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ABSTRACT:

We introduce three variations of the Hirshleifer-Skaperdas conflict game to study experimentally the effects of post-conflict behavior and repeated interaction on the allocation of effort between production and appropriation. Without repeated interaction, destruction of resources by defeated players can lead to lower appropriative efforts and higher overall efficiency. With repeated interaction, appropriative efforts are considerably reduced because some groups manage to avoid fighting altogether, often after substantial initial conflict. To attain peace, players must first engage in costly signaling by making themselves vulnerable and by forgoing the possibility to appropriate the resources of defeated opponents.

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1. Introduction

Conflict, defined as a situation in which agents employ costly resources that are adversarially combined against one another (Garfinkel and Skaperdas, 2012), is a widespread social phenomenon with occasionally huge socio-economic consequences. A clear example is warfare. Other examples are political competition for dominance in public or private institutions, rent-seeking by political interest groups, litigation by contending parties, and business contests in marketing or takeovers. At the heart of these examples is typically a choice between a productive and an appropriative use of resources as means of pursuing wealth. In their seminal studies Hirshleifer (1988; 1991a) and Skaperdas (1992) model this choice as a contest between two players who allocate effort between production and "predation", with a higher predatory effort increasing the probability of appropriating the other player's production.[1] In the meantime, this literature has branched into various directions, among other things dealing with dynamic issues (like economic growth) and the formation of alliances, and has become part of a more general theory of contests.[2] Next to theory, an empirical economic literature on conflict has developed. This literature includes, for example, Keynes (1920) classic critique on the reparations demanded from Germany after World War I, the assessment of the impact of military expenditures on economic growth (Dunne and Uye, 2010), and recent cost estimates of warfare such as Nordhaus (2002), Stiglitz and Bilmes (2008), and several studies in Hess (2009) and Garfinkel and Skaperdas (2012). In spite of their undeniable value, field empirical studies like these are handicapped by definitional issues (e.g., which non-monetary costs to include), severe difficulties in gathering data, and a lack of control to disentangle driving factors of conflict and to determine their impact (see e.g., Sköns, 2006). In this respect, laboratory experimentation serves as an important complementary tool

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[1] Garfinkel and Skaperdas (2012) review some earlier studies and refer to Haavelmo (1954) as the first one to model the basic choice between production and appropriation. Contest theory builds on the related rent-seeking model of Tullock (1980). The main differences between conflict models and rent-seeking models is that in the former the contested prize is endogenous and resources are locked into the contest (i.e., there is no safe haven; Neary, 1997a). These models are distinct from the literature on tournaments in that they focus on cases in which there are no positive externalities for third parties, which exclude, for example, sportive contests.

[2] Excellent surveys are provided by Garfinkel and Skaperdas (2007) and Konrad (2009).

because it can focus on fundamental mechanisms through the control and opportunity to replicate that it offers. The experimental literature on conflict is recent and small (see Abbink, 2012). For convenience, we will review this literature in the next section.

This paper presents an experimental study investigating the effects of post-conflict behavior and repeated interaction on behavioral factors fostering the escalation of conflict or the advancement of peace. Behavior in the aftermath of conflict is important for two reasons. First, its anticipation may influence the investment in conflict. For example, it may restrain conflict expenditures if the behavior of the defeated is expected to negatively affect the return on conflict. Second, in case of repeated interaction between the contestants, post-conflict behavior may be used for signaling purposes, affecting escalation or de-escalation of conflict and the possibility of peace.

We explore the importance of post-conflict behavior by extending the Hirshleifer-Skaperdas model in two notable ways. First, we realistically assume that appropriation of production after a contest is an act in itself instead of an automatic consequence of winning. This may be of importance, as experimental evidence suggests that agency matters, that is, people react differently to the same outcome depending on the intentions of the person behind it (e.g., Blount, 1995; Falk et al., 2008). Second, we include situations where the defeated party has the opportunity to increase the victor's appropriation costs by offering resistance or by applying scorched-earth tactics (Hirshleifer, 1991b). To some extent, the possibility that appropriation as such produces efficiency losses has been acknowledged in the literature by introducing an exogenous cost of predation (Neary, 1997b; Grossman and Kim, 1995; McBride and Skaperdas, 2009). In our setup, this cost is endogenous. More specifically, we investigate the following three extensions of the conflict game.

Total Conquest: In this extension, the winner of the contest gets to decide how much to appropriate of the loser's production (instead of automatically receiving all of it). This additional stage, which is formally equivalent to a dictator game, allows winners to restrain themselves. History shows that victors have treated their defeated very differently. However, in reality, many factors typically play a role and the underlying motives are hard to tease apart. Controlled experimental evidence on the dictator game suggests that people may show restraint in taking (see Camerer, 2003). Therefore, some investment in conflict might be due to defensive reasons (i.e., protecting one's own production) or to a strong dislike of being defeated (e.g., because of betrayal aversion, Bohnet et al. 2008) as opposed to the desire to appropriate someone else's production. Total Conquest also serves as a benchmark for our other extensions of the conflict game.

Resistance: Because appropriation generally takes time, there may be room for a response by the defeated. Often, the losing party of the contest may affect the ability of the victor to appropriate the capital, labor, or goods involved in production (see e.g. Sköns, 2006). This can happen through capital or population flight, sabotage (e.g. destruction of oil fields or crops), strikes, lower work morale, or the redirection of effort to a shadow economy. All of these reactions will typically be costly to both parties. In this extension, we therefore assume an additional stage where the loser of the contest—knowing how much the winner wants to appropriate—can decide to destroy part or all of his own production. In this case, the winner can commit to a rate of appropriation but cannot avoid an economically destructive response by the defeated that hurts both.[3]

Scorched Earth: The underlying argumentation for this extension is similar to the previous one but we now assume that the winner of the contest cannot credibly commit *ex ante*, so that the loser must decide how much to destroy of his own production before knowing how much the winner will appropriate.[4] For some dramatic military examples, one may think of the Kuwaiti oil fires started by the Iraqi military forces in 1990 when they were driven out by the U.S., or Hitler's order to destroy all of Germany's resources when he realized he had lost the war.

A second contribution of this paper is to study the differential impact of these three extensions of the conflict game on the dynamics of conflict and peace. As Garfunkel and Skaperdas (2007) conclude in their survey: "Very little is known about how to reduce, let alone eliminate, conflict." One obvious reason is that, typically, an unambiguously peaceful outcome does not exist. This holds for most rent-seeking experiments where, if there are no conflict expenditures, either no payoff is obtained or there is an equal probability of winning the contest. We give players the option to attain peace by simultaneously refraining from investing in conflict, which results in no appropriation by

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[3] Although commitment may never be completely feasible, reputational concerns may come close. The latter are often invoked in lobbying models to justify an implicit commitment assumption (Grossman and Helpman, 2001).

[4] The difference in commitment between Scorched Earth and Total Conquest, has been studied by Van Huyck et al. (1995) with the peasant-dictator game and by Gehrig et al. (2007) with the ultimatum game. Their designs are different in various respects. Most notably, they miss the first conflict stage.

all. This peaceful outcome is particularly relevant and interesting when combined with repeated interaction in the various post-conflict settings. The reason being that these settings offer additional opportunities to signal peaceful intentions—for example, by not appropriating as a victor in Total Conquest—that may be employed more often and be more effective than a unilateral reduction of conflict expenditures, which makes one vulnerable to the appropriative efforts of others.

We identify the differences between one-shot interaction and repeated play by comparing behavior when subjects are randomly re-matched after every iteration of the game (i.e., a *Strangers* matching protocol) to behavior when they always play the game with the same counterpart (i.e., a *Partners* matching protocol). Depending on the type of conflict one is thinking of, one or the other form of interaction may be more relevant. For instance, warfare against different opponents in empire building is more like Strangers, while repeated political competition for dominance between the same parties is better captured by Partners. An example where both forms of interaction are important is cattle raids, which occur as single instances or as waves of raids by rival communities. This regularly happens, for instance, in South Sudan, where cows are extremely important. On one tragic occasion, in 2011, the Murle ethnic group and community killed 600 people from the Lou Nuer community, abducted 200 children, and stole around 25,000 cows, while an estimated 400 Murle were killed (Copnall, 2011). The raid was part of a cycle of vendettas stretching back for decades, and rumors had it that the next raid was already being prepared.

2. Literature review

The recognition of laboratory experiments as useful tool for the analysis of behavior in conflict situations has generated a small but growing literature on this topic. Abbink (2012) provides a recent survey of laboratory experiments on conflict, while Dechenaux et al. (2012) reviews the experimental research on contests more generally, particularly Tullock contests, all-pay auctions, and rank-order tournaments (see also Öncüler and Croson, 2005; Herrmann and Orzen, 2008). Here we concentrate on the studies that are most closely related to ours.

Like us, Durham et al. (1998) base themselves on the model of Hirshleifer (1991a). Specifically, they examine whether changes in the technology of conflict affect productive activities and the manifestation of the "paradox of power" (i.e., poorer players improving their economic position relative to richer ones). They find broad support for the qualitative predictions of the model. We extend the work of Durham et al. (1998) by analyzing post-conflict behavior using the three extensions of Hirshleifer (1991a) described in the introduction.

A series of studies have looked at models that separate investments in defense from those in predation. Carter and Anderton (2001) conduct an experiment based on the predator-prey model of Grossman and Kim (1995) and find that increases in the relative effectiveness of predation against defense leads to behavioral changes in line with the theoretical prediction.[5] Kovenock et al. (2010), Deck and Sheremeta (2012), and Chowdhury et al. (2013) examine variations of the Colonel Blotto game. They find that behavior is qualitatively in line with the theoretical predictions, but aggregate expenditures tend to exceed the predicted levels. Unlike these studies, we do not consider investments that are exclusively defensive. In our games, players can exhibit defensive behavior by investing in conflict, winning the contest, and then not appropriating the resources of the vanquished player. Hence, players with peaceful intentions face a commitment problem in the sense that successful defense is accompanied by the subsequent temptation to appropriate.[6]

There are plenty of experimental studies showing that cooperation tends to increase with both indefinitely and finitely repeated interaction (see Andreoni and Croson, 2008). However, there is little evidence of the effects of repeated interaction in conflict games.[7] Durham et al. (1998) do consider partners and strangers matching protocols and find little evidence that repeated interaction leads to sustained peaceful relations. As argued in the introduction, this might be due to the absence of a completely peaceful outcome and post-conflict opportunities where players can signal peaceful intentions. Moreover, unlike Durham et al. (1998), we analyze the dynamics leading to the escalation and de-escalation of conflict. Our work is also related to Abbink and Herrmann (2009), Abbink and de Haan (2011), and Bolle et al. (in press), who study the dynamics of

[5] Two related studies that allow for differential investments in defense and predation are Duffy and Kim (2005) and Powell and Wilson (2008). The focus of these studies, however, is the emergence of productive societies from anarchic beginnings, and in the case of Duffy and Kim (2005), the role of the state in enabling this process.

[6] In this respect, our study relates to the alliance game of Ke et al. (2013), where appropriation opportunities after victory make prior alliances harder to form.

[7] McBride and Skaperdas (2009), Smith et al. (2011), and Tingley (2011) study situations diametric to ours, where the future interaction increases present conflict because it weakens rivals and improves one's relative position in the future.

destructive behavior in games where players (groups or individuals) have opportunities to hurt each other in repeated settings. They all find considerable evidence of destructive behavior. Bolle et al. (in press) also demonstrates how the escalation of this type of behavior is mediated by negative emotions. These studies, however, do not attempt to evaluate the impact of repeated interaction compared to a random-matching benchmark and use settings without appropriation.

Finally, a couple of studies analyze whether institutions such as the opportunity to make side payments (Kimbrough and Sheremeta, 2013) or political autonomy (Abbink and Brandts, 2009) facilitate the de-escalation of conflict. Kimbrough and Sheremeta (2013) show that both binding and non-binding side-payments significantly reduce the prevalence of conflicts. Abbink and Brandts (2009) demonstrate how costly struggle occurs because purely emotional elements impede players from agreeing on a mutually acceptable level of autonomy.

3. Total conquest

In this section, we introduce and subsequently analyze the experimental results of our first extension of the Hirshleifer-Skaperdas conflict game.

3.1 The game

In the Total Conquest (TC) game, two players $i \in \{1,2\}$ interact in two distinct stages. Each player is endowed with y points, which can be spent on conflict or used to generate income. In the first stage, each player i simultaneously decides how many points $c_i \in [0, y]$ to spend on conflict. For simplicity, i's generated income equals the remaining $y - c_i$ points. If both players spend zero points on conflict, the game ends and each player receives a payoff equal to their generated income. However, if either player's conflict expenditures are positive, both players compete in a *contest* and play the second stage. The contest's winner is determined with a lottery in which each player's probability of winning equals their relative conflict expenditures, $p_i = c_i/(c_i + c_j)$.[8] In the second stage, the winner of the contest decides how much of the loser's production to appropriate (the loser makes no decision). Specifically, if player i wins, she chooses a "take rate" $t_i \in [0,1]$, which is

[8] We apply the commonly-used contest function $p_i = c_i^m/(c_i^m + c_j^m)$ with $m = 1$. This functional form is also employed by Tullock (1980) and the literature on rent seeking. The parameter m is interpreted as the degree of uncertainty in the determination of the winner (Hirshleifer, 1989; Skaperdas, 1996).

the fraction of $y - c_j$ that she wishes to claim. In summary, if $c_1 + c_2 = 0$ then each player earns $\pi_1 = \pi_2 = y$ points, else if $c_1 + c_2 > 0$ then the expected earnings of each player $i \in \{1,2\}$ equal

$$E[\pi_i] = \frac{c_i}{c_i + c_j^e}\left(y - c_i + t_i\left(y - c_j^e\right)\right) + \frac{c_j^e}{c_i + c_j^e}\left(1 - t_j^e\right)(y - c_i), \tag{1}$$

where c_j^e and t_j^e are i's expected value for c_j and t_j. Note that the first element in the expression corresponds to i's expected earnings if she wins multiplied by her probability of winning, and the second element is i's expected earnings if she loses multiplied by her probability of losing.

As a benchmark, we calculate the optimal conflict expenditures of risk neutral players who maximize their monetary earnings in a one-shot TC game.[9] In section 4, we discuss the consequences of relaxing these assumptions. The model is solved by backward induction. If player i wins the contest, she will appropriate all of j's production, i.e., she chooses $t_i = 1$. Therefore, labeling c_j^e and t_j^e as i's expected value for c_j and t_j, if i expects j to choose $c_j^e > 0$, we can obtain i's best reply by maximizing expression (1), which gives:[10]

$$c_i^* = \sqrt{c_j^e\left(\left(1 + t_j^e\right)y - \left(1 - t_j^e\right)c_j^e\right)} - c_j^e, \tag{2}$$

else if i expects j to choose $c_j^e = 0$ then she simply has to spend the smallest possible amount $c_i^* = \epsilon$ in other to win the contest with certainty and take all of j's income. If we further assume that it is common knowledge that all players are risk neutral and maximize solely their monetary earnings, in the Nash equilibrium of the game both players spend half of their endowment on conflict, $c_i^* = c_j^* = \frac{1}{2}y$, and each player has an equal probability of winning $p_i^* = p_j^* = \frac{1}{2}$.

Compared to Durham et al. (1998) implementation of the Hirshleifer-Skaperdas model, our game differs in that: (i) appropriable resources are not part of a common pool, and therefore, players can avoid the contest altogether if they do not invest in conflict, (ii) investment in conflict determines only the probability of winning, and (iii) final earnings are decided on by the winner.[11] Thus, our model is more representative of situations in which two independent players can

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[9] Assuming common knowledge and using backward induction, this benchmark also holds for the finitely repeated game.

[10] We assume that i does not expect j will condition t_j on the value of c_i. If this were the case, i would have to take into account how her conflict expenditures affects her earnings when she loses the contest.

[11] In Durham et al. (1998), the contest function directly determines the players' final earnings as a share of the total surplus—with our parameters this translates to i's earnings being equal to $\pi_i = p_i(c_i, c_j)(y - c_i + y - c_j)$.

(unilaterally) engage in conflict to try to take complete control of the other's resources, but who also have the option of avoiding each other by coordinating on the peaceful outcome. As pointed out by Neary (1997a), conflict games show some similarity to the rent-seeking model of Tullock (1980). In our case, if players cannot avoid conflict by choosing $c_i = c_j = 0$, we fix $t_i = t_j = 1$, and $y = 0$ then our game becomes formally equivalent to a Tullock contest with a prize of $2y$. Note that, under risk neutrality and own-earnings maximization, all these models result in the same expected payoff function (for a systematic comparison of conflict models see Chowdhury and Sheremeta, 2011),[12] but this is no longer the case if individuals are risk averse or possess social preferences.

3.2 Experimental procedures

We conducted a laboratory experiment in which subjects played twenty repetitions of the TC game (i.e. twenty periods). In ten of the twenty periods, subjects were randomly rematched such that they faced a different opponent in every period. We refer to this matching procedure as *Strangers*. The random rematching and lack of individual identifiers makes behavior in Strangers approximate behavior in a one-shot TC game. To investigate whether and how repeated interaction helps subjects avoid conflict, in the remaining ten periods, subjects were always matched with the same opponent. We refer to this matching procedure as *Partners*. Subjects were informed of the matching procedure just before they played the first of the respective ten periods. To control for sequence effects, half the subjects played the ten first periods as Partners and the second ten periods as Strangers whereas the other half played in the reverse order.

Subjects received an endowment of 1000 points in every period. At the end of the experiment, two periods (one from each series of ten periods) were randomly selected for payment at an exchange rate of 100 points for €1. The experiment was conducted in the CREED laboratory at the

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[12] In order to check whether behavior is different in the TC game compared to the Hirshleifer-Skaperdas conflict game, we run two additional treatments. In one treatment, we exogenously set $t_i = t_j = 1$ so that the winner is forced to take all of the loser's production. Comparing this treatment to the TC-game allows us to see whether endogenously selecting the take rate affects conflict expenditures. In the other treatment, we remove the lottery and set earnings equal to the share of conflict expenditures, as in Durham et al. (1998). Comparing the second treatment to the first allows us to test whether the lottery and the winner-takes-all nature of the contest affects conflict expenditures. In both treatments, conflict is avoided altogether when neither player spends points in it. We report the results of these treatments in Section 3.3.

University of Amsterdam. In total, 76 subjects participated.[13] The detailed experimental procedures and the instructions are available in the online supplementary materials.

3.3 Data analysis

In this section, we analyze the subject's behavior when they play the TC game. Throughout the paper, when we make multiple pairwise comparisons across treatments or matching procedures, we correct p-values using the Benjamini-Hochberg method.[14] Furthermore, we use individual averages for the relevant periods as observations when conducting Wilcoxon signed-rank (WSR) and Mann-Whitney U (MW) tests. Given that we found no sequence effects, we report the results using the pooled data. Lastly, we report p-values of two-tailed tests.

TC-Strangers

We start by analyzing behavior in TC-Strangers. On average, subjects in TC-Strangers spend 0.631 of their endowment on conflict (descriptive statistics for all treatments are available in the appendix). Notably, a WSR test confirms that mean conflict expenditures are significantly higher than 0.500 ($p \leq 0.001$), which is the equilibrium if it is commonly known that all players are risk neutral and maximize solely their monetary earnings.[15] If we look at the mean take rate, we can see

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[13] In addition, 84 subjects participated in the additional treatments described in footnote 12 (40 in the first and 44 in the second). For these treatments, we used only Strangers matching.

[14] This method reduces the risk of false positives due to multiple testing while controlling for the rate of false negatives (Benjamini and Hochberg, 1995). It requires ordering the K hypotheses $H_1, H_2, \ldots, H_K$ according to their p-value so that $p_1 \leq p_2 \leq \cdots \leq p_K$. Then reject all $H_k, k \leq \bar{k}$ where $\bar{k}$ is the largest k for which $\alpha \geq p_k\, K/k$. When reporting test results we report the adjusted p-value $p_k\, K/k$.

[15] We find the following results for the treatments described in footnote 12. If winners are forced to take all of losers' production, mean conflict expenditures equal 0.686 of their endowment, which is somewhat higher than in TC-Strangers (MW test, p = 0.086). By contrast, if there is no lottery and earnings are proportional to expenditures, mean conflict expenditures equal 0.578 of their endowment, which is somewhat lower than in TC-Strangers (MW test, p = 0.096). Hence, it appears that the endogenous selection of the take rate reduces conflict expenditures and the winner-takes-all nature of our game increases them. As Sheremeta et al. (2012), we find that a winner-takes-all lottery results in significantly higher conflict expenditures than the proportional allocation of earnings (MW test, p = 0.003). In both additional treatments, mean conflict expenditures significantly exceed 0.500 of the endowment (WSR tests, $p \leq 0.001$).

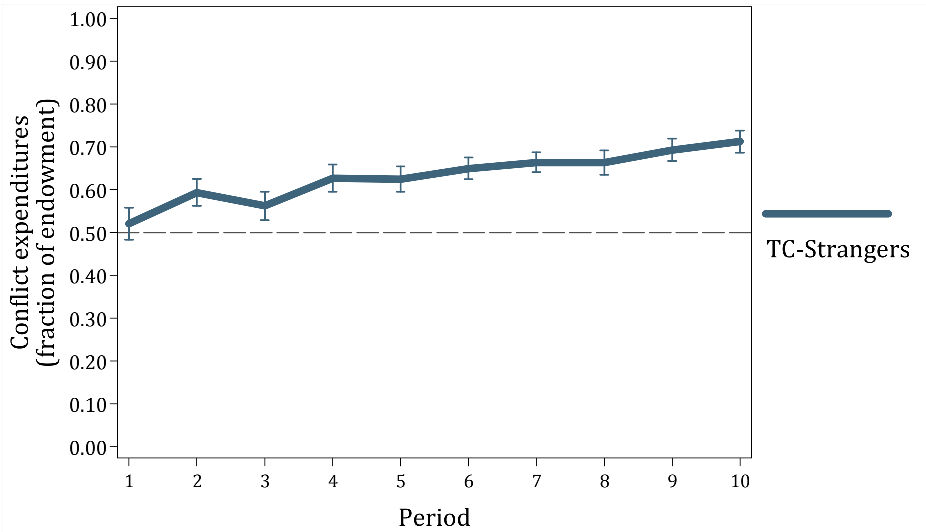

Figure 1 – Mean conflict expenditures in TC-Strangers

Note: Mean fraction of the endowment spent on conflict. Error bars correspond to ± one standard error.

that it is very close to complete appropriation (it equals 0.981). In fact, the modal take rate is the money-maximizing rate of 1, which is chosen 88.2 percent of the time.[16]

If we look at how conflict expenditures change over time, we find that they noticeably increase with repetition (see Figure 1). In period 1, conflict expenditures equal 0.520 of the endowment, which is not significantly different from our theoretical benchmark of 0.500 (WSR test, p = 0.512). However, they consistently increase until they reach 0.715 of the endowment in period 10, which amounts to a sizable 36.9 percent increase (0.744 standard deviations). In fact, in period 10, 80.3 percent of the subjects spend more than 0.500 of their endowment on conflict, which is remarkable given that expression (2) indicates that risk neutral players who maximize solely their monetary earnings will not spend more than 0.500 of their endowment irrespective of the expected behavior of the other player. Throughout the paper, we test significant differences in time trends by calculating for each subject i a Spearman's rank correlation coefficient between the variable of interest and period number: ρ_i. Thereafter, we use standard nonparametric tests to evaluate

[16] This take rate is remarkably high compared to that in dictator games. For example, Forsythe et al. (1994) find that on average dictators take 77.3 percent of the available money and that only 30.4 percent take everything. Interestingly, comparable take rates are seen when dictators first earn the money they latter divide. In this case, mean take rates equal 94.7 percent and 73.8 percent take everything (Cherry et al. 2002). Thus, it is possible that winning the contest has a similar effect as earning the money. Namely, it makes winners feel entitled to the loser's earnings.

whether the distribution of ρ_i's differs significantly across treatments or whether its median differs significantly from zero. In addition to the p-value, we also report the mean value of ρ_i, which we denote as $\bar{\rho}$.[17] Using this procedure we confirm that conflict expenditures significantly increase over time in TC-Strangers ($\bar{\rho}$ = 0.269; WSR test, $p \leq 0.001$).[18] Thus, unlike in most rent-seeking experiments, where repetition moves play closer to the equilibrium implied by risk neutrality and own-earnings maximization (see Herrman and Orzen, 2008), in this case repetition leads subjects *away* from this theoretical benchmark.[19]

In order to shed some light on why conflict escalates, we analyze how subjects adjust their conflict expenditures. Table 2 presents two GLS regressions that use subject i's change in conflict expenditures from period x to period $x+1$, i.e. $c_{i,x+1} - c_{i,x}$, as the dependent variable. In the first regression (column A), we use four independent variables, labeled (i) to (iv). Variables (i) and (ii) allow us to see how subjects react to differences in the probability of winning, taking into account that they might react differently to positive and negative differences. Specifically, (i) equals the absolute difference between i's and j's probability of winning in period x, i.e. $|p_{i,x} - p_{j,x}|$, if $p_{i,x} > p_{j,x}$ and zero otherwise, and (ii) equals the same absolute difference in probabilities if $p_{i,x} < p_{j,x}$ and zero otherwise. Variable (iii) is a dummy variable that equals one if i lost the contest in period x, which allows us to see whether there is an effect of losing or winning irrespective of the probability of doing so. Lastly, we control for the level of conflict expenditures by including i's conflict expenditures in period x, i.e. $c_{i,x}$, as variable (iv), which we standardize to have a mean of zero and a standard deviation of one to easily interpret the regression coefficients. In our second

[17] This procedure is similar to Page's trend test (Page, 1963). Compared to Page's trend test, our procedure will tend to be more conservative, but it has the advantage that it can be used to make between-subject comparisons and within-subject comparisons when the number of observations per subject varies.

[18] The increasing time trend in conflict expenditures is pervasive. Of the 76 subjects in TC-Strangers, 50 subjects (65.8 percent) display an increasing time trend while only 17 subjects (22.4 percent) display a decreasing one.

[19] In the treatments described in footnote 12, mean conflict expenditures display a positive trend, but according to WSR tests it is not significantly different from zero: $\bar{\rho}$ = 0.081 (p = 0.200) if winners are forced to take all of losers' production and $\bar{\rho}$ = 0.066 (p = 0.137) if earnings are proportional to expenditures (the correlation coefficients in both treatments are significantly lower than in TC-Strangers, MW tests, $p \leq 0.026$). Hence, it appears that the ability of winners to choose the take rate is an important component for conflict to escalate.

Table 1 – Change in conflict expenditures in TC-Strangers

	Independent variables	(A) coef.	(A) s.e.	(B) coef.	(B) s.e.
(i)	$\lvert p_{i,x} - p_{j,x} \rvert$ if $p_{i,x} > p_{j,x}$	0.001	(0.039)	0.005	(0.037)
(ii)	$\lvert p_{i,x} - p_{j,x} \rvert$ if $p_{i,x} < p_{j,x}$	0.295**	(0.079)	0.297**	(0.079)
(iii)	i lost	0.035*	(0.014)	0.036*	(0.014)
(iv)	$c_{i,x}$ (standardized)	–0.175**	(0.018)	–0.175**	(0.018)
(v)	$(1 - t_{i,x})$ if i won			–0.082	(0.182)
(vi)	$(1 - t_{i,x})$ if i lost			–0.197	(0.172)
	Constant	–0.040*	(0.016)	–0.039*	(0.017)
	R^2	0.344		0.338	
	# of observations/subjects	682/76		682/76	

Note: GLS regressions with i's change in conflict expenditures from periods x to $x + 1$ as the dependent variable and subject fixed effects. Robust standard errors are shown in parenthesis. Asterisks indicate significance at the 1 percent (**) and 5 percent (*) level.

regression (column B), we add two independent variables that capture post-contest behavior: (v) equals the fraction of j's endowment that i did *not* take, i.e. $(1 - t_{i,x})$ if i won the contest in period x and zero otherwise, and (vi) equals the fraction of i's endowment that j did not take, i.e. $(1 - t_{j,x})$ if j won the contest in period x and zero otherwise. Both regressions have subject fixed effects and robust standard errors.[20]

From the table, we can see that *ceteris paribus* subjects who had a lower probability of winning than their opponent significantly increase their conflict expenditures ($p \leq 0.001$). However, the reverse is not true: subjects who had a higher probability of winning than their opponent do not significantly decrease their conflict expenditures ($p > 0.892$). In addition, winning the contest *per se* has an effect. Namely, losers tend to increase their conflict expenditures compared to winners irrespective of the probability of winning. Moreover, the negative coefficient of (iv) shows that there is a tendency to regress to the mean. Lastly, the post-contest variables do not seem to affect the change in conflict expenditures. Albeit, the lack of significance might be due to the small number

[20] We drop two observations from the one case in which subjects avoided the contest by spending zero points on conflict.

of observations with a take rate lower than 1. Overall, it seems that the main reason behind the escalation of conflict is the subjects' asymmetric reaction to differences in the probability of winning.[21] We summarize the findings so far as our first result.

RESULT 1 (ESCALATION OF CONFLICT): *In TC-Strangers, subjects' initial conflict expenditures are similar to those predicted if it is commonly known that all players are risk neutral and maximize their own-earnings. However, the subjects' conflict expenditures steadily and significantly increase with repetition such that over ten periods the amount spent on conflict well-exceeds the amount predicted by this theoretical benchmark. This escalation is due to a sharp increase in conflict expenditures by subjects who face a lower probability of winning without an equivalent decrease in conflict expenditures by subjects who face a higher probability of winning.*

TC-Partners

Next, we analyze behavior in TC-Partners. We are particularly interested in observing whether repeated interaction with the same opponent reduces overall levels of conflict and prevents it from escalating over time. In TC-Partners, the subjects' mean conflict expenditures equals only 0.381 of their endowment, which is significantly lower than expenditures in TC-Strangers (39.6 percent lower) and the 0.500 theoretical benchmark (WSR tests, $p \leq 0.001$). Take rates are also significantly lower in TC-Partners (the mean take rate equals 0.811; WSR test $p \leq 0.001$).

Interestingly, the difference in conflict expenditures between Partners and Strangers is mostly due to the ability of the former to coordinate on the peaceful outcome: in 26.3 percent of all periods subjects in TC-Partners manage to simultaneously spend zero points on conflict and avoid the contest altogether (in TC-Strangers this fraction is only 0.3 percent). Moreover, peaceful outcomes are highly concentrated in a sizable minority of the groups: 25 out 38 groups (65.8 percent) did not attain a single peaceful outcome whereas the remaining 13 groups (34.2 percent) attained five or more (on average, 7.7 periods). We distinguish between these groups by referring to the former as

[21] We also ran equivalent regressions where instead of differences in the probabilities of winning we use differences in conflict expenditures. The results are very similar but the R^2 of these regressions is lower. We also included a one period lag for the independent variables, but none of the lagged variables has a significant effect and we cannot reject the hypothesis that the lagged variables are not jointly significant.

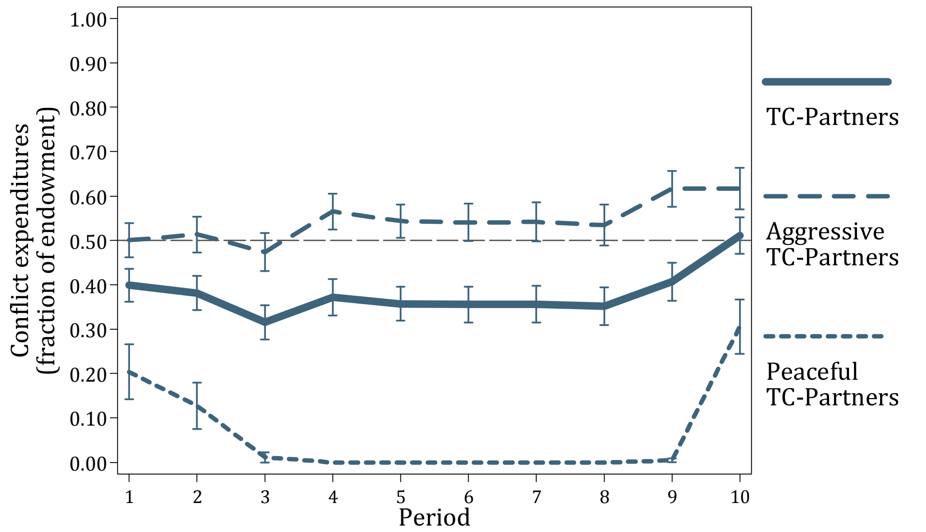

Figure 2 – Mean conflict expenditures in TC-Partners

Note: Mean fraction of the endowment spent on conflict. Error bars correspond to ± one standard error.

aggressive groups and to the latter as *peaceful groups*. Given the stark differences in conflict expenditures, it is worthwhile to analyze aggressive and peaceful groups separately (descriptive statistics for aggressive and peaceful groups in all treatments are available in the appendix).

Remarkably, if subjects do not manage to attain peace, their conflict expenditures in TC-Partners are not that different from their expenditures in TC-Strangers (see Figure 2). On average, subjects in aggressive groups spend 0.545 of their endowment on conflict, which is only 13.6 percent less than TC-Strangers. Moreover, like in TC-Strangers, in most periods mean conflict expenditures in aggressive groups exceed the 0.500 theoretical benchmark and increase with repetition. By contrast, conflict expenditures in peaceful groups are 89.7 percent less than in TC-Strangers (on average, 0.065 of their endowments), are well below the 0.500 theoretical benchmark, and decline sharply over periods such that all peaceful groups spend zero points on conflict from period 4 onwards, until an endgame effect in the last period.[22]

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[22] Conflict expenditures in peaceful groups are significantly lower than in aggressive groups (MW test, $p \leq 0.001$) and groups in TC-Strangers (WSR test, $p \leq 0.001$). Also, the time trend of conflict expenditures in peaceful groups is significantly different from that in aggressive groups ($\bar{\rho}$ = –0.187 vs. $\bar{\rho}$ = 0.078; MW test, $p = 0.020$) and that in TC-Strangers (WSR test, $p \leq 0.001$). To compare time trends, we omit the last period due to a clear endgame effect in peaceful groups. Although the difference in conflict expenditures is small, it is significantly lower in aggressive groups than in TC-Strangers (WSR test, $p \leq 0.002$), but the time trend between the two is not significantly different (WSR test, $p = 0.280$).

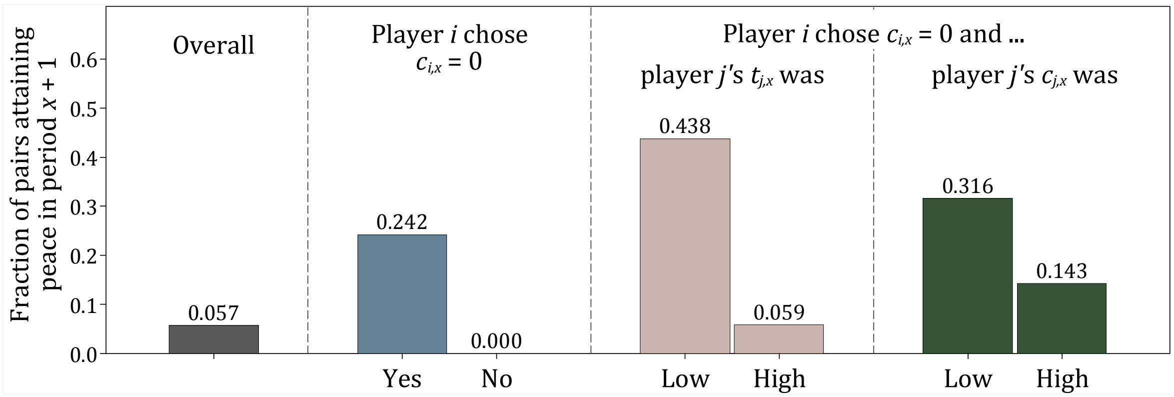

Figure 3 – Fraction attaining peace depending on previous period behavior in TC-Partners

Note: Fractions are calculated based on the first five periods.

Next, we explore why some groups manage to reach a long-lasting peaceful relationship while others do not. Some of the groups are lucky enough to start a peaceful relationship in the first period (5 of the 13 peaceful groups). Thus, knowing *ex ante* that they will interact with the same opponent for some time already produces an important number of peaceful groups. Nevertheless, the majority of peaceful relationships are attained after a few periods in which conflict did occur. To observe how groups de-escalate an initially conflicting interaction, we investigate which type of behaviors lead to peaceful relationships.

Our findings are summarized in Figure 3. The figure shows the fraction of times peace is attained in a period $x + 1$ given that there was a contest in period x and conditioning on the subjects' behavior in that period. Since all peaceful relations were reached in the first five periods, we calculate these fractions for $x \leq 5$. Overall, a peaceful relationship is reached after a contest in only 0.057 of all periods. However, this fraction increases to 0.242 if one of the players spent zero points on conflict. In fact, this seems to be a necessary condition to attain peace as *all* peaceful relationships are preceded by a period in which one of the two players chose not to fight.

In addition, the behavior of the player who spends a positive amount on conflict, and therefore wins the contest, affects whether a peaceful relationship is attained. In particular, peace is attained in 0.438 of the periods that follow a winner who chooses a low take rate (below the median) while this is the case in only 0.059 of the periods that follow a winner who chooses a high take rate. In other words, a peaceful relationship is more than seven times more likely if, after observing an opponent who spends zero points on conflict, the winner chooses a low rather than a high take rate.

A similar, albeit weaker, pattern is observed if we divide the outcomes depending on the conflict expenditures of the winner: peace is almost twice as likely in periods following a winner whose conflict expenditures were below the median compared to periods following a winner whose conflict expenditures were above or equal to the median. We test whether these latter effects are statistically significant with a Probit regression. We find that a low take rate significantly increases the probability of attaining a peaceful relationship (p = 0.010) whereas winning with low conflict expenditures does not (p = 0.860).[23] We summarize these findings as our next result.

RESULT 2 (DE-ESCALATION OF CONFLICT): *Conflict expenditures are considerably lower in TC-Partners, where subjects are repeatedly interacting with the same counterpart. This difference is due to a sizable fraction of the groups avoiding conflict altogether and attaining a long-lasting peaceful relationship. Peace typically happens after periods of conflict if one subject cuts conflict expenditures to zero points and the other responds by choosing a low take rate.*

4. Scorched earth and resistance

As discussed in the introduction, in this section, we extend the TC game by giving losers of the contest the opportunity to destroy some or all of their remaining resources. We do so with two different games: the Scorched Earth (SE) game and the Resistance (RE) game.

4.1 The games

The SE and RE games have three stages. In the first stage of both games two players simultaneously decide how many points to spend on conflict. If both players spend zero points on conflict, the game ends and each player earns $\pi_1 = \pi_2 = y$ points. Otherwise, a contest takes place where the probability of winning is given by the players' relative conflict expenditures.

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[23] We run Probit regressions with a dependent variable that equals one if a pair of subjects i and j achieve peace in period $x + 1$ and zero otherwise. We look at cases in which j does not spend points on conflict in period $x \leq 5$, which leaves us with 33 observations in 20 pairs of subjects. As independent variables we use dummy variables indicating (i) whether i's conflict expenditures were below the median, and (ii) whether i's take rate was below the median. The estimated regression equation is: Probability of peace in $x + 1$ = –1.607 (0.654) + 0.116 (0.656) × Low conflict expenditures + 1.362 (0.526) × Low take rate. Numbers in parenthesis correspond to robust standard errors clustering on pairs of subjects. These results are robust to using all ten periods and the continuous version of the independent variables.

Like in the TC game, a winner i chooses a take rate $t_i \in [0,1]$, which determines the fraction of loser j's remaining income that i wishes to appropriate. However, unlike the TC game, in the SE and RE games the loser of the contest also makes a decision. It consists of choosing the fraction of her income that she wishes to destroy. Specifically, j selects a "destruction rate" $d_j \in [0,1]$, which is the fraction of $y - c_j$ that is destroyed and thus unavailable for i to appropriate. In other words, t_i applies only to the income not destroyed: $(1 - d_j)(y - c_j)$. Therefore, in both the SE and RE games, if $c_1 + c_2 > 0$ then the expected earnings of each player $i \in \{1,2\}$ are given by

$$E[\pi_i] = \frac{c_i}{c_i + c_j^e}\left(y - c_i + t_i(1 - d_j^e)(y - c_j^e)\right) + \frac{c_j^e}{c_i + c_j^e}(1 - t_j^e)(1 - d_i)(y - c_i), \qquad (3)$$

where c_j^e, t_j^e, and d_j^e are i's expected value for c_j, t_j, and d_j. The first element of expression (3) corresponds to i's expected earnings if she wins multiplied by her probability of winning, and the second element is i's expected earnings if she loses multiplied by her probability of losing.

The difference between the SE and RE games is the sequence in which the winner and the loser make their decision. In the SE game, the loser first chooses a destruction rate, which is subsequently communicated to the winner who then chooses a take rate. One can think of the SE game as representing situations in which players have time between the moment they know they lost the contest and the moment the winner takes control of their resources. This sequence is reversed in the RE game. In other words, in the RE game, the winner first chooses a take rate, which is subsequently communicated to the loser who then chooses a destruction rate. The RE game can be thought of as a situation in which winning the conflict gives the winner power to utilize the loser's remaining resources, but it does not give her complete control over them. Specifically, after learning how much the winner wants to take (e.g. through taxation) the loser can reduce the amount of appropriable resources (e.g., the tax base). Therefore, the crucial difference between the two games is that in RE the loser can condition her destruction rate on the winner's take rate whereas in SE it is the winner who can condition her take rate on the loser's destruction rate.

Next, we calculate optimal conflict expenditures under the theoretical benchmark of risk neutral players who maximize their monetary earnings in a one-shot SE or RE game. Compared to the TC game, we need to introduce extra notation. Let's label d_j^e as i's expected value for d_j. Moreover, let t_i^* and d_i^* denote the value of t_i and d_i that i expects will maximize her earnings given the expected behavior of j. Note that i always sets $t_i^* = 1$ and $d_i^* = 0$ as long as she expects j to choose $d_j^e < 1$ and $t_j^e < 1$. If i expects $t_j^e = 1$ then she is left with no income and is therefore indifferent between any value $d_i^* \in [0,1]$, and similarly, if she expects $d_j^e = 1$ then she is left with nothing to take and is indifferent between any value $t_i^* \in [0,1]$. Regardless, if i expects j to choose $c_j^e > 0$, we can obtain i's best reply by maximizing expression (3), which gives:[24]

$$c_i^* = \sqrt{c_j^e \left(\left(t_i^*\left(1-d_j^e\right) + t_j^e + \left(1-t_j^e\right)d_i^*\right)y - \left(t_i^*\left(1-d_j^e\right) - t_j^e - \left(1-t_j^e\right)d_i^*\right)c_j^e\right)} - c_j^e. \quad (4)$$

If i expects j to choose $c_j^e = 0$ then as long as she expects j will choose $d_j^e < 1$ in some situations, she simply chooses $c_i^* = \epsilon$, wins the contest with certainty, and takes all of the income that j does not destroy. On the other hand, if i expects $c_j^e = 0$ and for j to always choose $d_j^e = 1$ then, since there is nothing to gain from winning, her optimal response is to avoid the contest by choosing $c_i^* = 0$. Note that expression (4) is increasing in t_j^e and decreasing in d_j^e, which implies that i will chose lower conflict expenditures the less j takes or the more she destroys.

If we further assume that it is common knowledge that all players are risk neutral and maximize their monetary earnings, we get a straightforward prediction in the RE game. Using backward induction, one can see that once a winner i and loser j are determined, it is a subgame-perfect Nash equilibrium for i to choose $t_i^* = 1$ and j to choose $d_j^* = 0$. It follows that, as in the TC game, in this equilibrium both players spend half their endowment in conflict $c_i^* = c_j^* = \frac{1}{2}y$, and each one has the same probability of winning, $p_i^* = p_j^* = \frac{1}{2}$. In the SE game, the optimal strategy of a winner i is $t_i^* = 1$ and therefore the loser j is indifferent between any $d_j^* \in [0,1]$. If we assume that in equilibrium both players chose the same $d_1^* = d_2^* = d^*$ then for every $d^* < 1$ there is an equilibrium where the optimal conflict expenditures are equal to $c_i^* = c_j^* = y\,(2-d^*)/(4-d^*)$. In the special case where $d^* = 1$, we even obtain two equilibria: one where players spend $c_i^* = c_j^* = \frac{1}{3}y$ with the sole purpose of defending their income from appropriation (i.e., a self-fulfilling equilibrium in which players spend resources on conflict simply because they expect the other will do so as well), and one where players choose $c_i^* = c_j^* = 0$ and completely avoid the contest. However, note that if we introduce small perturbations in the actions of players, we do get a unique prediction in the SE game. Namely,

[24] Once again, we are assuming that i does not expect j will condition t_j and d_j on the value of c_i. If this were the case, i would have to take into account how her conflict expenditures affect her earnings.

as long as there is a small probability that the winner chooses $t_i^* < 1$ then the loser's optimal choice is $d^* = 0$ and the optimal conflict expenditures are once again $c_i^* = c_j^* = \frac{1}{2}y$.

In summary, we introduce two variants of the TC game to model situations where the winner of a contest does not wield total control over the loser's resources. In particular, the loser gets the opportunity to destroy some or all of her income before it is appropriated by the winner. Introducing the possibility of destruction does not fundamentally change the equilibrium predictions if one assumes players are risk-neutral and maximize their own earnings. However, if (winners believe that) losers are willing to sacrifice earnings in order to reduce the takings of the winner, then (expected) destruction ought to reduce overall conflict expenditures.

4.2 Experimental procedures

The experimental sessions for the SE and RE games were conducted in an identical way to those of the TC game, including the use of Strangers and Partners matching procedures. They are described in detail in the online supplementary materials. In total, 64 subjects played the SE game and 66 played the RE game.

4.3 Data analysis

In this section, we analyze the subject's behavior in the SE and RE games. We concentrate on whether the option to destroy income affects the findings reported for the TC game.

SE-Strangers and RE-Strangers

We start by analyzing behavior in Strangers (see the appendix for descriptive statistics). On average, conflict expenditures are lower when losers have the option to destroy their income: subjects spend 0.573 of their endowment on conflict in SE-Strangers and 0.456 in RE-Strangers (9.2 and 27.7 percent less than in TC-Strangers). Pairwise MW tests confirm that conflict expenditures are significantly lower in SE-Strangers and RE-Strangers compared to TC-Strangers ($p \leq 0.001$). They also reveal a significant difference between SE-Strangers and RE-Strangers ($p = 0.044$).

The differences in conflict expenditures are in line with a reduction in the profitability of winning the contest due to differences in post-contest behavior. For instance, in TC-Strangers a winner i gets on average 98.3 percent of the loser's remaining points, i.e. of $y_j - c_j$. In SE-Strangers,

i's winnings significantly shrink to 62.7 percent of $y_j - c_j$ (MW test, $p \leq 0.001$), and in RE-Strangers they are further reduced to a mere 46.0 percent of $y_j - c_j$ (MW test, $p \leq 0.001$).

In SE-Strangers, the reduction in the profitability of winning is attributable to a considerable number of subjects choosing positive destruction rates. The mean destruction rate is 0.351, which reflects the fact that losers destroy *all* their income 29.8 percent of the time.[25] If the loser does not destroy, winners in SE-Strangers appropriate almost all of the losers' income: the mean take rate is 0.929, which is only 5.3 percent less than in TC-Strangers.[26] In other words, in SE-Strangers winners get a smaller percentage of the losers' income due to preemptive destruction by the losers.

In RE-Strangers, winners receive an even smaller fraction of the loser's remaining income due to a combination of lower take rates and positive destruction rates. Compared to the other treatments, take rates are significantly lower in RE-Strangers: they average 0.645 (MW tests, $p \leq 0.001$). As in SE-Strangers, losers in RE-Strangers are willing to choose positive destruction rates: the mean destruction rate is 0.249 and most destruction is due to the fact that losers destroy all their income 20.4 percent of the time. However, there is an important difference between these two games. Namely, in RE-Strangers losers can and do condition their destruction on the take rate chosen by the winner. For example, the mean Spearman's correlation coefficient between take rates and destruction rates in RE-Strangers is $\bar{\rho}$ = 0.326 and is significantly different from zero (WSR test, $p \leq 0.001$). In other words, winners in RE-Strangers extract an even smaller percentage of the losers' income either because it is destroyed if they choose a high take rate or because in order to avoid destruction they chose a low take rate in the first place.

In other words, the destruction behavior of losers explains both the differences in take rates and the differences in conflict expenditures between the three games. In fact, if we take as given the destruction rate in SE-Strangers and we assume winners in RE-Strangers choose the take rate that maximizes their earnings given the observed behavior of losers (a take rate of 0.620, which implies

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[25] The destruction rate is constant over time. We do not find that the correlation between destruction rates and the period number is significantly different from zero in SE-Strangers ($\bar{\rho}$ = 0.054; WSR test, p = 0.802).

[26] We do not find a relationship between take rates and destruction rates in SE-Strangers. For instance, the median Spearman's correlation coefficient between take rates and destruction rates is not significantly different from zero ($\bar{\rho}$ = –0.024; WSR test, p = 0.920).

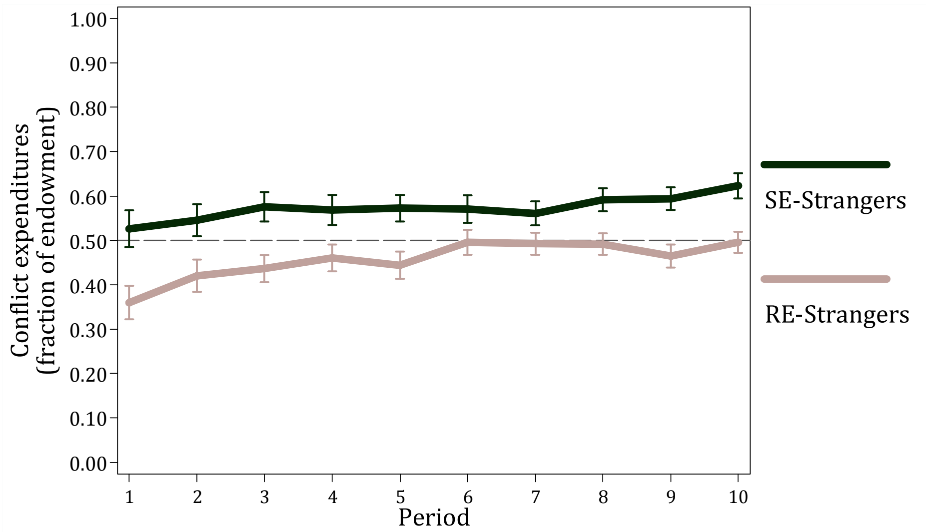

Figure 4 – Mean conflict expenditures in SE-Strangers and RE-Strangers

Note: Mean fraction of the endowment spent on conflict. Error bars correspond to ± one standard error.

an average destruction rate of 0.190), then, for conflict expenditures of 0.600 of the endowment, expressions (2) and (4) predict that players will spend 6 percent less in SE-Strangers and 40 percent less in RE-Strangers compared to TC-Strangers, which is not very far removed from the observed treatment differences (respectively, 9 percent and 28 percent).[27]

Importantly, although empowering the loser with the opportunity to destroy her income reduces overall conflict expenditures, this reduction translates into higher earnings only in RE-Strangers, where destruction can be conditioned on the take rate. As a fraction of their endowment, mean earnings equal 0.369 in TC-Strangers, 0.338 in SE-Strangers, and 0.467 in RE-Strangers. The difference in earnings between RE-Strangers and the other two treatments is statistically significant (MW tests, $p \leq 0.001$) but that between TC-Strangers and SE-Strangers is not (MW test, $p = 0.202$).

Like in TC-Strangers, in both in SE-Strangers and RE-Strangers we observe increasing conflict expenditures over time (see Figure 4). In SE-Strangers, conflict expenditures increase 18.5 percent over the ten periods (0.386 standard deviations), and in RE-Strangers they increase 37.5 percent (0.557 standard deviations). If we test whether there are treatment differences in the distribution of Spearman's correlation coefficients between conflict expenditures and periods, we do not find a

[27] The losers' behavior and expressions (2) and (4) explain well the *relative* treatment differences in the conflict stage, but they fail to explain the levels of conflict expenditures, which are predicted not to exceed 0.500 of the endowment.

Table 2 – Change in conflict expenditures in SE-Strangers and RE-Strangers

	Independent variables	SE-Strangers coef.	SE-Strangers s.e.	RE-Strangers coef.	RE-Strangers s.e.
(i)	$\lvert p_{i,x} - p_{j,x} \rvert$ if $p_{i,x} > p_{j,x}$	–0.068	(0.035)	–0.024	(0.028)
(ii)	$\lvert p_{i,x} - p_{j,x} \rvert$ if $p_{i,x} < p_{j,x}$	0.001	(0.064)	0.119*	(0.047)
(iii)	i lost	0.072**	(0.019)	–0.064	(0.049)
(iv)	$c_{i,x}$ (standardized)	–0.210**	(0.035)	–0.178**	(0.022)
(v)	$(1 - t_{i,x})$ if i won	0.070	(0.058)	–0.190*	(0.095)
(vi)	$(1 - t_{i,x})$ if i lost	–0.018	(0.087)	–0.019	(0.069)
(vii)	$d_{i,x}$ if i won	0.024	(0.024)	–0.045	(0.033)
(viii)	$d_{i,x}$ if i lost	–0.021	(0.031)	–0.038	(0.028)
	Constant	–0.014	(0.014)	0.077	(0.039)
	R^2	0.308		0.253	
	# of observations/subjects	572/64		594/66	

Note: GLS regressions with i's change in conflict expenditures from periods x to $x+1$ as the dependent variable and subject fixed effects. Robust standard errors are shown in parenthesis. Asterisks indicate significance at the 1 percent (**) and 5 percent (*) level.

significant different between TC-Strangers and SE-Strangers or RE-Strangers ($\bar{\rho}$ = 0.095 and $\bar{\rho}$ = 0.188; MW tests, p = 0.089 and p = 0.467). We also find similar effects across treatments if we look at how subjects adjust their conflict expenditures from one period to the next. Specifically, we run regressions for SE-Strangers and RE-Strangers with the same specification as the second regression in Table 1, but we include two additional independent variables to capture the losers' post-contest behavior. Variable (vii) equals the destruction rate chosen by j, i.e. $d_{j,x}$ if i won the contest in period x and zero otherwise, and (viii) equals the destruction rate chosen by i, i.e. $d_{i,x}$ if j won the contest in period x and zero otherwise. We present the estimated coefficients in Table 2.

Like in TC-Strangers, in RE-Strangers, subjects who had a lower probability of winning significantly increase their conflict expenditures (p = 0.014) while those who had a higher probability of winning do not significantly decrease their conflict expenditures (p = 0.395), which explains why there is an upward trend in conflict expenditures. However, unlike in TC-Strangers, we do not find that winning or losing the contest influences the subjects' behavior in RE-Strangers.

In SE-Strangers, we see the opposite pattern. Namely, we do not find that subjects react significantly to differences in the probabilities of winning ($p > 0.054$), but we do see that, irrespective of differences in the probability of winning, losers significantly increase their conflict expenditures compared to winners ($p \leq 0.001$). In SE-Strangers, this effect is quite pronounced and is the driving force behind the overall increase in conflict expenditures. By and large, postcontest actions do not influence the adjustment of conflict expenditures in either SE-Strangers or RE-Strangers.[28] We summarize these findings in the following result.

RESULT 3 (DESTRUCTION AND THE ESCALATION OF CONFLICT): *Compared to TC-Strangers, overall conflict expenditures are lower if losers have the opportunity to destroy their income before it is appropriated. The decrease in conflict expenditures is explained by the loser's destruction behavior, which reduces the incentive to win the contest. The option to destroy, however, does not change the escalation of conflict expenditures over time.*

SE-Partners and RE-Partners

Next, we analyze behavior in Partners. The introduction of repeated interaction significantly decreases conflict expenditures in the SE and RE games. Compared to Strangers, mean conflict expenditures decrease to 0.371 and 0.278 of the endowment in SE-Partners and RE-Partners, which corresponds to reductions of 35.3 and 39.1 percent (WSR tests, $p \leq 0.001$).[29] Moreover, just like for the TC game, in the SE and RE games the difference in conflict expenditures between Partners and Strangers is due to some groups consistently attaining five or more periods of peace—10 groups in SE-Partners (31.3 percent) and 14 groups in RE-Partners (42.4 percent)—which accounts for more than 87.5 percent of all the peaceful periods.[30] Once again, we refer to these groups as *peaceful groups* and to the rest as *aggressive groups* (see the appendix for descriptive statistics).

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[28] The only exception occurs in RE-Strangers where subjects significantly decrease their conflict expenditures if they win the contest and then choose a low take rate ($p = 0.049$).

[29] Interestingly, repeated interaction seems to reduce the differences in conflict expenditures between the games. Conflict expenditures are still lowest in the RE game and highest in the TC game, but there are no longer any statistically significant differences between the three treatments (MW tests, $p > 0.063$). The comparative statics for take and destruction rates are very similar between Partners and Strangers in the three games.

[30] There is not a significant difference in the frequency of peaceful groups per treatment (χ^2 test, $p = 0.619$).

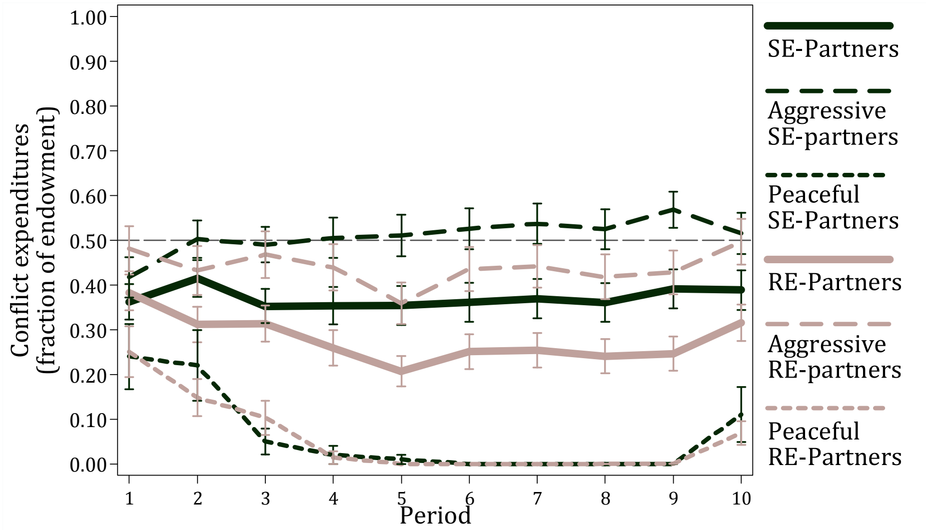

Figure 5 – Mean conflict expenditures in SE-Partners and RE-Partners

Note: Mean fraction of the endowment spent on conflict. Error bars correspond to ± one standard error.

As in the TC game, behavior in aggressive groups in SE-Partners and RE-Partners is similar to that in SE-Strangers and RE-Strangers (see Figure 5). First, compared to Strangers, mean conflict expenditures in aggressive groups are only 11.0 percent less in the SE game and 3.5 percent less in the RE game. Second, conflict expenditures increase with repetition in both cases. By contrast, mean conflict expenditures in peaceful groups in SE-Partners and RE-Partners are at least 87.0 percent less than those in Strangers, and they decline over time until the endgame effect in the last period.[31]

Many of our findings concerning peaceful groups in TC-Partners carry through to the SE and RE games.[32] This can be seen in Figure 6, which like Figure 3, shows the fraction of times peace is attained in period $x + 1$ conditioning on the subjects' behavior in period $x \leq 5$. Like in TC-Partners,

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[31] If we test for statistically significant differences, we find that conflict expenditures are significantly lower in peaceful groups compared to aggressive groups (MW tests, $p \leq 0.001$) and to groups in Strangers (WSR tests, $p \leq 0.001$) in both the SE and RE games. Moreover, we find that peaceful groups exhibit a significantly different time trend of conflict expenditures compared to aggressive groups (MW tests, $p \leq 0.003$) and to subjects in Strangers (WSR test, $p \leq 0.002$). Once again, when comparing time trends we exclude the last period due to the endgame effect in peaceful groups. Finally, comparing aggressive groups to groups in Strangers, we find that conflict expenditures are significantly lower in the former in the SE game but not in the RE game (WSR tests, $p = 0.005$ and $p = 0.067$), and we do not find a significant difference in the time trend in either game (WSR tests, $p > 0.102$).

[32] As in TC-Partners, although some groups start a peaceful relationship from the first period (3 out 10 peaceful groups in SE-Partners and 2 out of 14 in RE-Partners), most peaceful relationships are reached after some conflict occurred.

all peaceful relationships are preceded by a period in which one of the two players spends zero points on conflict, which reinforces the notion that this behavior is a necessary condition to attain peace. In addition, the conflict expenditures of the winner of the contest in period x affects whether a peaceful relationship is attained in period $x + 1$. Specifically, peace is twice as likely in SE-Partners and almost three times as likely in RE-Partners when the winner's conflict expenditures are below the median compared to cases where conflict expenditures are above or equal to the median. We also find that, like in TC-Partners, peace is attained more often in SE-Partners in periods that follow a low take rate (below the median) compared to periods that follow a high take rate—note, though, that in SE-Partners the ability to take is conditioned on the loser not destroying all her income. By contrast, in RE-Partners we do not find that choosing a low take rate facilitates peace. Interestingly, the losers' postconflcit behavior has no effect on the attainment of peace. In both SE-Partners and RE-Partners, the probability of starting a peaceful relationship is about the same in periods following a high destruction rate (above the median) and periods following a low destruction rate (below or equal to the median). Hence, for the purpose of attaining peace, destruction as a form of punishment is simply a cost that does not produce any benefits.

To test whether these latter effects are statistically significant we run a Probit regression for each treatment.[33] We find that low conflict expenditures by the winner in period x do have a significant impact on the probability of attaining a peaceful relationship in period $x + 1$ in RE-Partners (p = 0.008) but not in SE-Partners (p = 0.061). Conversely, low take rates significantly increases the probability of peace in SE-Partners (p = 0.003) but not in RE-Partners (p = 0.376).

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[33] We run Probit regressions with the same dependent and independent variables as the regression described in footnote 23. We concentrate on cases in which j does not spend points on conflict in period $x \leq 5$, which leaves us with 36 observations in 17 pairs of subjects in SE-Partners and 41 observations in 22 pairs of subjects in RE-Partners. Finally, we include an additional independent variable: a dummy variable indicating whether j's destruction rate was above the median. The estimated regression equation for SE-Partners is: Probability of peace in $x + 1$ = –1.900 (0.490) + 1.067 (0.570) × Low conflict expenditures + 1.526 (0.520) × Low take rate + 0.539 (0.419) × High destruction rate. The estimated regression equation for RE-Partners is: Probability of peace in $x + 1$ = –0.668 (0.626) + 1.041 (0.391) × Low conflict expenditures – 0.466 (0.527) × Low take rate – 0.259 (0.547) × High destruction rate. Numbers in parenthesis correspond to robust standard errors clustering on pairs of subjects.

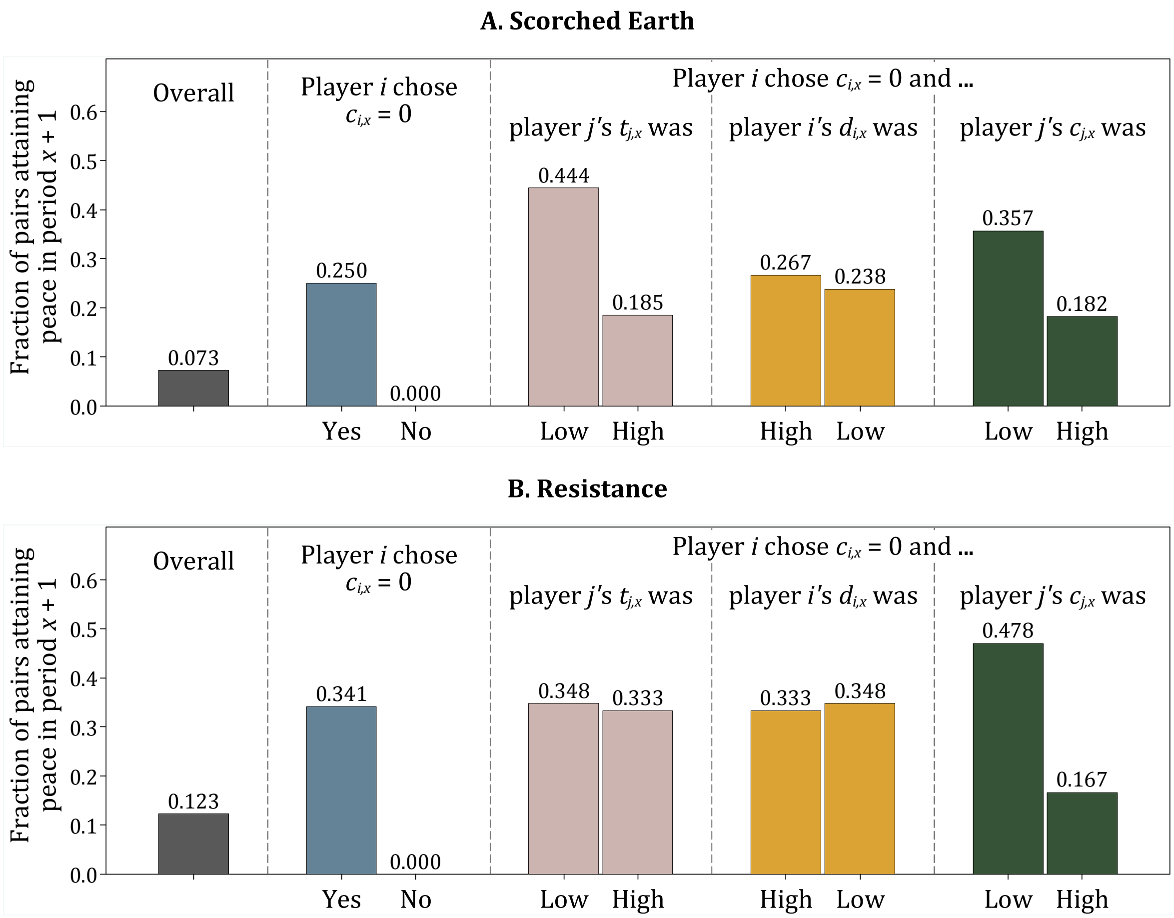

Figure 6 – Fraction attaining peace depending on previous period behavior in SE-Partners and RE-Partners

Note: Fractions are calculated based on the first five periods.

Lastly, high destruction rates have no significant effect in either treatment ($p > 0.198$). We summarize these and previous findings as our last result.

RESULT 4 (DESTRUCTION AND THE DE-ESCALATION OF CONFLICT): *Giving losers the opportunity to destroy their income does not affect the reduction in conflict expenditures due to repeatedly interacting with the same counterpart. Long-lasting peaceful relationships are attained with equal frequency when losers can destroy their income than when they cannot. It appears that punishment through the destruction of income is not an effective signal of peaceful intentions.*

5. Discussion

In this section, we discuss potential explanations for the experimental results. So far, we have used as the theoretical benchmark the equilibria obtained by assuming players are risk-neutral and maximize own their earnings. This is a useful benchmark as it gives us clear predictions. However, we see important deviations from this benchmark for both Strangers and Partners treatments. We will consider potential explanations for these deviations in turn.

5.1 Escalation of conflict among strangers

In the Strangers treatments, we observe three important deviations from the risk-neutral and own-earnings maximization benchmark used above. First, mean conflict expenditures are above the theoretical benchmark of $\frac{1}{2}y$ in TC-Strangers. Second, there are differences in conflict expenditures between TC-Strangers, SE-Strangers, and RE-Strangers that are driven by the willingness of contest losers to destroy their income. Third, conflict expenditures escalate over time in all three games.

We start by considering risk aversion. There is plenty of evidence that individuals display risk-averse behavior in laboratory experiments (e.g. Holt and Laury, 2002). High conflict expenditures in TC-Strangers can be the result of subjects being risk averse (for a detailed analysis of risk aversion in conflict games see Skaperdas, 1991).[34] The basic intuition is that risk-averse players can be seen as being more fearful of losing and therefore they insure themselves against a loss by investing more in conflict. However, although risk aversion can explain higher conflict expenditures, it does not predict different behavior in the post-contest stages. Therefore, introducing risk aversion does not explain why we observe important differences between the three games. For that, we need an explanation for why contest losers would be willing to destroy their income.

Numerous experiments have shown that individuals are willing to destroy their own resources in order to sanction another person's unkind or unfair behavior (see Camerer, 2003). For this reason, models of *social preferences*, which were created to explain this kind of behavior, can

[34] For example, if we assume all subjects possess the same CRRA utility function $U_i(\pi_i) = \pi_i^{1-r}/(1-r)$, then conflict expenditures in equilibrium equal $c_i^* = c_j^* = y/(2-r)$ in the TC game. Thus, a coefficient of relative risk aversion of r = 0.415 can explain the observed mean investment in TC-Strangers. This value for r falls well within the range of estimates elicited in other experiments (e.g., see Holt and Laury, 2002).

explain some of the deviations from our theoretical benchmark (for an overview of these models see Fehr and Schmidt, 2006). Models of social preferences generate two effects on the amount of resources spent on conflict. On the one hand, individuals with strong-enough social preferences are willing to cooperate on the peaceful outcome if they are certain-enough that the other player also possesses strong-enough social preferences. On the other hand, when facing an opponent with solely selfish preferences, a heightened dislike of being in the loser position or a desire to sanction the other's aggressive behavior motivates individuals with social preferences to spend more on conflict than individuals with solely selfish preferences. Thus, whether these models predict higher or lower conflict expenditures depends on the percentage of individuals in the population that possess strong-enough social preferences.[35]

For the post-contest behavior, models of social preferences make clearer predictions. Namely, these models predict that some of the contest losers are willing to destroy their income if they expect/face a high take rate. Therefore, they also predict that, compared to TC-Strangers, winning the contest is less profitable in both SE-Strangers (because losers sometimes destroy) and RE-Strangers (because winners must lower their take rates to avoid destruction), which gives players a smaller incentive to spend resources on conflict.[36]

Consequently, models of social preferences take us a long way in predicting the subjects' behavior. Namely, with the right parameterization, these models can help explain conflict expenditures above $\frac{1}{2}y$, positive destruction rates, and differences in conflict expenditures between the TC game and the SE and RE games. However, current models of social preferences face two notable difficulties to explain our experimental data. First, they cannot explain behavior across all *three* games unless one changes the models' parameters depending on the game. Second, without extra assumptions about how behavior changes over time, these models cannot describe the escalation of conflict. We discuss these difficulties in turn.

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[35] For example, if we use the inequity aversion model of Fehr and Schmidt (1999) and utilize their proposed distribution of types, we find that for TC-Strangers the latter effect dominates resulting in mean conflict expenditures of $0.632y$.

[36] Once again, if we take the model of Fehr and Schmidt (1999) with their distribution of types, mean conflict expenditures are predicted to be $0.438y$ for both SE-Strangers and RE-Strangers, compared to $0.632y$ for TC-Strangers.

Although social preferences models can easily explain a difference in conflict expenditures between the TC game and the other games, they have more difficulties explaining the observed differences between the SE and RE games. In particular, to the best of our knowledge, current models of social preferences cannot reconcile the difference in destruction behavior between SE-Strangers and RE-Strangers. If contest losers in SE-Strangers correctly anticipate the winner's take rate then, for comparable take rates, they should destroy at the same frequency as in RE-Strangers. However, we find that they destroy less. For instance, for take rates in the upper quintile in RE-Strangers (on average 0.875), the mean destruction rate is 0.567, which is significantly higher than the mean destruction rate in SE-Strangers (i.e., 0.351), where take rates average 0.929 (MW test, p = 0.020). In other words, punishment behavior is different depending on whether one is punishing an action that already took place or an expected action that has not yet occurred. This finding calls for a model of social preferences that distinguishes these two situations, perhaps by modeling punishment as being driven by immediate emotions such as anger as opposed to anticipatory emotions such as fear (for a discussion of the role of emotions, expectations, and punishment, see van Winden, 2007; Reuben and van Winden, 2008; Hopfensitz and Reuben, 2009).

Clearly, using models of social preferences and looking at equilibria of the one-shot version of the games will not explain changes in conflict expenditures over time. Therefore, explanations for the escalation of conflict require additional assumptions concerning how subjects adapt their behavior. We can think of two approaches that fit well with models social preferences.[37] The first approach is to assume that subjects have different initial *beliefs* concerning the behavior of others (e.g., they could have different priors of the fraction of individuals with strong-enough social preferences), and then they gradually update their beliefs and converge to an equilibrium (e.g., Crawford, 1995; Fudenberg and Levine, 1998). However, for this approach to predict an increasing trend in conflict expenditures one must assume that the subjects' initial beliefs are biased such that a majority starts choosing conflict expenditures that are below the equilibrium. The second approach is to assume that changes in behavior are due to changes in the subjects' preferences due to unanticipated *emotional reactions* (see Loewenstein and Schkade, 1999). We are unaware of an existing model that would predict the dynamics observed in our experiment. However, a promising

[37] Reinforcement learning models could be a third approach (e.g., Selten and Stoecker, 1986; Erev and Roth, 1998).

way forward could be to combine a framework like Cox et al. (2007), which formalizes how emotional states determine an individual's social-preferences, and a theory of how emotional states can change over time (e.g., van Winden, 2001) to model a subject's emotional reaction and its subsequent behavioral effect. With this approach, increasing conflict expenditures may ensue if after choices $c_i < c_j$, i's negative emotional reaction induces an increase in conflict expenditures that is stronger than the decrease in conflict expenditures induced by the positive emotions of winner j, which triggers a win-stay-lose-shift like reaction. Particularly, in our case, where the fact that the winner *chooses* to appropriate resources that belong to the loser ought to trigger relatively strong negative emotions—in contrast to an exogenous prize obtained in a standard rent-seeking game—which may fuel affective states over time (Bosman and van Winden, 2002).

Although our experiment is not explicitly designed to test the merits of these two approaches, we think that the regressions in Tables 2 and 3 provide some guidance as to which approach is more consistent with our data. In particular, the fact the in both TC-Strangers and SE-Strangers, winning/losing the contest *per se* has an effect on conflict expenditures speaks against most belief-updating models (which are unaffected by the realized outcome of the contest), but is easily reconcilable with a model of emotional states.

5.2 Partners attaining peace

In Partners treatments, the most important deviation from the risk-neutral and own-earnings maximization benchmark is that average conflict expenditures are below $\frac{1}{2}y$ in all three games because a sizable fraction of the groups manages to coordinate on the peaceful outcome for many consecutive periods. As we explain below, we are unaware of an existing theoretical model that predicts the subjects' behavior. Therefore, we concentrate on discussing two general approaches that we think have the potential to explain our data.

At first glance, it might seem straightforward to explain this behavior with a standard *reputation model* that assumes the existence of two types of players, self-interested and conditional cooperators (i.e., tit-for-tat players who start with $c_{i,1} = 0$ and then play $c_{i,x} = 0$ if $c_{j,x-1} = 0$ and best respond otherwise), and incomplete information regarding player types (see Kreps et al., 1982). With these assumptions, it is straightforward to show that as long as it is believed that there is a large enough fraction of conditional cooperators, there are equilibria in which self-interested players spend zero points on conflict until the final periods of the game. The drawback of such a model is that it predicts peace is no longer possible once positive conflict expenditures have occurred. This prediction is clearly wrong since most groups attain a long-lasting peaceful relationship after experiencing positive conflict expenditures for one or more periods.

Therefore, to utilize this kind of reputation model to explain our data, one would have to assume a more complex type (or types) of conditional cooperators.[38] In this sense, our analysis of the behavior that leads to peaceful relationships is informative as it reveals the characteristics of conditional cooperators. We find that peaceful relationships are preceded by subjects choosing low conflict expenditures and above all by one subject spending zero points on conflict (which never maximizes period earnings unless losers always destroy all their income). In the post-contest stages, we find that peace is preceded by low take rates, but only in TC-Partners and SE-Partners where winners do not immediately benefit from a take rate less than one. By contrast, in RE-Partners, where earnings maximization implies taking little (i.e., because winners expect losers will destroy if they take too much), low takes rates are not conducive to peace. Lastly, we also find that reducing the amount the winner can appropriate through a high destruction rate does not promote peace. In summary, the actions that lead to peaceful relationships are those that entail subjects unambiguously forgoing earnings in a way that benefits their opponent.

A different approach that could potentially explain the subjects' behavior is that of *affective social ties* (e.g., van Dijk and van Winden, 1997; Sally, 2001; van Winden, 2012). In these models, individuals care about the earnings of another player depending on the strength and valence of their social tie. Moreover, social ties are strengthened or weakened depending on the positive or negative emotional impulses that players experience as they interact, where an emotional impulse is determined by another player's behavior compared to a reference point. In our games, if a pair of players shares a strong-enough tie then they both will be willing to spend zero points on conflict. Therefore, if one assumes that costly actions benefiting someone else produce a strong positive emotional impulse in the latter, it is easy to see how these models can explain a substantial part of

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[38] For example, if conditional cooperators play a mixture of tit-for-tat and suspicious tit-for-tat (Boyd and Lorberbaum, 1987) then one can have equilibria where peaceful relationships are sometimes attained after a first period of conflict.

the observed behavior. In particular, they easily explain why low conflict expenditures and low take rates in TC-Partners and SE-Partners lead to peace while high destruction rates and low take rates in RE-Partners do not.

Note that these two approaches as not mutually exclusive. In fact, we think of them as being complementary. On one hand, reputation models can be used to predict the strategic behavior of players when some individuals possess social preferences, but they generally overlook how such preferences depend on the dynamics of play. On the other hand, models of social ties concentrate on explaining how preferences depend on the players' experienced interaction, but tend to neglect the more complicated strategic considerations introduced by such ties. For this reason, a hybrid model incorporating elements from both approaches might be a fruitful line of future research (see van Winden, 2012).

6. Conclusions

We investigate the effects of post-conflict behavior and repeated interaction on the allocation of effort between production and appropriation. We find that, in the absence of repeated interaction with the same counterpart, investment in conflict is not only considerably higher than the standard theoretical benchmark (as is frequently observed in rent-seeking experiments) but also escalates over time. Escalation is due to a sharp increase in conflict expenditures by the player with the lower probability of winning without an equivalent decrease in conflict expenditures by the player with the higher probability of winning, which goes to show how easily conflict escalates at the expense of economic efficiency. We also observe important differences in conflict expenditures depending on the post-contest structure of the games. In particular, if given the choice to destroy their remaining resources, many defeated players prefer to do so rather than allow the victor take them away. Given the willingness of losers to destroy, winning becomes less profitable and leads to less investment in conflict. Hence, both winners and losers do better when the power to appropriate is curbed by the threat of destruction (the Resistance game) than when winners can appropriate as much as they like (the Total Conquest game). For this to occur, however, winners need to be able to commit to a moderate appropriation rate and avoid preemptive destruction (the Scorched Earth game).

A notable characteristic of the conflict games in this study is that players can avoid the contest altogether by not investing any resources in conflict. We find this outcome to be particularly important when players repeatedly interact with the same counterpart as a significant number of groups manage to establish long-lasting peaceful relationships, even after substantial initial conflict. To attain peace, players use costly signals to communicate their willingness to stop fighting. The most important signal is refraining from any investment in conflict, which implies an almost certain loss of the contest. In addition, appropriating little when it unambiguously implies giving up income also serves as a signal for peace. In contrast, using destruction as a punishment device does not promote peaceful relationships.

Our study provides a first step into the analysis of post-conflict behavior and repeated interaction in conflict games. Further work, both theoretical and empirical, is needed to underpin the specific motivations behind the behavior we observe. In this respect, research on the dynamics of the players' expectations and emotional reactions is a promising way forward as both emotions and beliefs play a crucial role in retaliatory behavior (Hopfensitz and Reuben, 2009; Bolle et al., in press). In addition, variations of the games presented here can be used to study different appropriation and destruction technologies, larger group sizes, cheap-talk communication, resource asymmetry, and additional contest functions.

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Appendix

Table A1 displays descriptive statistics for all treatments. It shows the mean conflict expenditures, take rate, destruction rate, and earnings. For ease of presentation, conflict expenditures and earnings are shown as a fraction of the endowment. In addition, the table also shows the fraction of periods in which subjects choose to spend zero points on conflict (labeled as 'peaceful attempts') and the fraction of periods in which the contest is avoided because the two subjects in a pair choose to spend zero points on conflict (labeled as 'peaceful periods'). Table A2 presents the same statistics for peaceful and aggressive groups in the Partner treatments.

Table A1 – Descriptive statistics

Variable	TC-Strangers	SE-Strangers	RE-Strangers	TC-Partners	SE-Partners	RE-Partners
Conflict expenditures	0.631	0.573	0.456	0.381	0.371	0.278
	(0.262)	(0.252)	(0.243)	(0.351)	(0.336)	(0.318)
Peaceful attempts	0.038	0.058	0.035	0.339	0.350	0.424
	(0.192)	(0.234)	(0.184)	(0.474)	(0.477)	(0.495)
Peaceful periods	0.003	0.006	0.000	0.263	0.275	0.318
	(0.051)	(0.079)	(–)	(0.441)	(0.447)	(0.466)
Take rate	0.981	0.929	0.645	0.811	0.781	0.573
	(0.098)	(0.017)	(0.179)	(0.289)	(0.250)	(0.203)
Destruction rate		0.351	0.249		0.407	0.283
		(0.447)	(0.416)		(0.461)	(0.437)
Earnings	0.369	0.338	0.467	0.619	0.542	0.645
	(0.442)	(0.412)	(0.372)	(0.483)	(0.171)	(0.388)

Note: The table reports means and standard deviations in parenthesis

Table A2 – Descriptive statistics for peaceful and aggressive groups in Partners

	Peaceful groups			Aggressive groups		
Variable	TC	SE	RE	TC	SE	RE
Conflict expenditures	0.065	0.065	0.059	0.545	0.510	0.440
	(0.193)	(0.199)	(0.163)	(0.298)	(0.292)	(0.308)
Peaceful attempts	0.838	0.850	0.804	0.080	0.123	0.145
	(0.369)	(0.358)	(0.398)	(0.272)	(0.328)	(0.352)
Peaceful periods	0.769	0.770	0.700	0.000	0.050	0.037
	(0.422)	(0.422)	(0.459)	(–)	(0.218)	(0.189)
Take rate	0.698	0.630	0.581	0.825	0.791	0.571
	(0.374)	(0.377)	(0.330)	(0.274)	(0.237)	(0.160)
Destruction rate		0.545	0.457		0.392	0.243
		(0.510)	(0.480)		(0.454)	(0.418)
Earnings	0.935	0.876	0.876	0.455	0.390	0.475
	(0.306)	(0.329)	(0.318)	(0.478)	(0.428)	(0.345)

Note: The table reports means and standard deviations in parenthesis