposition 2 suggests, players who care enough about winning might switch from Always Defect to Grim in the *Tournament* treatment. This is actually the result we empirically observe, which we report in Section 3.2, where we estimate the strategies played by participants.

To prove the first proposition, we followed the proof of Nash reversion, introducing the utility W and taking into account the probability of winning given each strategy. We followed the same logic to prove proposition 2, while following the proof of Blonski and Spagnolo (2015). The detailed proofs can be found in appendix A.

5 Conclusions

This study provides robust evidence that competition between groups can significantly improve cooperation in strategic decision-making scenarios, even without material rewards

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

for the winners. The experimental results show a significant increase in cooperation in the tournament compared to the control condition, with the effect strengthening as participants gain experience. We also uncover how competition influences participants' strategic behavior, promoting a shift from strategies that prescribe starting by defection to the least risky cooperative strategy, Grim. This insight relies on the Prisoner's Dilemma game, which represents a key methodological innovation compared to the existing literature. To interpret these findings, we present a simple theoretical model in which hedonic utility from winning a tournament lowers the threshold for sustaining cooperation in equilibrium. While other explanations based on group identity or social preferences remain plausible, our model offers a complementary perspective grounded in individual strategic incentives. Interpreted through this lens, competition acts as a coordination device that makes the cooperative path focal and deviations saliently punishable.

These findings highlight the effectiveness of non-monetary competition in fostering cooperation and underline the added value of our methodological approach. The use of the indefinitely repeated Prisoner's Dilemma enabled precise estimation of the strategies employed by participants and supported a more tractable theoretical framework, offering valuable insights into the impact of competition on strategic decision-making and cooperative behavior.

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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 weighted by the probability of winning given the strategy played. Therefore, the equation becomes the following:

$$\sum_{t=t^*}^{\infty} \delta^t \cdot 1 + W\mathbb{P}(win|\text{AC}) \geq 1 + g + \sum_{t=t^*+1} \delta^t \cdot 0 + W\mathbb{P}(win|\text{G})$$

where AC is the continuation strategy in which both players keep cooperating, while G is the Grim strategy in which the player "pulls the trigger" at time t^*, and after that, both players play *Defect*. Since $2 > 1 + g - \ell$, the strategy AC gives more points than the strategy G, thus $\mathbb{P}(win|\text{AC}) - \mathbb{P}(win|\text{G}) \geq 0$.

Rearranging the formula, we obtain:

$$\delta^{SPE^*} = \frac{g - W\Big(\mathbb{P}(win|\text{AC}) - \mathbb{P}(win|\text{G})\Big)}{1 + g - W\Big(\mathbb{P}(win|\text{AC}) - \mathbb{P}(win|\text{G})\Big)} \leq \frac{g}{1+g}, \qquad \forall\ W > 0.$$

$\square$

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 (G), which is the least risky among cooperative equilibria (proof in Blonski and Spagnolo (2015)), and always defect (AD). We build an accessory 2×2 game using only these two equilibrium points. According to Harsanyi and Selten (1988), risk dominance in 2×2 games can be determined by comparing the Nash-products of the two equilibria, namely the product of both players' disincentives not to behave according to the equilibrium under consideration. We call these disincentives u_i for G and v_i for AD, and they are defined as:

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

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

The grim trigger strategy G 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 δ below which G is risk-dominated is the following:

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

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

$$u_i = \sum_{t=t^*}^{\infty} \delta^t \cdot 1 + W\mathbb{P}(win|\text{AC}) - \Big(1 + g + \sum_{t=t^*+1} \delta^t \cdot 0 + W\mathbb{P}(win|\text{G}) \Big) \geq 0$$

$$v_i = \sum_{t=t^*}^{\infty} \delta^t \cdot 0 + W\mathbb{P}(win|\text{AD}) - \Big(-l + \sum_{t=t^*+1} \delta^t \cdot 0 + W\mathbb{P}(win|\text{G}) \Big) \geq 0.$$

Using the same procedures as before, we obtain,

$$\Big(l + W\Big(\mathbb{P}(win|\text{AD}) - \mathbb{P}(win|\text{G})\Big)\Big)^2 - \Big(\frac{1}{1-\delta} - (1+g) + W\Big(\mathbb{P}(win|\text{AC}) - \mathbb{P}(win|\text{G})\Big)\Big)^2 \geq 0$$

and by rearranging the formula, we obtain:

$$\delta^{RD^*} = \frac{g + l - W\Big(\mathbb{P}(win|\text{AC}) - \mathbb{P}(win|\text{AD})\Big)}{1 + g + l - W\Big(\mathbb{P}(win|\text{AC}) - \mathbb{P}(win|\text{AD})\Big)} \leq \frac{g+\ell}{1+g+\ell}, \qquad \forall\ W > 0.$$

Where the strategies AC, AD, and G are, respectively, Always Cooperate, Always Defect, and the Grim strategy. $\square$

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 experience have you had with LEEN before?

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.

	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. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

D Strategies 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 following a defection of the opponent in the last 2-3 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		
β	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 removed 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 parameter distribution. β represents the implied probability that the population in each treatment follows the considered set of strategies. The log-likelihood (LL) and the Bayesian Information Criterion (BIC) of the estimated model are displayed in the last two rows. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

	Shares		β	
	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	0.000 (0.025)	0.089 (0.064)	0.66 (0.092)	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. Standard errors are bootstrapped from 10,000 resamples and reported in parentheses. The statistical significance of each share is assessed based on the estimated parameter distribution. β represents the implied probability that the population in each treatment follows the prescribed strategy. The log-likelihood (LL) and the Bayesian Information Criterion (BIC) of the estimated model 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)
β	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 removed 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 parameter distribution. β represents the implied probability that the population in each treatment follows the considered set of strategies. The log-likelihood (LL) and the Bayesian Information Criterion (BIC) of the estimated model 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)
β	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 removed 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 parameter distribution. β represents the implied probability that the population in each treatment follows the considered set of strategies. The log-likelihood (LL) and the Bayesian Information Criterion (BIC) of the estimated model are displayed in the last two rows. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$