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

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Abstract

This paper studies how competition between groups affects cooperation. In the control condition, pairs of subjects play an indefinitely repeated Prisoner's Dilemma game without external competition. In the treatment, two pairs compete against each other. No monetary rewards are tied to winning, isolating the bare impact of competition. In the treatment, cooperation increases by 16 percentage points. Strategies estimation shows a shift from selfish strategies (Always Defect) to cooperative ones (Grim Trigger). A theoretical model provides a rationale for the experimental results.

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

JEL code: C73, C92, D81.

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1 Introduction

Empirical and anecdotal evidence shows that cooperation within groups is vital in many institutions, as it promotes productive and harmonious team dynamics. However, the conflict between selfish and cooperative choices endures in many social and economic interactions, presenting a trade-off between individual and collective interests. As a consequence, uncovering the mechanisms that promote cooperative behavior over selfish decisions remains of critical importance.

In this paper, we investigate whether competition between groups can foster within-group cooperation by conducting a laboratory experiment in which pairs of subjects play an indefinitely repeated Prisoner's Dilemma (PD). We compare behavior in this task with choices in a treatment that introduces a tournament among pairs of players without changing the game's payoffs. While participants' earnings are based on the individual outcome of the PD, there are no monetary rewards for winning the competition, allowing us to isolate the bare impact of competition on cooperative behavior. We find that cooperation increases by 16 percentage points in the tournament compared to the control condition, and this effect unfolds as subjects gain experience. The result is driven by a change in the strategies participants play. While in the control condition, the most common strategy is always to defect, a significant fraction of subjects in the tournament adopt the less risky strategy that reinforces mutual cooperation. This difference highlights how competition affects participants' decision-making in ways that cannot be observed by merely looking at aggregate cooperation rates. The estimation of the strategies subjects play relies on the features of the Prisoner's Dilemma and constitutes the main innovation of this paper.

Although this work is not designed to compare or test alternative theories directly, we integrate our experiment with an ad-hoc theoretical framework. We demonstrate that intergroup tournaments can positively affect cooperation even though no monetary prizes are awarded to the winners, and players have no other-regarding preferences but only experience a hedonic utility from winning. This result confirms that non-monetary tournament incentives are effective even for self-interested individuals who typically exhibit the lowest levels of cooperation. Our theoretical analysis corroborates the experimental findings by showing that, in the tournament, a share of individuals prefer the grim trigger strategy – the least risky cooperative strategy – over consistently defecting. Our prediction is grounded on principles different from those underlying prevailing theories, which often assume that players consider the well-being of others (Ellingsen, Johannesson, Mollerstrom, & Munkhammar, 2012), or rely on "team reasoning" (Bacharach, 1999), and do not apply to purely self-interested individuals.

This paper provides evidence that intergroup competition fosters within-group cooperation, even when individual and collective interests diverge, and no monetary payments are awarded to the winners. Our results can translate to real-world settings, where competition can be implemented as an effective performance management strategy. By structuring tournaments between distinct teams or business units, organizations and institutions can harness the benefits of competition with virtually no additional costs.

Mechanisms that have been shown to foster within-group cooperation are punishment (Dai, Hogarth, & Villeval, 2015; Fehr & Gächter, 2000; Nikiforakis & Normann, 2008), communication (Isaac & Walker, 1988), charitable donations (Butz & Harbring, 2020), and redistribution (Sausgruber & Tyran, 2007), to name a few. In this paper, we instead focus on competition among groups. The use of intergroup competition to improve cooperation is a practice prevalent in merit-based promotions within internal labor markets, R&D, and academic research, among others. Its benefits are well documented in the experimental literature as it fosters cooperation among team members by providing monetary rewards for their group's relative performance (e.g., Abbink, Brandts, Herrmann, & Orzen, 2010; Chen, 2020; Markussen, Reuben, & Tyran, 2014; Puurtinen & Mappes, 2009; Reuben & Tyran, 2010; Tan & Bolle, 2007).

To the best of our knowledge, the interplay between cooperation and intergroup competition has only been experimentally investigated within the Public Goods Game (PGG) framework.[1] With a few notable exceptions that will be discussed later, this literature has predominantly combined tournaments with monetary incentives. Our paper departs from this approach. In what follows, we clarify how our work differs from previous studies and explain its contributions to the relevant literature.

Our first contribution resides in the use of the indefinitely repeated Prisoner's Dilemma, which, despite its simplicity, captures the tensions between individual and collective interests. This methodological choice is particularly advantageous, as its binary decision framework (Cooperate or Defect) clearly represents participants' intentions. The decision to cooperate unequivocally indicates a willingness to prioritize collective interests over individual gains, offering an unambiguous measure of cooperative behavior. This contrasts with PGGs, where the broader choice set available to participants introduces potential ambiguity in the interpretation of cooperative behavior, which is further exacerbated by efficiency considerations. For instance, a contribution below the group's average may be interpreted as free-riding, even though the individual is still engaging in cooperative behavior. The binary nature of the decision framework of the PD allows us to estimate the strategies employed by participants rather than merely observing aggregate levels of cooperation. Estimating strategies from actual choices is not a trivial task for two main reasons. First, the number of possible strategies is virtually infinite (Fudenberg

[1]Other studies employing intergroup contests focus on different outcomes such as effort provision or voting. See De Jaegher (2021) and Sheremeta (2018) for recent overviews of the literature. Bornstein and Ben-Yossef (1994) study contests using the Intergroup Prisoner's Dilemma (IPD). Unlike our design, in their experiment, there is a monetary bonus that depends on the number of in-group contributors relative to the out-group.

& Maskin, 1986). Second, while each choice is conditional to a specific history, we only observe one actual choice and not what subjects would have done at other decision stages. To study the strategies individuals play in our experiment, we use the Strategy Frequency Estimation Method (SFEM) introduced in Dal Bó and Fréchette (2011). This method consists of pre-specifying a set of strategies whose individual occurrence is then estimated via maximum likelihood. The SFEM has been widely used in the literature (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; Fréchette & Yuksel, 2017; Fudenberg, Rand, & Dreber, 2012; Jones, 2014; Vespa, 2020), and has been shown to perform well in recovering strategies from repeated choices, and when compared to explicitly elicited strategies (Dal Bó & Fréchette, 2019). The ability to pinpoint the strategies participants use in the two experimental conditions provides insights into the decision-making processes that drive cooperation, offering a more nuanced understanding than studies adopting different designs and focusing on aggregate outcomes.

The second contribution of this paper is to show that a competitive framework that provides no monetary rewards can increase cooperation.[2] By removing monetary rewards, we isolate the effect of competition on cooperation without altering the fundamental structure of the game form. In our experiment, the intergroup conflict does not change payoffs. Group members face exactly the same intragroup dilemma in both experimental conditions. Thus, any treatment difference in behavior can be attributed to a hedonic utility derived from winning the tournament. Monetary incentives would likely change the strategic game by virtually altering the payoffs of each action, potentially undermining the comparison between treatments. This is relevant in light of previous studies, many of which use material rewards to incentivize competition between groups. For example, Cárdenas and Mantilla (2015) and Tan and Bolle (2007) vary the available information on groups' relative performance and/or the presence of monetary rewards for winning the competition. Both studies find higher contribution levels when competition is materially incentivized. Tan and Bolle (2007) further report a positive effect of groups' relative information on contributions. The two experiments differ from ours in a few aspects. First, they both employ a PGG framework, which suffers from the limitations highlighted before. Moreover, Cárdenas and Mantilla (2015) do not make a direct comparison with a treatment where no relative information is provided, while Tan and Bolle (2007) do not implement indefinitely repeated games. Despite the two papers sharing similarities with our research question, they implement different experimental designs.

The remainder of this paper is organized as follows: Section 2 introduces the game

[2] 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 centers on cooperation.

and describes the experimental design; Section 3 presents the theoretical analysis of the game; Section 4 reports the results; and Section 5 provides the conclusions.

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 each 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*.[3] 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 of stage games 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 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 (team). The rules of the competition are simple: at the beginning of each supergame, two teams are randomly matched. The team that accumulates more points (the sum of both players' individual payoffs) by the end of the supergame is declared the winner. Table 1 shows that the action *Cooperate* always yields more points. Therefore, the more the team members choose to cooperate, the greater the likelihood of winning

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

the tournament. The outcome of the competition — a win, a loss, or a tie — is displayed at the end of each supergame, but no information is given regarding the points achieved by the other team. It is important to note that winning the competition does not grant 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 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 are paid €0.5 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.[4] Table C.1 in Appendix C shows that treatment randomization is balanced with respect to variables elicited in the final questionnaire.

3 Theoretical Framework

In this section, we perform a theoretical analysis of the game introduced in the previous section. 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. No additional monetary payoffs are awarded to the winners. We assume that players experience hedonic utility when winning the tournament. Because cooperation leads to more *points*, cooperating increases the odds of winning. We demonstrate that this results in lower thresholds for the discount factors necessary to establish cooperative and risk-dominant equilibria, denoted as δ^{SPE} and δ^{RD}, respectively. Our theoretical model supports the experimental design, and the data aligns with the theoretical findings.

[4] See the questionnaire in Appendix B.

3.1 The Model

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 2.[5] 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 2 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.[6] 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 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 this context, the probability of winning the

[5] 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 $\delta = 0,75$.

[6] Harsanyi, Selten, et al. (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).

tournament, denoted as $\mathbb{P}(win|s)$, is a function that depends on the strategy profile s, and it increases with the *points* scored by the team. Given the constraints on the payoffs of the PD, *Cooperate* always gives the team more *points*. Because of this, in the tournament, a player must consider the utility W when they decide their strategy. In the following, we will refer to the strategies Always Cooperate, Always Defect, and the Grim Trigger as AC, AD, and G, respectively.

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:*

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

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 trigger strategy (G), which is the least risky among cooperative equilibria, and always defect (AD).[7] 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:*

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

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 0.78, which is higher than the continuation probability of $\delta = 0.75$. However, cooperation is not risk-dominant, as indicated by the

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

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 trigger in the tournament treatment. This is actually the result we empirically observe, and we report in subsection 4.2 where we estimate the strategies played by the subjects.

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.

4 Results

4.1 Treatment effect

The main objective of this study is to show that introducing a tournament — that bears no additional economic rewards — in an indefinitely repeated Prisoner's Dilemma game is sufficient to foster cooperation. The first part of this section presents results on the treatment effect, analyzing cooperation in the first round of each supergame.[8] Although focusing on first-round choices provides an incomplete picture of the data, it represents a standard practice in the literature and provides valuable insights using a simplified analysis.[9] Decisions in all rounds are exploited in the last part of this section to estimate the strategies participants used in the experiment.

Figure 1 reports the percentage of cooperation in the two experimental conditions. On average, we find that the tournament increases first-round cooperation by 16 percentage points, and this is statistically significant at the five percentage level ($p = 0.025$).[10]

Figure 1 represents a screenshot of our data and does not consider the evolution of behavior during the experiment. For example, participants may require some time to respond to the treatment manipulation. We provide visual support for different trends in Figure 2, which shows how behavior changes as the number of supergames played by subjects increases.

[8]In one session of the *Control* treatment, we encountered a problem as subjects continued playing the game even after the 50-minute mark. For this reason, in that session, we use supergames that were played until supergame 29 to have a fair comparison between treatments. Results do not qualitatively change if we include the subsequent supergames as round 1 cooperation in those "extra" supergames further decreases over time (31% on average).

[9]See Dal Bó and Fréchette (2011) or Dal Bó and Fréchette (2018) for an explanation of the practical reasons.

[10]Statistical significance is assessed from a random effects probit model with standard errors clustered at the participant level where round one cooperation is regressed against the treatment variable. See Table C.2 in Appendix C for the full regression output.

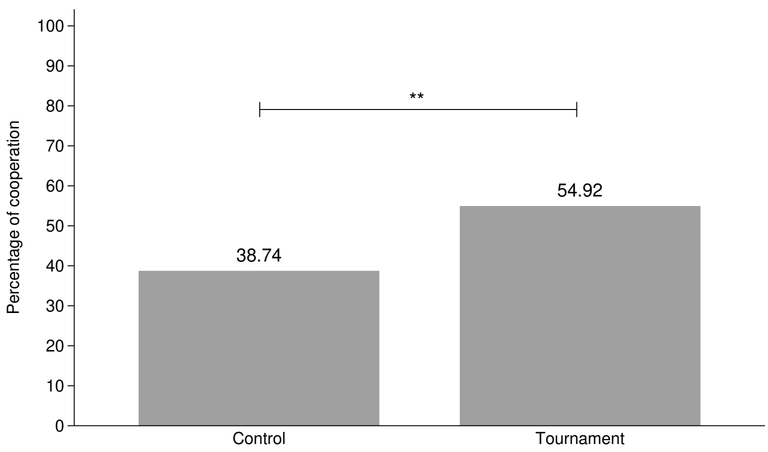

Figure 1 First-round cooperation.

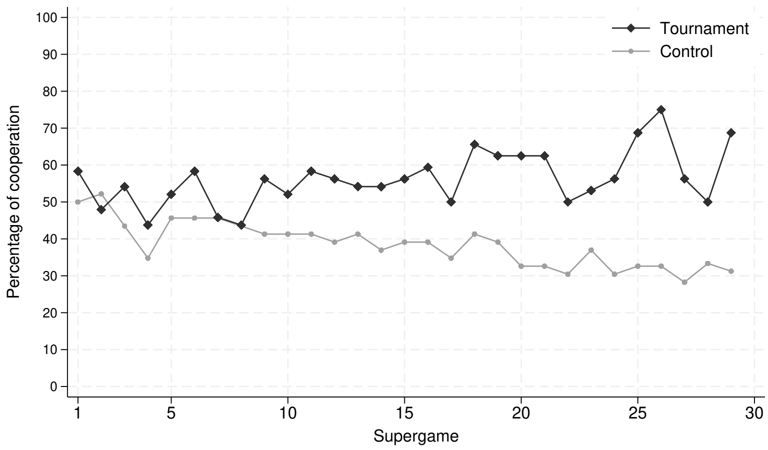

Figure 2 First-round cooperation by supergame.

The figure shows the percentage of subjects that cooperated in the first round of each supergame for both conditions. While first-round cooperation decreases over time in the control condition, in *Tournament*, it appears to be constant, with a slight increase in supergames that start later in the experimental session.

Table 3 provides a statistical analysis of the above result by showing marginal effects from probit regressions where the left-hand side variable is a dummy that takes a value of 1 if the subject cooperates in the first round and 0 otherwise. On the right-hand side, we include the variable *Supergame*, representing the number of the supergame at which the subject chooses whether to cooperate or not. Columns (2) and (4) include further controls from the questionnaire: *Economics* is equal to 1 if a participant has an economic background, 0 otherwise; *Experience* indicates the number of experiments a person previously participated in; *Risk* is a variable ranging from 0 (avoid risk) to 10 (love risk) that measures the self-reported willingness to take risks; *Trust* measures the

Pr(Cooperate)	*Control* (1)	(2)	*Tournament* (3)	(4)
Supergame	-0.010*** (0.00)	-0.009*** (0.00)	0.001 (0.00)	0.001 (0.00)
Age		-0.013 (0.01)		-0.010 (0.01)
Female		-0.238** (0.11)		0.141 (0.11)
Student		0.085 (0.16)		-0.372** (0.16)
Economics		-0.009 (0.11)		0.032 (0.10)
Experience		-0.019 (0.02)		0.005 (0.02)
Risk		0.035 (0.04)		0.042** (0.02)
Trust		0.088*** (0.03)		0.073*** (0.02)
Observations	1288	1288	1056	1056

Table 3 Effect of time on round 1 cooperation. Marginal effects from random effects probit models with standard errors clustered at the participant level in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

self-declared inclination to trust others (0 = better trust no one, 10 = better completely trust).

The two leftmost columns show the average impact of playing more supergames on the probability of cooperating in the first round in the *Control* treatment. The point estimates are negative and statistically significant, even when controlling for other covariates. On average, playing an additional supergame decreases the probability of cooperating by 1% in this experimental condition. In contrast, first-round cooperation in *Tournament* does not change over time. The coefficients of *Supergame* in columns 3 and 4 are positive and not statistically different from zero. These results support the conclusions drawn from Figure 2. In the control treatment, where participants play an indefinitely repeated prisoner's dilemma, cooperation diminishes over time. However, this trend does not hold when competition is introduced among pairs of players, even in the absence of additional monetary incentives.

4.2 Strategies

This section exploits the dependency of choices between and within supergames by estimating the strategies that participants used in the experiment. As mentioned in the introduction of this paper, a reliable method that has been widely employed in the literature is the Strategy Frequency Estimation Method (SFEM) (Dal Bó & Fréchette, 2011). With the SFEM, the occurrence of each strategy is estimated by maximum likelihood under the assumption that participants use the same strategies for the whole duration of the experiment but may make mistakes.[11] As the number of strategies is virtually infinite, we follow the literature focusing on the following small set of strategies: Always Defect (AD), Always Cooperate (AC), Grim (G), Tit for Tat (TFT), Win Stay

[11]For completeness we report the estimation procedure in Appendix C.2. Please refer to Dal Bó and Fréchette (2011) for further details.

Lose Shift (WSLS), and T2. G is a strategy that starts cooperating and then always defects following a defection from the other. TFT starts cooperating and then mimics the choice made by the opponent in the previous round. WSLS is a strategy that starts cooperating and then cooperates only if, in the previous round, either both or neither cooperated. T2 starts cooperating and then has two periods of punishment after a defection of the other. After these two rounds, T2 goes back to cooperation. Following Dal Bó and Fréchette (2011), we focus our analysis on supergames that start after approximately 90 interactions (decisions), where behavior is more likely to have stabilized.

	Control	*Tournament*
AD	0.557*** (0.09)	0.277*** (0.08)
AC	0.014 (0.03)	0.084* (0.05)
G	0.074 (0.05)	0.248*** (0.09)
TFT	0.333*** (0.08)	0.391*** (0.10)
WSLS	0.022 (0.03)	0.000 (0.00)
T2	0.000	0.000

Table 4 Estimated strategies. Bootstrapped standard errors in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table 4 reports the estimates of the proportions for each strategy, with the coefficient of T2 implied by the constraint that all coefficients must sum to one.[12] The table shows interesting differences between treatment conditions. In *Control*, the two most played strategies are AD — the most often identified (55.7%) — and a cooperative strategy, TFT (33.3%). No other strategy seems to play a significant role in this treatment. In contrast, in *Tournament* only 27.7% of participants opt for AD in favour of more cooperative strategies. The occurrence of Grim, which is the least risky strategy that fosters mutual cooperation, is estimated to be 24.8%. We also report a weakly significant fraction of subjects unconditionally cooperating in this treatment (8.4%) and a higher fraction of participants playing TFT (39.1%). Overall, these estimations reveal that the tournament fosters trust in the opponent and leads more subjects that would have otherwise defected to cooperate.

5 Conclusions

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

[12]In Table C.3 of Appendix C.2, we provide an indication of the precision of the estimates. For the sake of clarity, we left this discussion to the appendix.

participants gain experience. We also uncover how competition influences participants' strategic behavior, promoting a shift from predominantly selfish strategies like Always Defect to the least risky cooperative strategy, the Grim Trigger. This insight relies on the Prisoner's Dilemma game, which represents a key methodological innovation compared to the existing literature.

The theoretical framework developed in this paper offers a novel perspective by showing how hedonic utility derived from winning a tournament can lower the thresholds for cooperative equilibria, even without monetary incentives. Our model contrasts with traditional frameworks that often rely on assumptions of other-regarding preferences or team reasoning, providing an innovative explanation for how competition increases cooperation among self-interested individuals.

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:

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

□

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 et al. (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. □

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 Additional Material

C.1 Tables

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. Coefficients come from OLS regressions. Standard errors in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Pr(Cooperate)	(1)	(2)
Tournament (T)	0.194** (0.09)	0.150* (0.08)
Age		-0.015** (0.01)
Female		-0.097 (0.09)
Student		-0.098 (0.14)
Economics		0.011 (0.08)
Experience		-0.009 (0.01)
Risk		0.031 (0.02)
Trust		0.077*** (0.02)
Observations	2344	2344

Table C.2 Cooperation in first rounds. Marginal effects from a random effects probit with standard errors clustered at the participant level in parentheses. The left-hand side is represented by a dummy variable equal to 1 if the participant cooperates in that round and 0 otherwise. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

C.2 Strategies Estimation

Here, we describe the procedure used to estimate strategies presented in Table 4. In this, we follow Dal Bó and Fréchette (2011). The occurrence of each of the six strategies is estimated via maximum likelihood. In each round, we allow for deviations from the strategy so that the likelihood that the observed choice corresponds to the given strategy is given by:

$$y_{imr}(s^k) = 1\left\{s_{imr}(s^k) + \gamma\epsilon_{imr} \geq 0\right\}$$

where y is the choice (cooperate = 1, 0 otherwise), $1\{.\}$ is an indicator function, imr stands for subject i, match m and round r, s^k is a specific strategy, and $s_{imr}(s^k)$ indicates the choice implied by that strategy based on the history of the repeated game up to that round (it is coded with 1 if the strategy would cooperate and -1 otherwise), ϵ is the error term and γ is the variance in the error. Given the error term the implied likelihood has the usual logistic form as follows:

$$p_i(s^k) = \prod_S \prod_R \left(\frac{1}{1 + exp(\frac{-s_{imr}(s^k)}{\gamma})} \right)^{y_{imr}} \left(\frac{1}{1 + exp(\frac{s_{imr}(s^k)}{\gamma})} \right)^{1-y_{imr}}$$

for a given subject and strategy (where S and R represent the sets of all supergames and rounds). This leads to the following log-likelihood:

$$\sum_I ln\Big(\sum_K p(s^k)p_i(s^k)\Big)$$

with K being the set of considered strategies $\{s^1, ..., s^k\}$ and $p(s^k)$ is the proportion of the data which is attributed to strategy s^k.

In the following table we report the same estimates presented in the paper, along with the coefficient γ, which captures the amount of noise. In essence, this coefficient provides an indication of the precision of the estimates. As $\gamma \to 0$, the implied probability for the subject to take the action prescribed by the strategy approaches 1, while as $\gamma \to \infty$, the response becomes purely random with such a probability approaching 1/2. The estimated γ is close to zero and its value is in line with the findings of Dal Bó and Fréchette (2011).

	Control	*Tournament*
AD	0.557*** (0.09)	0.277*** (0.08)
AC	0.014 (0.03)	0.084* (0.05)
G	0.074 (0.05)	0.248*** (0.09)
TFT	0.333*** (0.08)	0.391*** (0.10)
WSLS	0.022 (0.03)	0.000 (0.00)
T2	0.000	0.000
γ	0.537*** (0.08)	0.510*** (0.10)

Table C.3 Estimated strategies. Bootstrapped standard errors in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$