

Intergroup Conflict and Intra-Group Punishment in an Experimental Contest Game

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We study how conflict in contest games is influenced by rival parties being groups and by group members being able to punish each other. Our motivation stems from the analysis of sociopolitical conflict. The theoretical prediction is that conflict expenditures are independent of group size and of whether punishment is available. We find, first, that conflict expenditures of groups are substantially larger than those of individuals, and both are above equilibrium. Second, allowing group members to punish each other leads to even larger conflict expenditures. These results contrast with those from public goods experiments where punishment enhances efficiency. (JEL C72, D74, H41)

In many areas of social life, different parties interact under conditions of rivalry, striving for something that not all can obtain. Examples of such rivalries in the economic and political realms are R&D competition, promotion tournaments in internal labor markets, lobbying for government favors, and electoral competition between political parties. As a result of such rivalries, considerable resources are spent on activities that have no direct productive value. For example, Thomas W. Hazlett and Robert J. Michaels (1993) estimated that, previous to the adoption of auctions by the Federal Communications Commission (FCC), the real resources spent on filing applications for cell phone license lotteries (with an estimated market value of \$1 billion at that time) was about \$400 million. Extreme instances of rivalry are military conflicts and sociopolitical conflicts, like those that arise between parts of a country, when one of them is fighting for a different political status or independence, and those between ethnic groups. Actual conflicts of this type are often very costly, both in human lives and in material losses.

Much of the economic analysis of conflict has been based on contest or rent-seeking models. Michelle R. Garfinkel and Stergios Skaperdas (2007) present an overview of the economics of conflict, and Kai A. Konrad (2007) provides a recent survey of the theoretical literature on contest models. In a contest, several rival parties expend resources in trying to secure a prize or rent for themselves. In models of sociopolitical conflict, winning the prize represents the implementation of the political solution more favorable to the winning party. A contest success function based on the set of the players' (nonrefundable) investments determines which contestant receives the prize. One of the most used contest models is the lottery game by Gordon Tullock (1967, 1980), in which each contesting party has a probability of winning the prize equal to the

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proportion of its investment out of the total investment by all parties. For players who maximize own material earnings, this game has a unique Nash equilibrium in pure strategies. In the equilibrium, contestants invest positive amounts in a fight for the prize. This is socially wasteful in the sense that, as a consequence of spending material resources on an inherently unproductive activity, a certain fraction of the original prize is lost or dissipated.

A number of experimental studies, like those of Marc Isaac and Stanley S. Reynolds (1988), Edward L. Millner and Michael D. Pratt (1989, 1991), Jason F. Shogren and Kyung Hwan Baik (1991), Douglas D. Davis and Robert J. Reilly (1998), Jan Potters, Casper de Vries, and Frans van Winden (1998), Ayse Öncüler and Rachel Croson (2005), and James E. Parco, Amnon Rapoport and Wilfred Amaldoss (2005), have studied the lottery contest game and some related contest games. The central question these studies focus on is whether observed behavior is consistent with standard Nash equilibrium predictions. For the most part, the expenditures on conflict activities exceed the relevant theoretical prediction (Öncüler and Croson provide a brief review). Deviations from equilibrium can have more than one explanation. Obstacles to convergence to equilibrium may be relevant. Another factor can be the interdependence of preferences. In other areas, like the analysis of public goods situations (see James Andreoni and John H. Miller 2002), or that of gift-exchange labor markets (see Ernst Fehr, Georg Kirchsteiger, and Arno Riedl 1993, 1998), it has been shown that elements of altruism, aversion to inequality, and reciprocity have a strong influence on behavior. In contest games, such motivational forces may also have an influence. In particular, given the rivalry between the parties in conflict, the desires to come out ahead or to hurt others, as well as other types of competitive motivational forces, may affect behavior (Benedikt Herrmann and Henrik Orzen 2008).

In all rent-seeking experiments mentioned above, it is individuals who compete for a prize. In many naturally occurring situations, however, players are groups, since political parties, social movements, and associations like trade unions, lobbyists, and terrorist groups are invariably composed of more than one individual. Rent-seeking competition between groups rather than single players introduces an additional layer of complexity to the strategic characteristics of the interaction. Although groups clearly have the potential to be more powerful competitors than individual agents, they face internal coordination problems that may severely undermine their efficacy. For example, wage increases eked out by striking workers typically benefit both striking and nonstriking workers, such that individual workers have an incentive not to participate in the strike and yet enjoy the pay rise. While a now substantial theoretical literature addresses this and related issues, beginning with Mancur Olson's (1965) seminal contribution, thus far it is poorly understood how human decision makers actually behave in simple collective rent-seeking contests.

Consider a setting where all group members reap the benefits of success, while the likelihood of success depends on the efforts of individual group members. If formal enforcement measures are absent, the conflict parties effectively compete on the basis of voluntary contributions, although informal sanctions against defectors, like social ostracism or mobbing, may help to overcome the inherent free-riding incentives. To date, we have no systematic empirical evidence on how intergroup conflict is likely to evolve in such a setting.

In the work we present here, we use laboratory methods to study how conflict in contest games is influenced by parties being groups instead of individuals, and by the existence of the possibility of punishment between members of a party. We believe that these two variables are important parts of a good simplified representation of the conditions under which social conflict takes place. We base our analysis on a version of Tullock's simple contest game in which two parties compete for an indivisible prize by investing into conflict budgets. The prize is characterized by rivalry in consumption and excludability at the level of conflict parties, and by nonrivalry in consumption and nonexcludability *within* each conflict party.

One can see this as a representation of a situation where the prize has a public good flavor for the successful party, as is the case in some political confrontations in which all members of the winning party benefit from the outcome, much like in the example of industrial action mentioned earlier, or in the struggle for ethnic or religious dominance. While the nonrivalry in consumption property implies that adding a member to a group does not dilute the benefit of obtaining the prize for existing members, the new member's contribution to the group effort "crowds out" some of the existing members' contributions—in equilibrium to an extent that exactly counterbalances the new member's contribution itself. Hence total group contribution is invariant to group size, a property that provides a neat theoretical benchmark for behavioral analyses. Despite this theoretical property, rivalry between actual groups and intragroup dynamics not captured by static equilibrium analysis, may influence behavior in ways that are not easy to predict. With groups as parties, the equilibrium expenditure level can come about through different configurations of investments by the individual group members. Individuals' attempts to "free ride" on other party members' contributions may lead to overall lower expenditures than the ones predicted. At the same time, issues of intergroup competitiveness can conceivably push party members to higher than predicted investment levels.

The inclusion of within-group punishment possibilities in a static representation of conflict between groups also has no effect on the theoretical prediction, since sanctioning other group members is a costly activity and can only be applied *ex post*: thus, forward-looking players motivated only by own material payoffs will never use punishment. However, in a situation of strong rivalry between groups it may be used and have an influence on conflict expenditures. Starting with the influential paper by Fehr and Simon Gächter (2000), a number of studies have analyzed the effects of punishment on behavior in public goods type of environments.¹ The results may suggest that under certain circumstances punishment opportunities can have a positive effect on intragroup cooperation, but there is a fundamental difference between contributions to a public good game and contributions to a group conflict. While in the former case overall efficiency rises with the level of contributions, in the rent-seeking game contributions are unproductive waste. Thus, socially desirable contribution levels differ radically between the two settings, and this may affect behavior, especially in a repeated game context.

Our results for the case without punishment show that expenditure levels in contests between groups are much higher than in contests between individuals, and both exceed equilibrium levels. On average, we observe that teams spend more than four times as much on conflict as predicted and about twice as much as single players. We also find that individual parties fighting against group parties invest similar levels to individual parties fighting against other individual parties. Group parties fighting against individual parties invest like group parties fighting against other groups.

In contests with punishment opportunities, expenditure levels are in turn much higher than in any of the treatments without punishment. In the final rounds of the experiment, investments in conflict are more than twice as high with punishment as without. The consequence is a large waste of resources: more than three-quarters of the prize that parties are fighting over is dissipated by direct conflict expenditures. However, to determine the true efficiency loss, the costs imposed by punishment and the costs borne to punish others need to be added. With these costs included, material losses are now 869 percent of the equilibrium level and rent dissipation is in excess of 100 percent. These results strongly contrast with those from those public goods experiments where punishment tends to enhance efficiency.

¹ See, e.g., David Masclet et al. (2003), Nikos Nikiforakis (2004), Armin Falk, Fehr, and Urs Fischbacher (2005), Laurent Denant-Boemont, Masclet, and Noussair (2007), Martin Sefton, Robert Shupp, and James Walker (2007), Herrmann, Christian Thöni, and Gächter (2008), and Gächter and Herrmann (2009).

I. Experimental Design and Research Questions

All our treatments are based on the same contest game between two parties. Our design is composed of five treatments. The first four vary with respect to the number of individuals composing each of the two parties and with respect to the existence of punishment possibilities, and all have the same time horizon of 20 rounds. The baseline treatment, which we call 1:1, consists of a conventional Tullock contest game with the two parties being individuals, without punishment. In two other treatments, called 1:4 and 4:4, one or both of the two parties are composed of a team of four individuals.² In the treatment 4:4P we add the possibility of punishment in a way that will be explained below. In our fifth treatment, called 4:4/40, teams interacted with each other over 40 rounds (without punishment opportunities). In our dataset each group of two rival parties constitutes a statistically independent observation. We have data on 14 groups for the 1:1 treatment, 11 for 1:4, 8 for 4:4, 8 for 4:4P, and 6 for 4:4/40. The total number of participants was 259.

In field settings, one typically observes repeated interactions among the same agents, and we therefore decided to let our subjects interact in fixed parties and with a fixed opponent party during the course of the 20 rounds of the experiment. This and all the features of the experiment that we refer to were common information to all participants.³

At the beginning of each round each participant received an endowment of 1,000 points from us and could use these to buy “contest tokens” for his or her party.⁴ Each contest token cost 1 point and each subject could buy any integer amount of contest tokens between 0 and 1,000. Any points that were not spent on contest tokens were added to the participant’s point balance. As soon as everybody had chosen how many contest tokens to buy, each participant was informed about how many tokens each of the other members of the team had invested in that round (in teams of size 1 the participant was simply reminded of how much he/she had invested) and of the total amount invested by the rival party. Own team members were identified by a number that remained constant over the 20 rounds, so that others’ behavior could be traced over time. However, participants did not know the identity of the others in their team, or the identity of their opponent(s).

An on-screen lottery wheel was then used to determine which of the two parties would win the prize. The members of the winning party received an extra 1,000 points each, regardless of the team size. This reflects our intention to study a setting where the benefits from winning are nonrival and nonexcludable within a team. The probability of a party winning the prize was equal to the total number of tokens invested by that particular party, divided by the sum of tokens invested by both parties. After the lottery each participant was informed of whether he or she, or his or her team, had won or lost. The prize money was added to the winning party members’ point balances, and in the treatments without punishment the experiment then proceeded to the next round.

In the 4:4P treatment, where punishment was possible, participants could, before moving to the next round, assign “deduction tokens” to each of the other own team members (not to members of the other team). Each deduction token received from a teammate reduced a participant’s

² In the following we will use the term “team” to refer to a set of four players who jointly compete against a single player or another four-player team, and will reserve the term “group” to refer to a set of matched opponents. Furthermore, we will use the word “party” as a generic term for teams and single players.

³ Appendix A contains a copy of the instructions we use. The experiment itself was fully computerized using purpose-built software developed in Visual Basic.

⁴ In the theoretical model, there is no endowment that puts a limit on the choice of the number of contest tokens. In the experiment one needs to specify this endowment for technical reasons. Our choice of 1,000 was guided by the simple considerations of not having it be binding and also not setting it too high. It is possible that the endowment level has an influence on the behavior we observe.

point balance by three points. This could possibly wipe out a participant's earning from a particular round.⁵ In addition, each deduction token a participant *actively* assigned to a teammate reduced the participant's point balance further, by one point. Thus, punishing others was costly. The maximum number of deduction tokens that a participant could assign to others in a round was 500. Overall, this could lead to negative earnings in a particular round.⁶ Subjects were explicitly told that they could choose not to assign any deduction tokens by simply filling out a "0" in the corresponding field. After all team members had made their decisions on the allocation of deduction tokens, participants were informed about received punishment, and point balances were updated. Then the experiment proceeded to the next round. All rounds developed in the same way.

The symmetric Nash equilibrium of this finitely repeated game, given the assumption that players are risk-neutral and motivated only by their own monetary earnings, predicts that each party invests 250 points in contest tokens, regardless of whether the treatment is 1:1, 1:4, 4:4, or 4:4/40. To see this formally, let $\pi_i(x_i, X, Y)$ denote the payoff of a representative player i , where x_i is the number of contest tokens purchased by player i , X is the sum of contest tokens purchased by player i 's team ($X = x_i$ when player i is on his or her own), and Y is the total number of contest tokens bought by the opponent party. The player's payoff function in this game can then be written as

$$\pi_i(x_i, X, Y) = E + \frac{X}{X + Y} 1000 - x_i,$$

where E denotes the player's initial endowment. The first-order condition, derived in the usual way, is $(X + Y)^2 = 1,000Y$. The same calculation can, of course, be made for a representative member of the opponent party, yielding $(X + Y)^2 = 1,000X$, and hence we must have $X = Y$ in equilibrium. Therefore, the equilibrium per-party investment must solve $(X + X)^2 = 1,000X$ and $(Y + Y)^2 = 1,000Y$, and so we get $X^* = Y^* = 250$ as the equilibrium prediction. Note that although players optimize their own *individual* contributions, the first-order conditions contain only *aggregate* contribution levels—hence the independence of equilibrium contribution levels from team size.

Equilibrium theory provides a clear-cut solution at the level of conflict parties, but is silent about the behavior of individual team members: any combination of investments by individual team members that add up to 250 points constitutes an equilibrium. This is due to the fact that the members of each team have identical valuations and that the marginal cost of effort is constant (see Konrad 2009). Another important background assumption is that players maximize their individual payoffs, not the team payoff, which creates a free-riding problem within each team.⁷ Another assumption is that players are risk-neutral. In Appendix B we discuss the impact of risk aversion. We show that equilibrium expenditures may, in the most general case, increase or decrease for risk-averse players, with an upper limit of 500 points per conflict party. For conventional functional forms (such as constant absolute risk aversion (CARA) and constant relative risk aversion (CRRA)), equilibrium expenditures decrease unambiguously with risk aversion.

In addition to the amount of equilibrium investment, the degree of equilibrium rent-dissipation—the ratio of total resources spent in the contest to the value of the prize—is another benchmark against which one can compare behavior. Because of the public good properties of

⁵ When the recipient of deduction tokens would nominally have earned a *negative* amount due to being punished, the computer disregarded the "excess" reduction and set the recipient's round earnings to zero.

⁶ To avoid bankruptcies we gave participants in the 4:4P treatment a starting balance of 3,000 points. Even with this extra endowment, bankruptcies were still possible, but in the experiment this never occurred.

⁷ The situation within a team somewhat resembles a public good game with an interior equilibrium and an interior social optimum (as long as the effects on the other party are ignored). It would be interesting to compare our results with those from experiments on a public good game with such a feature. However, to our knowledge no such studies exist.

TABLE 1—EXPERIMENTAL DESIGN AND EQUILIBRIUM BENCHMARKS

Treatment	Data generating process	Standard equilibrium predictions	
		Expenditures per conflict party	Rate of rent dissipation
1:1	20 rounds, fixed matching, 14 ind. obs.	250 points	50.0 percent
1:4	20 rounds, fixed matching, 11 ind. obs.	250 points	31.3 percent
4:4	20 rounds, fixed matching, 8 ind. obs.	250 points	12.5 percent
4:4P	20 rounds, fixed matching, 8 ind. obs.	250 points	12.5 percent
4:4/40	40 rounds, fixed matching, 6 ind. obs.	250 points	12.5 percent

the prize, its value is dependent on the size of the winning party. Taking this into account, the degree of equilibrium rent-dissipation with our parameters is $500/1,000 = 0.5$ for the 1:1 treatment and $500/4,000 = 0.125$ for the 4:4 treatments. In the 1:4 treatment the degree of rent-dissipation depends on whether the individual or the team wins the prize. In equilibrium the *expected* rent-dissipation level in this case is $(1/2)(500/1,000 + 500/4,000) = 0.3125$. Note that, while the equilibrium investment levels are the same, the levels of equilibrium rent-dissipation vary across treatments, as a result of the difference in the effective prize across treatments.

The equilibrium prediction is also not affected by the existence of intrateam punishment possibilities. Using the standard backward induction argument, it is clear that in the last round, after having seen team members' investments in contest tokens, nobody should be expected to invest in costly punishment tokens; continuing this argument, one gets to the prediction that punishment will not be used in any of the rounds.

Table 1 summarizes our design and the relevant predictions. Our research questions emerge directly from the equilibrium analysis above.

Question 1: Will participants in the 1:1 treatment involving only individuals invest equilibrium level quantities?

This first question is about establishing a baseline for the treatments involving teams. We are also curious about how closely our data replicates results from previous contest experiments. As noted above, most studies find excessive rent-seeking expenditures relative to standard predictions. However, a few papers report contest behavior close to equilibrium (Shogren and Baik 1991) or even below equilibrium (David Schmidt, Shupp, and Walker 2005).

Question 2: Will teams fighting teams invest more or less than individuals fighting individuals?

This is one of the key questions we are interested in and, as discussed in the introduction, a priori it is not at all clear what the answer is. One possibility is that groups end up investing less than individuals, since every member of a team might rely on teammates to contribute sufficiently to the team effort. There is also some evidence that groups display more risk-averse behavior than individuals (Masclet et al. 2004; Bettina Rockenbach, Abdolkarim Sadrieh, and Barbara Mathauschek 2007). Another possibility is that team rivalry and intrateam dynamics lead to more conflict than between individuals. There exists evidence in other contexts that groups can be more competitive than single players (Gary Bornstein and Meyrav Ben-Yossef 1994) and that individuals are less willing to trust and reciprocate when they decide on behalf of a group (Fei Song 2008).

Question 3: Will individuals and teams behave differently when competing against individuals than when competing against teams?

The answer to this question will be of interest as a means of understanding possible differences between the treatments involving only teams and only individuals.

Question 4: How will the possibility of within-team punishment affect conflict expenditures, and to what extent will subjects use the punishment opportunities?

Again, a priori it is not clear how the presence of punishment possibilities will affect behavior. One conjecture is that it will be used only to get team members who are taking a cheap ride on others' contest tokens to increase their contributions to the level of others. It may also be hypothesized, however, that team members be punished for investing too much, since this decreases overall social efficiency.

II. Procedures

The experiment was conducted at the University of Nottingham. Subjects were recruited from a university-wide subject pool comprising undergraduates who had indicated a willingness to be paid volunteers in decision-making experiments. Each subject participated in only one session, and no subject had taken part in experiments similar to the present one. On arrival, participants were seated at visually separated computer terminals. Information was transmitted only through the computer network, and any other form of communication was prohibited. Subjects were not told with whom they interacted during the experiment, but they knew that the composition of groups did not change in the course of a session.

Each session began with a brief introductory talk, after which the written instructions were read aloud. The total earnings of a subject were equal to the sum of all the profits he or she made during the experiment. Subjects were paid at the end of the experiment, in private and in cash, at a conversion rate of 1p per 30 points accumulated. Participants earned between £3 and £11.70 with an average of £7.83 for sessions lasting about 45 minutes, including the time spent reading the instructions. At the time of the experiment, the exchange rate to other major currencies was approximately US\$1.85, €1.45, RMB14, and ¥200 for £1.

III. Results on Individuals versus Teams

In this section we report the results from treatments 1:1, 1:4, 4:4, and 4:4/40. Section IIIA concentrates on the main differences in behavior across the treatments with a 20-round horizon. In Sections IIIB and IIIC we will look in more detail at individual behavior in order to find explanations for the treatment effects we observe, and in Section IIID we examine the effects of extending the time horizon to 40 rounds (4:4/40 treatment). In Section IV we move to the analysis of the effects of the presence of punishment.

A. Time Trends and Differences between Treatments and between Conflict Parties

Figure 1 shows how average contest expenditures evolve over time in all three treatments without punishment; this is per team, so that, for a team of four, what is shown is the sum of contributions by all team members together. For the 1:4 treatment, we plotted separate time series for teams and single players.

Based on the figure, three observations seem noteworthy. First, overall actual contest expenditures appear to be much higher than the equilibrium prediction. There is, however, a downward trend over time, particularly in the teams. Nevertheless, even toward the end of the experiment, expenditures appear to be higher than in equilibrium. We will need to study to what extent the downward trend is significant over all 20 rounds. Second, on average teams invest much more than single players, although there appears to be some degree of convergence toward the end of the experiment. Third, there is a striking similarity in how much both teams and single players invest with different opponents—indeed, on first sight it almost seems as if the conflict parties choose their expenditures independently of whether the opponent is a single player or a team. In

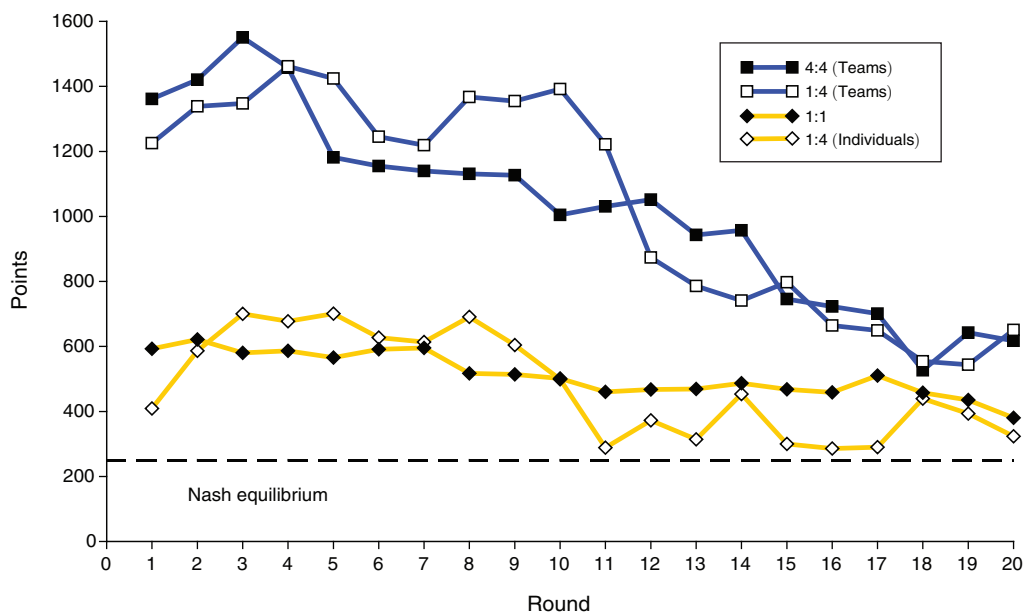


FIGURE 1. CONTEST EXPENDITURES OVER TIME IN THE 20-ROUND NO-PUNISHMENT TREATMENTS

the analysis below we try to uncover what is behind this regularity. We now move to a statistical analysis of these observations.

To examine to what extent there is a decline over time and when (if at all) this trend comes to a halt, we use the following three-step procedure. First, we calculate, for each of our 33 pairings (treating individuals and teams separately in the 1:4 treatment), the difference in average expenditures across the two halves of the data (rounds 1 to 10 versus rounds 11 to 20) and then employ a two-sided Fisher one-sample randomization test for each treatment under the null hypothesis that the difference is zero. Second, we conduct the same analysis to compare the third and fourth quarter of the data (rounds 11 to 15 versus rounds 16 to 20). Finally, focusing on the final quarter, we compute, for each pairing, the Spearman rank order correlation coefficient (r_s) between the round-data from the last five rounds and the round number, and then test for each treatment whether r_s differs significantly from zero. The results of our trend analysis are shown in Table 2.

As the table shows, there is strong evidence for a negative trend between the first and second half of the experiment. The effect is more pronounced for the teams but is also present in the data from individual players. For individuals, however, the decline in investments does not appear to continue into the second half: differences between the third and fourth quarter are marginal and not statistically significant. In contrast, the teams continue to systematically lower their investments by substantial amounts, even after entering the second half.

Note that in none of the treatments does our analysis indicate systematic trends within the final quarter of the experiment. After some rounds with considerable downward trends, behavior reaches a kind of rest point.

We now look at conflict expenditure levels and compare them with the equilibrium level. Recall that, in equilibrium, each conflict party spends 250 points on contest tokens, regardless of team size. Averaging over all rounds, we observe that teams actually spend more than four times as much (1,035 points) and single players about twice as much (498 tokens). When we focus on

TABLE 2—MEASURES OF TIME TRENDS IN EXPENDITURES (*p*-values in parentheses)

	Rounds 1–10 versus 11–20: Average differences		Rounds 11–15 versus 16–20: Average differences		Rounds 16–20: Average r_s b/t round data and number	
	Individuals	Teams	Individuals	Teams	Individuals	Teams
1:1	–107.2 (0.012)	n/a	–21.9 (0.564)	n/a	–0.193 (0.237)	n/a
1:4	–264.7 (0.007)	–589.3 (0.009)	0.7 (0.981)	–271.5 (0.050)	0.065 (0.766)	–0.135 (0.434)
4:4	n/a	–459.0 (0.039)	n/a	–303.7 (0.008)	n/a	–0.063 (0.796)

the final quarter of the experiment, we find that expenditures are still very high. In the last five rounds, teams in the 4:4 treatment spend on average 642 points and teams in the 1:4 treatment only slightly less than that (612 points). These deviations from the theoretical prediction are statistically significant: the *p*-values are 0.008 for the 4:4 teams and 0.017 for the 1:4 teams (two-sided Fisher one-sample permutation test). Single players in the last quarter of the 1:1 treatment invest, on average, 448 points (*p*-value = 0.004), and we fail to reject the null hypothesis (*p*-value = 0.295) only for single players in the 1:4 treatment (347 points on average in the last quarter).⁸ Our first result contains the answer to question 1 above:

Result 1: *In the 1:1 treatment, average expenditures substantially and significantly exceed the equilibrium level. The material losses due to the (inherently unproductive) investments in the conflict amount to 205 percent of the equilibrium level (179 percent based on the last five rounds).*

The finding that individual contestants invest excessively relative to standard predictions is consistent with the results reported in the majority of previous studies on behavior in experimental contests.

Turning to observations 2 and 3 at the beginning of the section, we first use two-sample permutation tests to compare investment behavior of individuals and teams across treatments. Based on all 20 rounds, we reject the null hypothesis that investment levels in contests between individuals are the same as investment levels between teams of four (*p*-value = 0.001, two-sided). Based on the last five rounds, the difference between the investment levels in the 1:1 and the 4:4 treatment is still substantial, although no longer significant at conventional levels (*p*-value = 0.127).

Result 2: *Average contest expenditures in the 4:4 treatment are twice as high as in the 1:1 treatment (nearly one and a half times as high based on the last five rounds). The observed level of material losses is now 409 percent of the Nash equilibrium level (257 percent based on the last five rounds).⁹*

Comparing the behavior of individuals and teams within the 1:4 treatment, we find that team expenditures exceed single players' expenditures by 118 percent (77 percent based on the last five rounds). A two-sided Fisher permutation test based on the difference between individual and team investment in each 1:4 pairing yields *p*-values of 0.001 (all 20 rounds) and 0.012 (last 5

⁸ Not surprisingly, based on all 20 rounds, the null hypothesis would be rejected in all treatments.

⁹ As discussed in Section I, the equilibrium prediction refers to risk-neutral players. Our analysis in Appendix B shows that risk aversion decreases expenditures for common utility functions. Under less conventional functional forms, expenditures may increase relative to the risk-neutral case, but there is an upper bound of twice the risk-neutral level. The investments we observe here exceed even this upper bound.

rounds). Thus, teams continue to be the dominant conflict party up to the end; any tendency of convergence between teams and single players that Figure 1 might suggest is far from complete.

Finally, to answer Question 3 above, we fail to reject the null hypothesis that individuals behave identically in the 1:1 and the 1:4 treatments, regardless of whether this comparison is based on all 20 rounds (p -value = 0.669) or just the last 5 (p -value = 0.306). The same is true for teams when we compare the 1:4 with the 4:4 treatment (p -value all 20 rounds = 0.925; p -value last 5 rounds = 0.876).

Result 3: Single players' expenditure levels are not significantly different in the 1:1 and 1:4 treatments. Team expenditure levels are not significantly different in the 4:4 and 1:4 treatments.¹⁰

B. Responsiveness of Conflict Parties to Opponents' Behavior

The previous subsection leaves us with a puzzle: the behavior of single players and teams—with respect to investment levels as well as adjustments over time—does not vary systematically with the type of opponent, despite that these different types make vastly different choices! Finding out what is behind this regularity will allow us to better understand observed behavior.

We address this question using Figure 2, which shows average contest expenditures per conflict party in the final quarter of the experiment. Consider the data for the 1:4 treatment shown in the middle of the figure, and note first that there is considerable variability in behavior across single players (the coefficient of variation is 0.807) and across teams (the coefficient of variation is 0.700). We find strong evidence, however, that this variability is not independent across the conflict parties: the Spearman rank order correlation coefficient between individuals and teams is 0.679, and under the null hypothesis that there is no correlation, we obtain a two-sided p -value of 0.022. A very similar picture emerges in the 1:1 treatment—there appears to be a lot of variation across groups, but quite similar behavior within each group. Since we deal with unordered pairs in this treatment, we compute the single-measure intraclass correlation coefficient and obtain a value of 0.835 (two-sided p -value < 0.001). This correlation suggests that the behavior of the contest parties is, to a considerable degree, dependent on the history of interaction between them.

In 4:4 there is again a lot of variation across groups, yet here the correlation between opposing teams, though positive, is much less pronounced and not statistically significant: the intraclass correlation coefficient is only 0.363 (two-sided p -value = 0.155).

Why is the correlation between opponents lower in the team-versus-team treatment than in the other two treatments? We suggest alternative explanations. The first is that intrateam dynamics influence the decisions of individual team members and “distract” them from the simultaneous interaction with the rival. Thus, according to this explanation, while single players try to “best respond” to their rival in the broadest sense (whoever that rival is) teams tend not to do that to the same extent. This would imply that it is mainly the single players, not the teams, that produce the high correlation we observe in the 1:4 treatment. An alternative explanation is based on the thought that teams may be expected to display more erratic and inconsistent behavior relative to single players, because four individuals are involved in each investment decision. As a result, the nature of one's interaction with a rival team may be seen as “less strategic” than with a rival single player. Taking this into account, the opponent of a team (whether this opponent is a single

¹⁰ To check the robustness of our results, we examined whether our data contain potential outliers, applying Peirce's Criterion (Stephen M. Ross 2003) to the group-level data. For the observations that average over all 20 rounds, this method does not detect outliers. For the observations that average over the last five rounds, the method detects one outlier each in 1:1, 1:4, and 4:4. None of our conclusions changes if the affected data points were to be discarded.

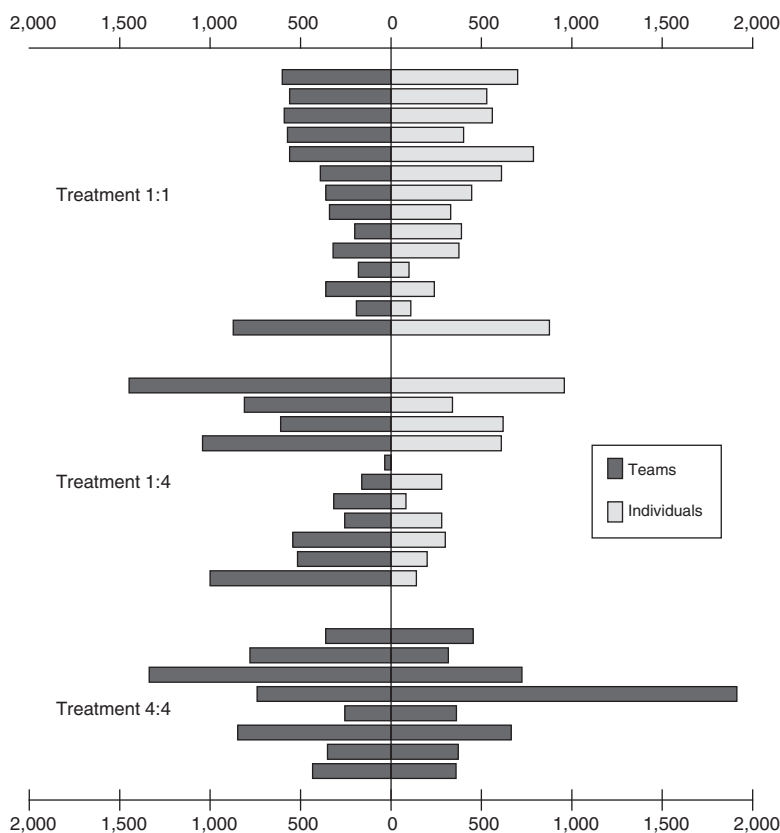


FIGURE 2. AVERAGE CONTEST EXPENDITURES PER CONFLICT PARTY (IN POINTS)
(Based on last five rounds)

player or a member of a rival team) would find it less advantageous to try to react to the team's round-by-round decisions.

Put simply, the question is whether teams tend to ignore the behavior of their opponents or whether teams' opponents tend to ignore teams' behavior. To investigate the two competing hypotheses, we ran a number of regressions that analyze to what extent conflict parties make their current investment decisions dependent on decisions in the preceding round. We included, as independent variables, the parties' own and their opponents' lagged expenditures, as well as the current round number, to control for the time trend we observed in our earlier analysis. To account for the possibility of nonlinearities in a party's response to its rival's choices, we also included a squared term for the opponent's expenditure in $t - 1$.

Table 3 shows the regression results. The coefficients for own lagged expenditures are positive and highly significant in all treatments, which indicates the presence of a considerable degree of path dependency. The squared term for the opponent's expenditure in $t - 1$ is insignificant in all cases and is not reported in the table. The coefficients for the opponent's lagged expenditures give more support to our second than to our first interpretation of the observed patterns of correlation: the coefficients for single players in the 1:1 treatment and for teams in the 1:4 treatment are nearly as high as the own lagged investment coefficients, and are statistically significant, whereas the coefficients for single players in the 1:4 treatment and for teams in the 4:4 treatment

TABLE 3—DETERMINANTS OF INDIVIDUAL AND TEAM EXPENDITURES IN ROUND t

Independent variables	Dependent variable: Conflict party's investment in t			
	1:1 Single players	1:4 Single players	1:4 Teams	4:4 Teams
Constant	174.433*** (52.1690)	227.106* (103.4751)	96.258 (79.0700)	231.496* (108.5051)
Round	-3.894** (1.6486)	-9.535* (4.4108)	-8.242** (3.3910)	-9.518 (5.0468)
Own expenditure in $t - 1$	0.411*** (0.0814)	0.525*** (0.1007)	0.686*** (0.0682)	0.750*** (0.0447)
Rival's expenditure in $t - 1$	0.372*** (0.0746)	0.158 (0.0885)	0.638* (0.3021)	0.112 (0.081)
	$N = 532$	$N = 209$	$N = 209$	$N = 304$
	$F(4, 13) = 47.88$	$F(4, 10) = 66.17$	$F(4, 10) = 46.57$	$F(4, 7) = 220.69$
	$\text{Pr} > F = 0.000$	$\text{Pr} > F = 0.000$	$\text{Pr} > F = 0.000$	$\text{Pr} > F = 0.000$
	$R^2 = 0.363$	$R^2 = 0.422$	$R^2 = 0.723$	$R^2 = 0.664$

Notes: Numbers in parentheses are robust standard errors clustered on groups.

*** Significant at the 1 percent level.

** Significant at the 5 percent level.

* Significant at the 10 percent level.

are much lower, and are not statistically significant. Thus, both single players and teams appear to make adjustments to their investments depending on their opponent's preceding choice, but only if that opponent is a single player, not if the opponent is a team. In other words, opponents of teams tend to ignore the round-by-round variation in those teams' behavior. Focusing on the 4:4 treatment in particular, the results from Table 3 suggest that competing teams do not pay too much attention to each other.

C. Behavior of Individual Team Members

To gain more insight into how teams arrive at their conflict investment decisions, we now look at behavior of individual team members. Within our teams, we find substantial heterogeneity in behavior. This is illustrated in Figure 3. To construct the figure we have, for each team and each quarter of the experiment, ranked the contest expenditures of the individual team members and then computed across all teams the average expenditures of the highest, second highest, third highest, and lowest contributors, respectively. In the absence of heterogeneity within teams, there would be no difference between the highest and the lowest contributors. In contrast, in our data we find extreme differences between team members from the start. In the first quarter of both treatments involving teams, the lowest investor spends less than a third of what the highest investor spends. Although investments then generally decline over time in all ranks (not always monotonically), there is no evidence that team members' behavior converges. Indeed, in the last quarter, the lowest contributor in 1:4 spends only 9 percent of what the highest contributor spends, and in 4:4 only 12 percent. Thus, in relative terms the spread is even higher toward the end than in the early rounds.

How important is the top contributor for the team performance? Consider the 1:4 treatment. While teams invest more than their single-player opponents, the investment per person is generally significantly lower for team members than for individual players (the p -values for each quarter are 0.004, 0.014, 0.056, and 0.018). However, we cannot reject the null when we focus on the

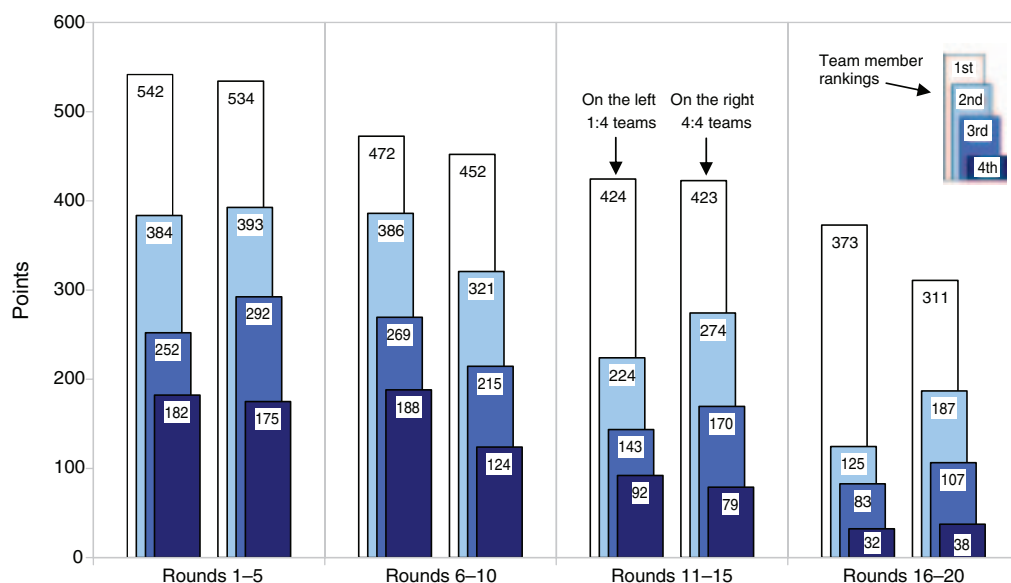


FIGURE 3. AVERAGE EXPENDITURES OF RANKED TEAM MEMBERS (IN POINTS)
(1:4 treatment and 4:4 treatment)

top contributors (p -values: 0.756, 0.154, 0.398, and 0.722). In other words, the top contributors *on their own* put their teams on an even footing with their single player opponents.

While this analysis is based on ranking team members separately for each quarter of the experiment, it is interesting to note that the orderings of individuals within teams are remarkably persistent over time. For instance, Kendall's coefficient of rank concordance across the four quarters is greater than 0.5 in 20 of our 27 teams. Indeed, in the last quarter the top contributors of the first quarter still spend more than their teammates, about 2.3 times as much as the bottom-ranked team members of the first quarter.

Thus, we find strong evidence that our subjects, who by design have identical positions in the experiment and whose identity is kept anonymous, do not behave symmetrically when interacting as members of a team. Some individuals behave as if they were activists and they do not seem to get tired of behaving that way.

The dynamics of choices of the team member who contributes most over the course of a session appear to differ from those of other team members. Table 4 extends our regression analysis above and considers individual team members as the unit of observation, separately for each team's "top contributor" (based on the average over all rounds) and the other team members. As before, the results indicate a significant correlation between current and own lagged expenditure.¹¹

To further examine the dynamics of contest expenditures within teams, we introduce lagged variables for the contributions of the three teammates of an individual. The data suggest that top investors pay attention and positively respond to the *highest* of the other three investments. The correlation between their choices and the lowest of the other three investments, on the other hand, is not statistically significant.

¹¹ Also consistent with what we have found above, the results of Table 3 suggest that the opponent's lagged expenditure has a greater impact on team members' decisions in 1:4 than in 4:4.

TABLE 4—DETERMINANTS OF TEAM MEMBERS' CONFLICT EXPENDITURES IN ROUND t

Independent variables	Dependent variable: team members' contest expenditure in t			
	1:4 Top contributors ^a	1:4 Others	4:4 Top contributors ^a	4:4 Others
Constant	6.021 (56.7962)	52.336** (23.4015)	206.937** (85.3716)	18.820 (16.0863)
Round	1.219 (2.2865)	-3.323** (1.2873)	-6.254* (3.2489)	-1.022 (0.8210)
Own expenditure in $t - 1$	0.566*** (0.1164)	0.298*** (0.0585)	0.392*** (0.1014)	0.352*** (0.0649)
Rival's expenditure in $t - 1$	0.178** (0.0731)	0.134*** (0.0138)	-0.027 (0.0299)	0.033* (0.0142)
Lowest of the teammates' expenditures in $t - 1$	-0.124 (0.1628)	0.468*** (0.0818)	0.234 (0.2365)	0.298*** (0.0823)
Median of the teammates' expenditures in $t - 1$	-0.100 (0.2339)	-0.007 (0.0488)	-0.014 (0.2888)	0.058 (0.0734)
Highest of the teammates' expenditures in $t - 1$	0.322** (0.1051)	0.008 (0.0274)	0.298*** (0.0797)	0.090*** (0.0177)
	$N = 209$ $F(6, 10) = 60.26$ $\text{Pr} > F = 0.000$ $R^2 = 0.529$	$N = 627$ $F(6, 10) = 84.93$ $\text{Pr} > F = 0.000$ $R^2 = 0.468$	$N = 304$ $F(6, 7) = 38.07$ $\text{Pr} > F = 0.000$ $R^2 = 0.322$	$N = 912$ $F(6, 7) = 16.920$ $\text{Pr} > F = 0.000$ $R^2 = 0.391$

Notes: Numbers in parentheses are robust standard errors clustered on groups.

*** Significant at the 1 percent level.

** Significant at the 5 percent level.

* Significant at the 10 percent level.

^a The top investor of each team is determined based on the average expenditure over all 20 rounds.

In contrast, we find that team members who are not “top contributors” appear to pay attention to the *lowest* of the other three investments but appear to care little about the highest investment.¹² Hence, the idea that top contributors particularly spur on their teammates is not well supported by our data. One interpretation of this pattern is that non-top contributors are principally self-motivated in their decisions but are also concerned about being exploited by a low performer who free rides on the team's effort. However, it should be kept in mind that the role of a low contributor is ambiguous in the context of a collective rent-seeking contest. While expending resources in the conflict involves a positive externality for other team members, it imposes a negative externality on the other party and reduces efficiency overall. In this sense, low expenditures could be viewed as exemplary and may affect the decisions of other team members for that reason.

D. Competition between Teams with a Longer Horizon

The tests shown in Table 2 documented that there is no significant downward trend in the last quarter of the 4:4 treatment. Nevertheless, the downward trend of contest expenditures for this treatment in earlier rounds, shown in Figure 1, leads to the question how behavior would look with a longer time horizon. Figure 4 shows average contest expenditure levels for the treatment 4:4/40, based on six groups of eight players, together with those of 1:4 and 4:4. One can see immediately that the average level remains substantially above the Nash equilibrium level (this is also true for each of the six separate groups). Expenditures level off after an initial downward

¹² In the 4:4 treatment, the correlation between the expenditures of those who are not top contributors and the lagged highest expenditure of their teammates is statistically significant. However, the coefficient is quite low.

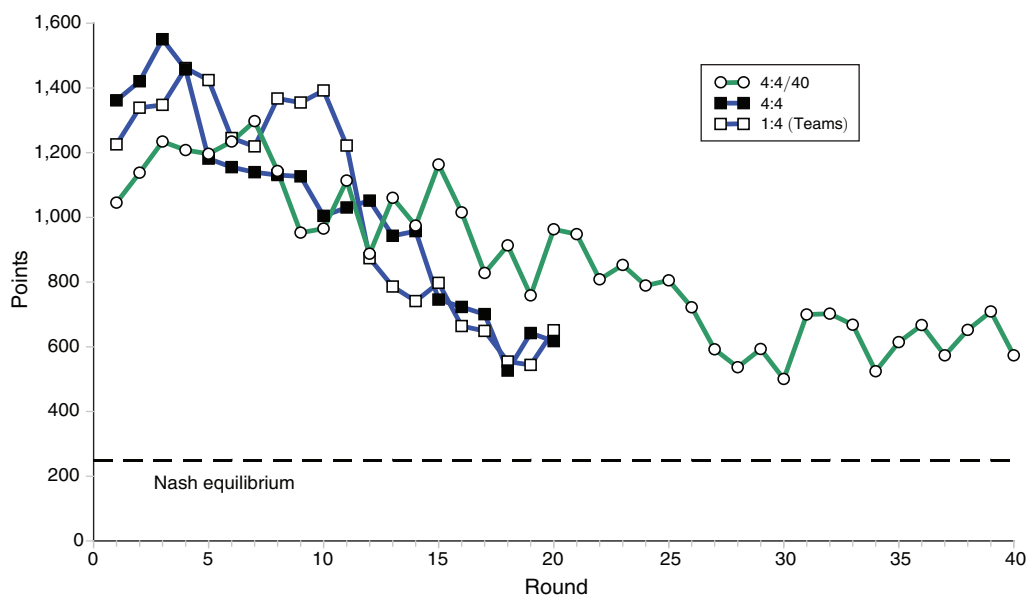


FIGURE 4. CONTEST EXPENDITURES OVER TIME IN THE 4:4/40 TREATMENT
(1:4 treatment and 4:4 treatment included for comparison)

trend. For the 4:4/40 treatment, the leveling off begins at about round 30, with no statistical difference between behavior in rounds 31–35 and that in rounds 36–40. Indeed, the level at which expenditures settle down in rounds 16–20 of the 4:4 and the 1:4 treatments is not statistically significantly different from the level in rounds 31–40 of the 4:4/40 treatment. Thus, while average behavior toward the end of the 40-round sessions is similar to average behavior toward the end of the 20-round sessions, in the 40-round case it takes longer to reach that level. This suggests that the downward trend we observe is not a result of a simple learning process, but more likely due to subjects employing dynamic strategies.¹³

IV. Results on the Effects of Punishment Opportunities

As in Section III, we first focus on aggregate behavior and move later to a more detailed analysis of several features of the results.

A. Time Trends and Differences between Treatments and between Conflict Parties

Figure 5 shows average contest expenditures over time for the 4:4 and the 4:4P treatments; for the latter case we show conflict investment both with and without counting punishment costs. Recall that the graphs show per-team investments and that the benefit a team obtains from winning the contest is 4,000 points overall. The figure reflects the data from eight groups for each treatment. In 4:4P, average direct contest expenditures are remarkably high over the whole range and in some rounds the sum of expenditures across the two rival parties is not far from 4,000, the value of the prize itself. The comparison with the 4:4 treatment shows that the punishment

¹³ Our result that group membership affects behavior is in the line with the minimal-group paradigm notion of Henri Tajfel et al. (1971) and with recent experimental results on the importance of identity by Yan Chen and Sherri Xin Li (2009) and of audience effects by Gary Charness, Luca Rigotti, and Aldo Rustichini (2007).

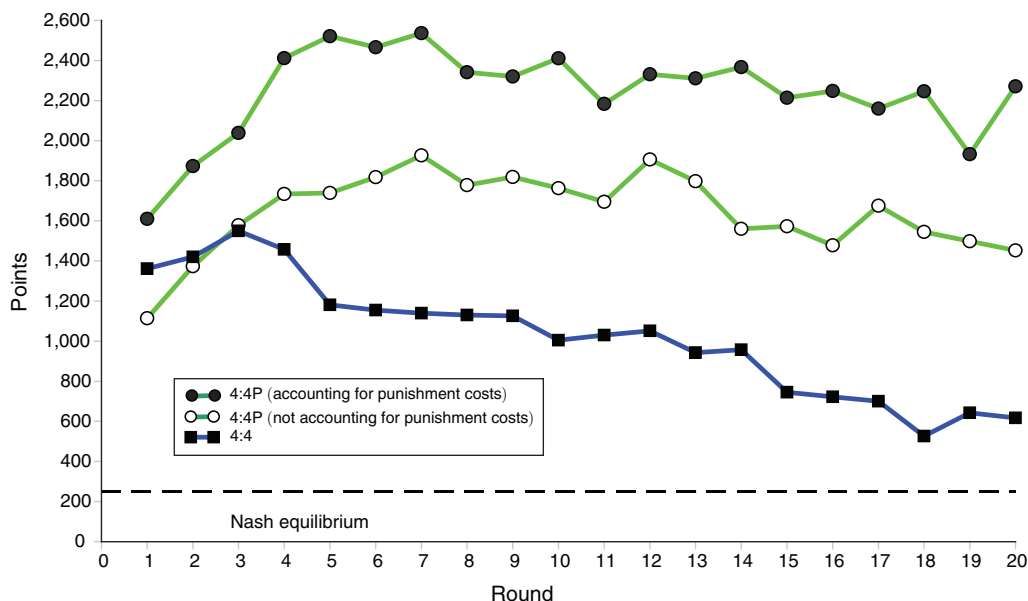


FIGURE 5. CONTEST EXPENDITURES OVER TIME IN THE 4:4 AND 4:4P TREATMENTS

opportunities facilitate this new persistence in fierce interteam competition. Moreover, punishment is not merely a hypothetical threat—it is actually used. Additional point losses due to intrateam sanctions constitute an indirect form of investment in the contest activities of a team. Figure 5 illustrates that, if we take into account these indirect contest expenditures, the total material losses are increased by a quite substantial amount.

The development of the gap between the two 4:4P time series in Figure 5 indicates that, like the direct investments themselves, punishment activities are relatively stable over time. Over the course of the experiment, the average per-round number of deduction tokens a team member allocates to other team members fluctuates around 40 (with a standard deviation of 9.5) and the average in the last quarter is 42. There is no endgame effect of the kind that one often observes in other environments. Note, also, that the level of punishment is less than 10 percent of its maximum value of 500. Nevertheless, this level suffices to cause considerable point losses at the level of teams: recall that each deduction token costs the punisher one point and normally reduces the receiver's point balance by three points. Hence, the average cost of punishment activities amounts to about 498 points per round and team.

Table 5 examines measures of trends over time more formally, using the same procedure as for Table 2. Comparing direct, as well as indirect, contest expenditures across the first and the second half of the sessions, we cannot reject that the levels are equal. Similarly, there is no statistically significant time trend across the last two quarters and within the last five rounds.

Focusing on the last quarter of the experiment, for which we know that contest expenditures in the 4:4 treatment level off, we find a large and significant difference between the two treatments. A two-sample permutation test to examine the difference between the 4:4 treatment (642 points per team in the last five rounds) and the 4:4P treatment (1,530 points, not accounting for punishment costs) yields a p -value of 0.006.¹⁴

¹⁴ Using the same procedure as in Section IIIA, we investigated whether the data contain outliers. No outliers were found in the 4:4P treatment. Furthermore, removing the potential outlier in 4:4 would only strengthen our conclusions regarding the effects of punishment opportunities.

TABLE 5—MEASURES OF TIME TRENDS IN EXPENDITURES AND PUNISHMENT
(Treatment 4:4P; *p*-values in parentheses)

	Rounds 1–10 versus 11–20: Average differences	Rounds 11–15 versus 16–20: Average differences	Rounds 16–20: Average r_s b/t round data and number
Contest expenditure	–46.1 (0.860)	–176.6 (0.110)	–0.301 (0.125)
Punishment activity	1.1 (0.867)	4.0 (0.547)	0.087 (0.734)

Using the observed levels of investment in contest tokens and in punishment tokens, we can now move to a more complete view of the material losses incurred in the 4:4P treatment. In doing this we consider, for a broader comparison, data from all four treatments.

Figure 6 shows, for each of our treatments, the actual levels of rent dissipation for each quarter of the experiment, and also the corresponding equilibrium rent dissipation level. For the 4:4P treatment, we show the rent dissipation levels with and without punishment costs. To calculate rent dissipation in the 1:4 treatment, we relate the observed contest expenditures in a particular round and group to the rent that has actually been produced in that round—1,000 if the single player has won the prize, 4,000 if the team has won. The relevant equilibrium prediction is calculated similarly as the *expected* level of rent dissipation.

The two crucial features of the graph are the actual rent dissipation levels in absolute terms and in relative terms when compared to the corresponding equilibrium prediction. One can see that the absolute level in the 1:1 treatment is extremely high. The relative levels, on the other hand, are highest for the team-versus-team treatments. When we account for punishment costs, the level of rent dissipation in 4:4P exceeds that in 1:1 even in absolute terms, despite the fact that the equilibrium level rent dissipation in 4:4P is only a quarter of that in 1:1.

We can now formulate the answer to our fourth question above in the following result.

Result 4: In the 4:4P treatment, average contest expenditures are 60 percent above those in the 4:4 treatment (119 percent above based on the last five rounds). The observed level of material losses is now 657 percent of the Nash equilibrium level (612 percent based on the last five rounds). Adding the costs of punishment, the observed level of material losses is 896 percent of the Nash equilibrium level (869 percent based on the last five rounds).

B. Details of Investment and Punishment Behavior

Like in the treatments without punishment opportunities, we again observe considerable variation of behavior across groups (recall that the term “group” refers to two teams together), as illustrated in Figure 7. Not accounting for punishment costs, total expenditures per group in the last quarter range from 1,348 points to 5,633 points, the latter figure being more than four times as high as the former (note also that the corresponding equilibrium prediction is 500 points). Compared to the 4:4 treatment, we find that the correlation of expenditures between the two teams of a group is slightly more substantial, with an intraclass correlation coefficient of 0.454 and a *p*-value of 0.097. If, however, we include the punishment expenditures, the correlation is weaker again, with an intraclass correlation coefficient of 0.301 and a *p*-value of 0.201.

Turning to the question of who punishes and who is punished, Figure 8 shows how getting punished depends on one’s investment in relation to team members’ average investment in the preceding round. Clearly, investing too little is what gets punished, whereas deviating upward does not have any effect of triggered punishment. Additionally, Figure 8 shows how the amount

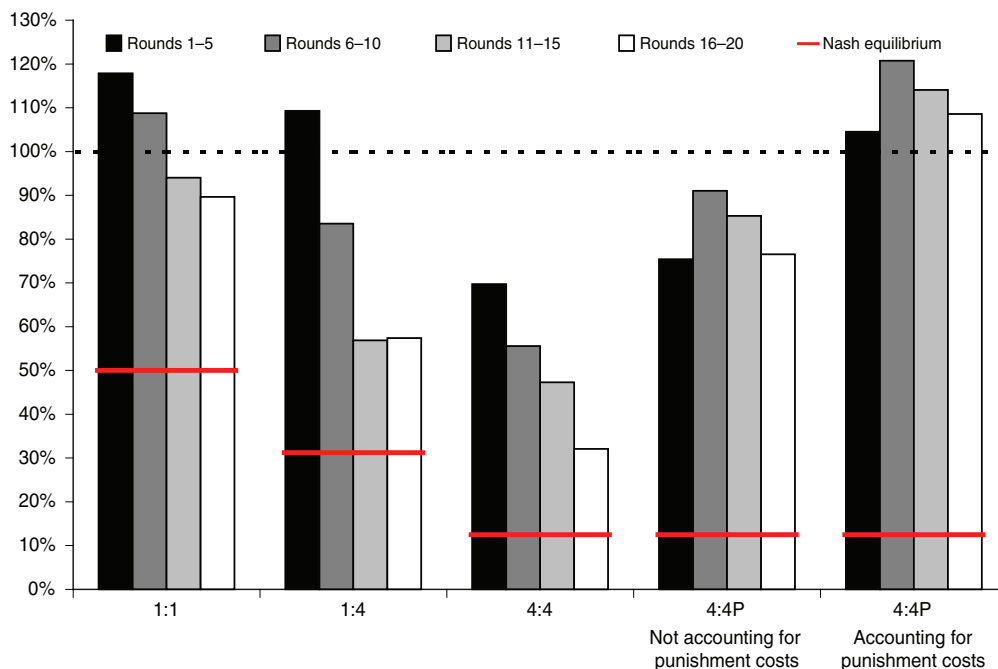


FIGURE 6. ACTUAL AND EQUILIBRIUM RENT DISSIPATION

of punishment imposed on others depends on the punisher's contribution to the team effort in relation to the other three team members' average contribution. Generally, the more somebody invests, the more he will tend to punish. The data shown in the figures are easy to summarize: the more one deviates downward from the team average, the more one gets punished, and most of this punishment comes from those who contribute most to the team effort. Note that these regularities are rather in line with the findings reported in Fehr and Gächter (2000) that subjects in public goods games were more heavily punished the more their contribution fell below the average contribution of other group members, and that contributions above the average were punished much less and did not elicit a systematic punishment response.

One effect of the introduction of punishment opportunities is a decrease in the heterogeneity among team members compared to the 4:4 treatment. We show this in Figure 9, which is constructed in the same way as Figure 3 in Section IIIC above. While there still are considerable differences between the stronger and weaker performers in a team, they are less pronounced, particularly in the later rounds. For example, in the last quarter of the experiment, the lowest contributor now spends 52 percent of the highest contributor, compared to only 12 percent in the 4:4 treatment. Also, unlike in the 4:4 treatment, the disparities within teams do not increase over time—if anything team members behave more homogeneously toward the end of the experiment than at the beginning. The figure also shows how dispatched and received punishment is distributed among the ranked team members. Consistent with Figure 8, top-ranked team members punish on average more than, and get punished less than, any of the other team members; conversely, bottom-ranked team members punish on average less than, and get punished more than, any of the other team members.

The question arises whether the punishment we observe is motivated by *atonement*, i.e., as penance for violating a norm, or by *deterrence*, i.e., to prevent deviators from doing it again.

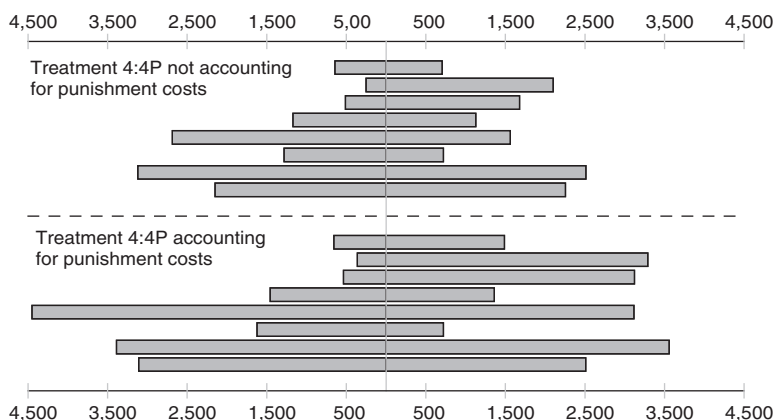


FIGURE 7. AVERAGE CONTEST EXPENDITURES PER CONFLICT PARTY (IN POINTS)
(Based on last five rounds)

There is some suggestion in our data that atonement plays an important role. In the last round it is implausible that punishment can be used as a deterrent, while it can still satisfy atonement motives. In our data we see that punishment is frequently used, even in the last round. On average, subjects spend slightly more on deduction tokens in the last round than in the rest of the experiment (55.5 points versus 38.6 in rounds 1 to 19), though this difference is not significant.

V. Concluding Remarks

The results of our experiments show that group contests with punishment opportunities can be extremely destructive. Contests between groups that rely solely on their members' voluntary contributions to the collective effort are already characterized by investments in fighting far above equilibrium, but it is the addition of punishment possibilities that drives contest expenditure levels at the end of the experiments to about six times the equilibrium levels. Taking into account the resources spent on punishment itself, the level of material losses is 869 percent that of the equilibrium level.

The data we present show one of the dark sides of within-group punishment. They may come as a surprise, given the well-known results on the efficiency-enhancing effects of punishment in public goods games (Fehr and Gächter 2000). In a conflict situation, the possibility of punishing others compounds the problem that putting people into rival groups makes them more competitive, even though that leads to large material losses for all involved. The strength of our results suggests that powerful motives are behind the observed behavior.

Some of the features of the process of punishment are quite similar to those found in public goods experiments. The more a person's investment in conflict deviates downward from the team average, the more that person gets punished. Those who punish more strongly are those whose investment deviates more strongly upward from the group average. It appears that fear of being punished has a disciplining effect on team members and leads to the very wasteful investment levels. On average, total expenditure borne for conflict even exceeds the prize that can be expected to be won in the contest. So, while some behavioral patterns are similar to those observed in previous public goods experiments, the consequences are in stark contrast to them.

Experiments such as ours may help explain the large losses often observed in sociopolitical conflict. When human groups are immersed in situations of rivalry, emotional forces may

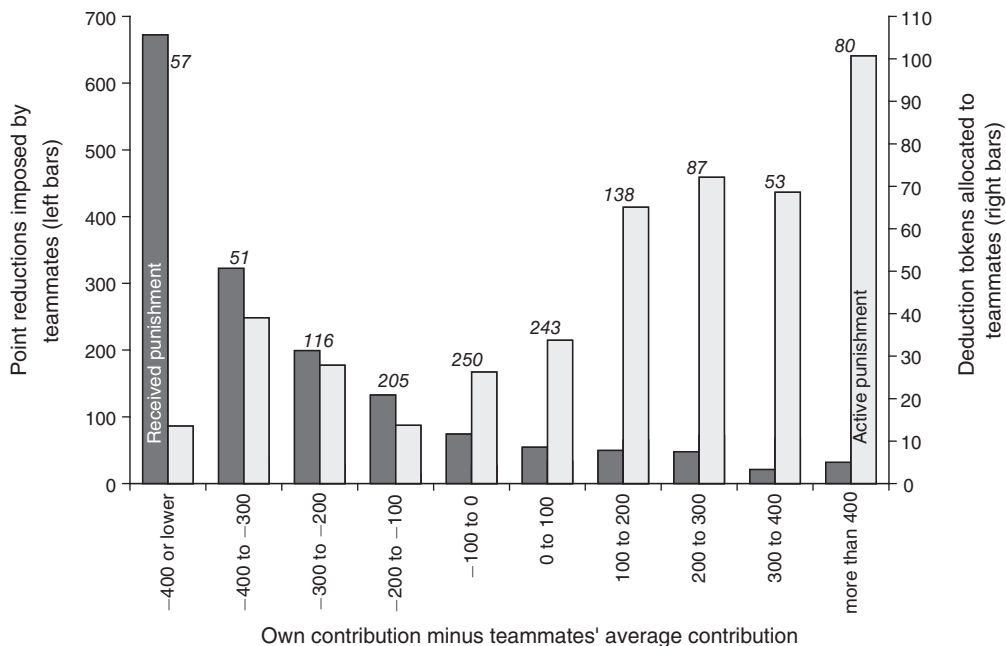


FIGURE 8. RECEIVED/ACTIVE PUNISHMENT IN RELATION TO OWN RELATIVE EXPENDITURES
(Number of data points behind each average in italics)

take over and lead to materially inefficient outcomes. We find these outcomes in the abstract, anonymous environment of a laboratory experiment, in absence of any ethnic, religious, or class division between the groups. Emotional forces related to rivalry between conflict parties can be conjectured to be much more intense in field environments involving parties that may have been in conflict for a long time. We are conscious of the fact that our work yields only some insights into issues of tremendous scope.

This is the first experiment on team rent-seeking and naturally it raises as many questions as it answers. One such question is how players deal with the two-dimensional nature of the strategic interaction in collective rent-seeking contests, where individuals interact within a team and at the same time the teams compete against each other. Our subjects seem to focus more on the interaction with other team members than on that with the rival team, but at this point one can only speculate whether this can be generalized and how this is best explained. Customized future experiments may examine this phenomenon more rigorously.

Our experimental setup was designed to explore the general nature of human behavior in the face of a conflict situation. Beyond fundamental behavioral research, we believe that the team rent-seeking paradigm is a suitable tool to analyze empirical questions about the causes of conflict, as a complement to field studies, or as a substitute where field data are unavailable. Numerous studies have empirically investigated the impact of economic growth (Edward Miguel, Shanker Satyanath, and Ernest Sergenti 2004), or ethnic polarization and fragmentation (James D. Fearon and David D. Laitin 2003; José G. Montalvo and Marta Reynal-Querol 2005) on likelihood and intensity of civil conflict. In the field, robust data are notoriously hard to come by, since outbreaks of conflicts are infrequent events happening under many idiosyncratic circumstances. In the laboratory, we can recreate a controlled set of conditions and incentives where we can analyze which factors of the economic and political environment are most likely

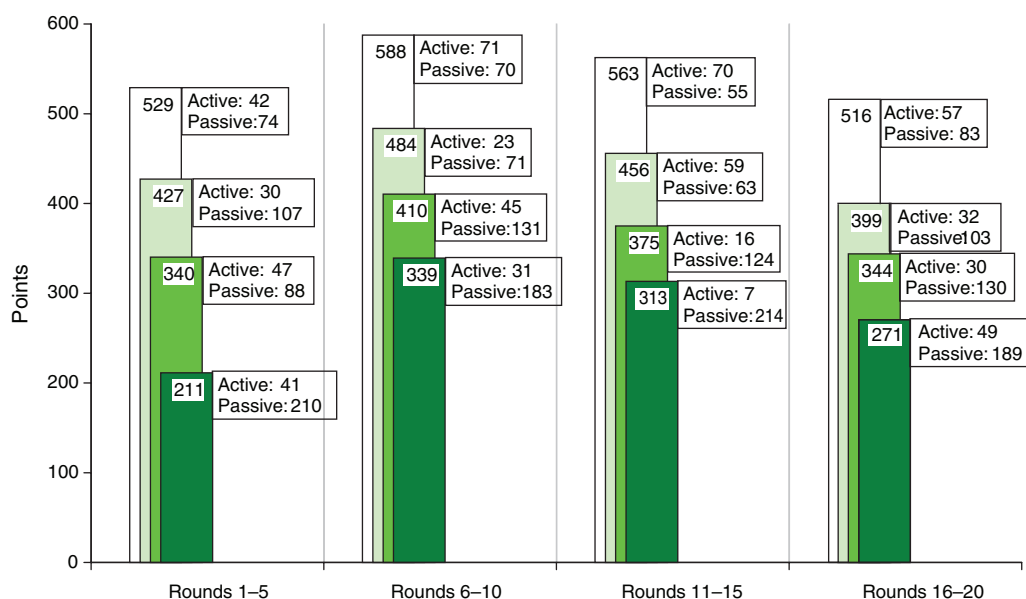


FIGURE 9. AVERAGE EXPENDITURES OF RANKED TEAM MEMBERS IN 4:4P (IN POINTS)
 (Boxed: active/passive punishment, measured in tokens and points, respectively)

to lead to conflict, keeping all other circumstances equal. The team rent-seeking paradigm seems a natural starting point for such empirical research, since it captures essential features of a conflict situation, yet is simple enough to implement, and its main components straightforward to manipulate.

Of course, our results are not the final word on the matter. To keep the experimental model simple, we had to leave out many important features of real-life conflicts. For instance, our experiment was conducted under anonymous laboratory conditions in order to establish the most controlled conditions. In real-life, communication and propaganda can affect the intensity of conflicts. Further, leaders are often important in order for groups to mobilize forces. One might also speculate that the influence of communication and leadership on conflict is critical, particularly in the larger groups involved in many real-life conflicts. Finally, we modeled the prize as perfectly nonrival. In reality, there are many instances in which the prize in a conflict is better described as a private good to be shared, or as a good that has a mix of private and public goods. Studying all these features is beyond the scope of the present study, but we believe our results pave the way for a promising future research agenda.

APPENDIX A: INSTRUCTIONS

The following is a copy of the instructions for the 4:4P treatment. The instructions for the other treatments are straightforward variations of these.

Instructions

Welcome! You are about to take part in an experiment in the economics of decision making. You will be paid in private and in cash at the end of the experiment. The amount you earn will depend on your decisions, so please follow the instructions carefully.

During the experiment you will have the chance to earn points, which will be converted into cash at the end of today's session, using an exchange rate of 30 points = 1p. Thus, the more points you earn, the more cash you will receive at the end of the session. You will start with an endowment of 3,000 points.

It is important that you do not talk to any of the other participants until the session is over.

At the beginning of the experiment you will be matched with three other people, randomly selected from the people in this room, to form up a team of four. In total there will be four teams (each consisting of four people). During the experiment your team will be playing against one of the other teams and that team will be the opponent of your team. Note that you will not learn who your team colleagues or your opponents are, neither during nor after today's session. Likewise, neither your team colleagues nor your opponents will learn about your identity.

The experiment will consist of 20 rounds, and in each round your team and your opponents will be competing for a prize, as will now be explained.

At the beginning of each round you will receive 1,000 points from us. You can then use these points to purchase "contest tokens" for your team. Each contest token you buy costs you 1 point and you can purchase up to 1,000 of these tokens. Any points you do not invest into contest tokens will simply be added to your point balance and are yours to keep. Likewise, your team colleagues and your opponents will have the chance to buy contest tokens, in exactly the same way.

As soon as everybody has chosen how many contest tokens to buy, a lottery wheel will determine whether your team or your opponents win the prize. The prize is worth 4,000 points (1,000 for each team member) and your chances of winning the prize depend on how many contest tokens your team has bought and how many contest tokens your opponents have bought. This works as follows:

The lottery wheel is divided into two shares with different colors. One share belongs to your team and the other share belongs to your opponents. The size of your share and the size of your opponents' share on the lottery wheel are exact representations of the number of contest tokens bought by your team and bought by your opponents. For instance, if your team and your opponents have each bought the same number of contest tokens, each team gets a 50 percent share of the lottery wheel. If your team has bought twice as many contest tokens as your opponents have, your team gets two-thirds of the wheel and your opponents get one-third of the wheel.

Once the shares of the lottery wheel have been determined, the wheel will start to rotate and after a short while it will stop at random. Just above the lottery wheel there is an indicator at the 12 o'clock position. If the wheel comes to a halt such that the indicator points at your team's share, your team wins. If the wheel comes to a halt such that the indicator points at your opponents' share, the opponent team takes the prize and your team will have lost.

Thus, your chances of winning the prize increase with the number of contest tokens your team buys. Conversely, the more contest tokens your opponents buy, the higher the probability that you lose. If one of the teams doesn't buy any contest tokens, the other team wins the prize with certainty. If nobody buys any contest tokens, no lottery takes place and the prize is lost.

At the end of each round, after the lottery is resolved and the winning team is determined, team members can, if they wish, assign "deduction tokens" to each other (*not* to members of the other team). Each deduction token you receive from a team colleague will reduce your point balance by three points. It is possible that this wipes out your earnings from a particular round. (Theoretically, the reduction could even *exceed* your earnings from the round, but the computer will disregard such "excess" reduction.)

Every deduction token you assign to a team colleague will cost you one point (and will reduce the recipient's point balance by three points). The maximum total number of deduction tokens you can assign to your team colleagues is 500. If you do not wish to assign deduction tokens to a person, simply fill in a "0."

The points you earn in each round will be added together. At the end of the session you will be paid based on your total point earning from all 20 periods.

APPENDIX B: RISK AVERSION IN GROUP RENT-SEEKING CONTESTS

We examine, here, to what extent risk aversion affects the standard prediction of a 250-point investment per conflict party, which was derived under the assumption of risk neutrality. There is a literature on the effects of risk aversion in rent-seeking contests, which includes Skaperdas and Li Gan (1995), Konrad and Harris Schlesinger (1997), and Richard Cornes and Roger Hartley (2003), but this research focuses on the behavior of individual contestants.

Consider a generalized model that employs an unspecified, continuous and differentiable concave utility function. Assuming that this utility function $u(\cdot)$ is the same for all players and that this is common knowledge, we write player i 's expected utility as

$$(B1) \quad \frac{X}{X+Y}u(R+E-x_i) + \frac{Y}{X+Y}u(E-x_i),$$

where R is the reward the player receives when her team wins the contest, and E is her initial endowment. As before, X denotes the sum of rent-seeking expenditures in player i 's team, Y denotes the expenditures of the opponent team, and x_i is player i 's individual contribution. Differentiating (B1) with respect to x_i and setting the result equal to zero yields

$$(B2) \quad \frac{X}{X+Y}(u(R+E-x_i) - u(E-x_i)) = Xu'(R+E-x_i) + Yu'(E-x_i).$$

We wish to focus on symmetric equilibria (i.e., $Y=X$) and hence we get

$$(B3) \quad \frac{u(R+E-x_i) - u(E-x_i)}{u'(R+E-x_i) + u'(E-x_i)} = 2X.$$

What are the most extreme equilibrium levels of X that can be sustained in equilibrium? As the equation shows, this will depend on the absolute difference in utility that is obtained when the player wins the prize and when she does not (numerator), and on the sum of the slopes of the utility function in these two points (denominator).

To illustrate this, consider Figure 10, which sketches the two relevant points (labeled A and B) in terms of material payoffs and accompanying utility levels. The utility function, not shown here, can take different concave forms but must pass through both points. A limit case emerges when the utility function becomes linear (risk neutrality). Then we have

$$(B4) \quad u'(E-x_i) = u'(R+E-x_i) = \frac{u(R+E-x_i) - u(E-x_i)}{R} \equiv m_{\text{lin}}$$

and using this in equation (B3) we immediately get

$$(B5) \quad X_{\text{risk neutrality}} = \frac{1}{4}R,$$

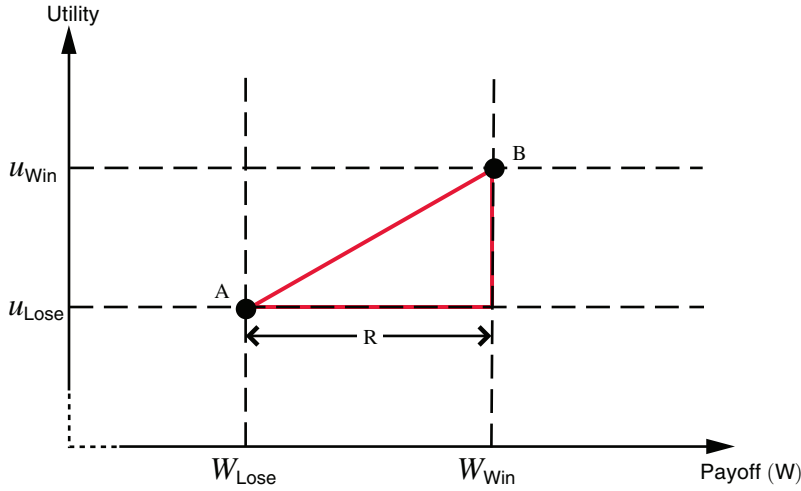


FIGURE 10

which replicates our result from the main text ($R = 1000$, hence $X_{\text{risk neutrality}} = 250$).

Considering another extreme, if we wanted to maximize the sum of the two slope values, we can imagine a concave function that passes through A with a near vertical slope, and passes through B with a slope approaching the value m_{lin} from below. Thus, the sum of the two values can be made arbitrarily high, and therefore

$$(B6) \quad X_{\min} \rightarrow 0.$$

Finally, if we wanted to minimize the sum of the two slope values, we can imagine a utility function that passes through A with a slope approaching m_{lin} from above, and passes through B with a slope approaching zero from above. In the limit,

$$(B7) \quad X_{\max} \rightarrow \frac{1}{2} \frac{u(R + E - x_i) - u(E - x_i)}{0 + m_{\text{lin}}} = \frac{1}{2} R.$$

Hence, the maximum level of rent dissipation that can be supported in equilibrium approaches twice the level that emerges under risk neutrality. To come close to this, however, an extreme utility function with a very peculiar shape is required. Therefore, we then turn to more conventional functional forms: (i) a CARA function, (2) a CRRA function, and (3) Atanu Saha's (1993) power-expo function utilizing parameter estimates from Charles A. Holt and Susan K. Laury's (2002) empirical study on risk aversion. As we will see, under these specifications, risk aversion always has a dampening effect on equilibrium expenditures relative to the risk-neutral benchmark.

Special case 1: CARA

Consider the specification $u(W_i) = -e^{-\alpha W_i}$, which is well known to be characterized by CARA. With this functional form, equation (B3) can be written as

$$(B8) \quad \frac{e^{-\alpha(R+E-x_i)} + e^{-\alpha(E-x_i)}}{\alpha e^{-\alpha(R+E-x_i)} + \alpha e^{-\alpha(E-x_i)}} = 2X.$$

When we divide both the numerator and the denominator by $e^{-\alpha(E-x_i)}$ and rearrange, we get

$$(B9) \quad X_{\text{CARA}} = \frac{1}{2\alpha} \frac{1 - e^{-\alpha R}}{1 + e^{-\alpha R}}.$$

Consider, first, the limit case when α approaches zero. Using l'Hôpital's rule, we obtain

$$(B10) \quad \lim_{\alpha \rightarrow 0} \left(\frac{1 - e^{-\alpha R}}{2\alpha(1 + e^{-\alpha R})} \right) = \frac{1}{4}R = X_{\text{risk neutrality}}.$$

Next, consider the slope of X_{CARA} :

$$(B11) \quad \frac{\partial X_{\text{CARA}}}{\partial \alpha} = \frac{e^{-2\alpha R} + 2\alpha R e^{-\alpha R} - 1}{2\alpha^2(1 + e^{-\alpha R})^2}.$$

The denominator is obviously positive for any $\alpha > 0$. The numerator can be shown to be negative for any $\alpha > 0$. To see this, let $h_1(\tau) = e^{-\tau} + 2\tau$, let $h_2(\tau) = e^{\tau}$, and note that the numerator in (B11) is negative for $\alpha > 0$ and $R > 0$ if and only if $h_1(\tau) < h_2(\tau)$ for $\tau > 0$. We prove that $h_1(\tau) < h_2(\tau)$ for $\tau > 0$ by showing that (a) $h_1(0) = h_2(0)$, (b) $h'_1(0) = h'_2(0)$ and (c) $h''_1(\tau) < h''_2(\tau)$ for any $\tau > 0$. If (b) and (c) hold, it follows that $h'_1(\tau) < h'_2(\tau)$ for $\tau > 0$, and this together with (a) implies that $h_1(\tau) < h_2(\tau)$ for $\tau > 0$.

Statement (a) is obviously true: $h_1(0) = h_2(0) = 1$. Statement (b) holds as well: the first derivatives of $h_1(\tau)$ and $h_2(\tau)$ are $h'_1(\tau) = 2 - e^{-\tau}$ and $h'_2(\tau) = e^{\tau}$, and thus $h'_1(0) = h'_2(0) = 1$. Finally, the second derivatives of $h_1(\tau)$ and $h_2(\tau)$ are $h''_1(\tau) = e^{-\tau}$ and $h''_2(\tau) = e^{\tau}$, and thus $h''_1(\tau) < h''_2(\tau)$ for any $\tau > 0$.

The results can be summarized as follows. First, as the CARA parameter α approaches zero, X_{CARA} approaches the equilibrium team expenditure level under risk neutrality. Second, as the CARA parameter α increases, equilibrium team expenditures decrease. Third, from (B9), the value of X_{CARA} does not vary with team size.

Special case 2: CRRA

Now consider the specification $u(W_i) = W_i^{1-\beta}/(1-\beta)$, which is well known to be characterized by CRRA. With this functional form, equation (B3) can be written as

$$(B12) \quad \left(\frac{1}{1-\beta} \right) \frac{(R + E - x_i)^{1-\beta} - (E - x_i)^{1-\beta}}{(R + E - x_i)^{-\beta} + (E - x_i)^{-\beta}} = 2X.$$

This problem is not tractable analytically. However, assuming symmetric behavior among team members in equilibrium ($x_i = X/n$), equilibrium expenditures for our parameters ($E = R = 1,000$) can be plotted as a function of β . We have done this in Figure 11.

As the figure shows, equilibrium expenditures decrease with β , the level of relative risk aversion. This effect is more pronounced for single contestants, but the difference and the overall effect are both very small.

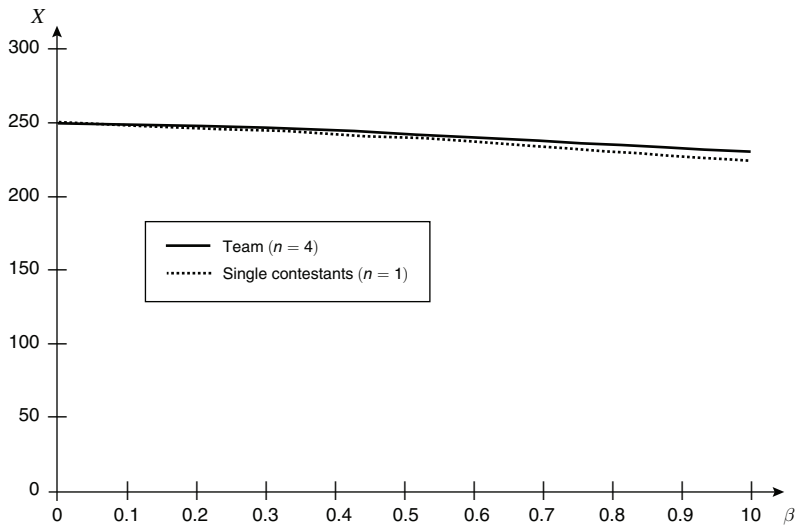


FIGURE 11. EQUILIBRIUM EXPENDITURES PER CONFLICT PARTY UNDER CRRA

Special case 3: Power-expo function with specific parameter estimates

This functional form was developed by Saha (1993). We employ, here, the parameter estimates calculated by Holt and Laury (2003), who find that this “model does a remarkable job of predicting behavior over a payoff range from several dollars to several hundred dollars” (1653). We obtain the following specification:

$$(B13) \quad u(W_i) = 34.4828 - \frac{1}{0.029} e^{-0.029 W_i^{0.731}}.$$

Using this in (B3) and solving numerically yields equilibrium values of $X = 133.64$ for single contestants ($n = 1$), and $X = 136.79$ for teams ($n = 4$). These values are extremely similar but substantially below the prediction under risk neutrality.

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