ThE Papers

Dpto. Teoría e Historia Económica
Universidad de Granada

Working Paper n. 16/04

Decisiveness, Peace, and Inequality in Games of Conflict

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May 30, 2016

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ABSTRACT

In this paper, we study two games of conflict characterized by unequal access to productive resources and finitely repeated interaction. In the *Noisy Conflict* game, the winner of the conflict is randomly determined depending on a players' relative conflict expenditures. In the *Decisive Conflict* game, the winner of the conflict is simply the player who spends more on conflict. By comparing behavior in the two games, we evaluate the effect that "decisiveness" has on the allocation of productive resources to conflict, the resulting inequality in the players' final wealth, and the likelihood that players from long-lasting peaceful relations.

This version: May 2016

JEL Codes: D72; D74; C92

Keywords: conflict; decisiveness; inequality; peace; rent seeking;

1. Introduction

The final outcome of most of conflicts is usually uncertain, even when the parties involved have perfect information about each other's capabilities. There are always unforeseen factors, or simply luck, that prevent parties from perfectly anticipating who is going to win the fight. This uncertainty is captured in theoretical models with *contest success functions*, which determine each party's probability of winning depending of the conflict expenditures of all the players involved.[1] In some settings, winning probabilities will closely depend on the resources spent on conflict, while in other settings, the determination of the winner will be closer to a random lottery, almost unaffected by conflict expenditures. The strength of the relationship between conflict expenditures and winning probabilities is referred to as the degree of *decisiveness* in a contest success function. (Hirshleifer, 1991).[2]

The aim of this paper is to experimentally investigate the effect of decisiveness on conflict behavior. For this purpose, we use the conflict game introduced by Lacomba et al. (2014), which is based on the models of Hirshleifer (1988; 1991) and Skaperdas (1992). In this game, two players allocate an initial endowment between productive resources and conflict expenditures. The amount spent on conflict determines a winner based on a contest success function. The winner can then appropriate the productive resources of the loser. We consider two extreme cases. In the less decisive case, the winner is randomly determined with the probability of winning depending on a players' relative conflict expenditures. In the more decisive case, the winner is simply the player who spends more on conflict. We implement a case in which players start with unequal endowments, which allows us to study the effect of decisiveness on the impact of conflict on the final distribution of wealth. Finally, we have players interact repeatedly a finite number of times. This lets us observe

[1] There is a prominent theoretical literature modelling the economics of conflict. Its focus has been mainly on the tradeoff between productive activities (production of goods) and appropriative activities (conflict expenditures). The aim of most of these papers is to determine what the optimal conflict expenditures are and how they depend on parameters such as risk aversion (Skaperdas, 1991), the likelihood of future interaction (Skaperdas and Syropoulos, 1996), and the opportunity to invest in defensive technology (Grossman and Kim, 1996).

[2] Hirshleifer (1991; 2000) presents a detailed theoretical analysis of the effects of decisiveness.

whether decisiveness promotes continuous violence or whether it helps build long-lasting peaceful relations.

Standard theoretical assumptions predict that increasing the decisiveness of the contest success function increases conflict expenditures. As the impact of conflict expenditures on the probability of winning increases, players have stronger incentive to allocate resources to the conflict. Since players face a tradeoff between production and conflict expenditures, this prediction also implies that the players' expected earnings decrease with decisiveness. In addition, the standard theoretical assumptions lead to an interesting prediction concerning the effect of the conflict on inequality. For low levels of decisiveness, the so-called *paradox of power* holds and conflict reduces initial inequality. More precisely, although the conflict reduces the earnings of both rich and poor players, its impact on the earnings of poor players is relatively smaller. By contrast, for high levels fo decisiveness, the opposite is true and conflict amplifies initial inequality.

Our results do not fully support these standard theoretical predictions. More specifically, we find that conflict expenditures in highly decisive conflicts are 12% *lower* than in conflicts with low levels of decisiveness. Although decisiveness increases the propensity that some subjects invest aggressively in conflict, it also makes it more likely that some subjects build long peaceful relations with their opponent. In other words, on average, the larger frequency of peaceful interactions is enough to compensate for the increase in conflict expenditures when a contest does take place. Our results do support the standard theoretical predictions concerning the impact of decisiveness on inequality. Conflicts with high levels of decisiveness increase inequality while conflicts with low levels of decisiveness decrease it.

The explanation for why conflict expenditures do not increase with decisiveness is not entirely clear. We propose that repeated interaction and incomplete information about the motivations of the other player introduces incentives to cooperate on the peaceful outcome (Kreps et al., 1982). In this environment, high decisiveness results in lower conflict expenditures because it helps subjects learn how to cooperate as it implies a clear link between actions and outcomes (as argued by Bereby-Meyer and Roth, 2006).

2. Related work

The recognition of laboratory experiments as a useful tool for the analysis of conflict 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. (2015) reviews the experimental research on contests more generally, particularly Tullock contests, all-pay auctions, and rank-order tournaments. Of these papers, Durham et al. (1998) and Lacomba et al. (2014) are the most related to this paper.

Durham et al. (1998) is the only other paper that has examined experimentally how changes in the decisiveness parameter affect conflict expenditures and inequality in a conflict game. They find that conflict expenditures increase as the contest success function becomes more decisive. Moreover, they find that for low decisiveness conflict leads to less inequality while for high decisiveness it leads to more inequality. Compared to their work, we study a somewhat different setting. First, we consider more extreme cases for decisiveness parameter, which allows us to test whether their results are robust to a different parametrization. Second, and more importantly, we study a game where completely avoiding the conflict is possible. In other words, cooperation on a peaceful outcome is a distinct action instead of simply a lower level of conflict. This modeling choice also introduces a difference in the outcome of cooperation. Namely, while in Durham et al. (1998) cooperation by spending the minimum (positive) amount in conflict implies that all players end up with equal earnings, in our setting, players simply avoid each other and therefore end up earning their initial unequal endowments.

In Lacomba et al. (2014), we study the effects of post-conflict behavior and repeated interaction on the allocation of effort between production and appropriation. We consider three post-conflict scenarios. In the first one, the winner of the contest decides how much to appropriate of the loser's production. In the other two scenarios, the loser has the opportunity to retaliate. Lacomba et al. (2014) find that, compared to random matching, finitely repeated interaction with the same partner noticeably reduces conflict expenditures. The main reason is that some partners manage to cooperate on the peaceful outcome for extended periods of time while randomly matched players do not. In this paper, we focus on the context where winners can appropriate as much of the losers' resources as they want. Unlike in Lacomba et al. (2014), here we study a setting where players start with unequal endowments. Moreover, we also consider a highly decisive contest.

Other experimental studies have been used to analyze strategic behavior in similar conflict models. Some of them 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. Duffy and Kim (2005) and Powell and Wilson (2008) focus on 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. 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.

Other related papers are studies that experimentally investigate the impact of player heterogeneity in Tullock contests. Fonseca (2009), Anderson and Freeborn (2010) and Kimbrough et al. (2014) find support for a discouragement effect. Namely, they find that more endowment heterogeneity leads to lower effort in noisy contests. By contrast, the experimental results in Anderson and Stafford (2003) do not support the prediction that cost heterogeneity decreases expenditures in rent seeking games. The results of Davis and Reilly (1998) are also not consistent with theoretical predictions. They find that individual expenditures increase with heterogeneity.

Finally, our work is also related to experiments that examine different conflict resolution mechanisms. While we analyze the effect of the decisiveness parameter, Abbink and Brandts, (in press) focus on political autonomy, Kimbrough and Sheremeta (2014; 2015) on side-payments, Kimbrough et al. (2013, 2014) on random devices, Lacomba et al. (2014) on retaliation, Bolle et al. (2014) on emotions, and McBride and Skaperdas (2014) on the length of the conflict.

3. Experimental design

In the experiment, we implement one of the games in Lacomba et al. (2014). We consider a two-player, two-stage game. Given our interest in conflict and inequality, we assume that one of the players is relatively more affluent. Specifically, at the beginning of the first stage, both players are endowed with a number of units of an exogenously given resource. The rich player is endowed with y_R units and the poor player with y_P units, where $y_R > y_P$.

In the first stage, each player i decides an amount $c_i \in [0, y_i]$ to spend on conflict, which leaves $y_i - c_i$ as i's production. The amount spent on conflict determines whether there is a contest between the two players and if so, each player's probability of winning it.

Unlike the majority of models in this literature, where conflict is unavoidable, we assume that players can completely avoid fighting each other if they both spend zero resources on conflict. Specifically, if both players choose $c_i = 0$, then there is no contest and the game ends. In this case, each player i receives earnings $\pi_i = y_i$.

If at least one of the players spends a positive amount in conflict, then there is a contest and the player's relative allocations to conflict determine their probability of winning. Specifically, the probability that a player i wins the contest is given by

$$p_i(c_i, c_j) = \frac{c_i^m}{c_i^m + c_j^m},$$

where m is the so-called *decisiveness parameter*, which determines the degree to which larger conflict expenditures translate into higher a probability of winning. In other words, m defines the amount of uncertainty in the determination of the winner (see Hirshleifer, 2000).

After the winner of the contest is determined, the second stage begins. In this stage, the winner decides how much of the loser's production to appropriate. Specifically, winner i chooses a "take rate" $t_i \in [0,1]$ that determines the fraction of $y_j - c_j$ that she usurps, giving i earnings of $\pi_i = y_i - c_i + t_i(y_j - c_j)$. The loser does not make a decision in the second stage and her earnings are given by $\pi_j = (1 - t_i)(y_j - c_j)$.

Compared to the models of Hirshleifer (1988) and Skaperdas (1992), our game differs in three important ways: (i) players can avoid conflict altogether, (ii) conflict expenditures determine the probability of winning instead of the share of the total production, and (iii) the winner determines the final allocation of earnings. Thus, our game is more representative of conflicts where the winning party can take complete control of the loser's productive resources.[3]

We study two starkly different contest success functions: one with a lot of noise in the selection of the winner and one where the winner is selected deterministically.

3.1 Noisy conflict

In the *Noisy Conflict* game, we set $m = 1$. Hence, conditional on $c_i + c_j > 0$, the probability that player i wins the contest is

$$p_i(c_i, c_j) = \frac{c_i}{c_i + c_j},$$

and her expected earnings are given by

$$E[\pi_i] = \frac{c_i}{c_i + c_j}\Big(y_i - c_i + t_i(y_j - c_j)\Big) + \frac{c_j}{c_i + c_j}(1 - t_j)(y_i - c_i).$$

The first element of the sum corresponds to i's earnings if she wins multiplied by her probability of winning, and the second element is i's earnings if she loses multiplied by her probability of losing.

3.2. Decisive conflict

In the *Decisive Conflict* game, we set $m = \infty$. When m goes to infinity, the winner of the contest is the contender who spends more in conflict. Thus, conditional on $c_i + c_j > 0$, the probability that player i wins the contest is

$$p_i(c_i, c_j) = \begin{cases} 1 & \text{if } c_i > c_j, \\ 0.5 & \text{if } c_i = c_j, \\ 0 & \text{if } c_i < c_j. \end{cases}$$

Therefore, her expected earnings are given by

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[3] If players cannot avoid conflict and we set $t_i = t_j = 1$, then our game coincides with a Tullock contest in which players compete for a prize of $y_i + y_j$ (Tullock, 1980). Note that if one assumes risk neutrality and own-earnings maximization, these models result in the same expected payoff function (for a systematic comparison of conflict models see Chowdhury and Sheremeta, 2011).

$$E[\pi_i] = \begin{cases} y_i - c_i + t_i(y_j - c_j) & \text{if } c_i > c_j, \\ 0.5\left(y_i - c_i + t_i(y_j - c_j)\right) + 0.5(1 - t_j)(y_i - c_i) & \text{if } c_i = c_j, \\ (1 - t_j)(y_i - c_i) & \text{if } c_i < c_j. \end{cases}$$

3.3. Standard predictions

If one assumes agents play only once, are risk neutral, and rationally maximize their monetary earnings, then it is straightforward to calculate the optimal conflict expenditures in each game. Both games are solved by backward induction. In order to maximize their earnings in the second stage, in both games, contest winner i sets $t_i^* = 1$ in order to appropriate all of the losers' production.

Given this behavior in the second stage, in the first stage the best response of player i in *Noisy Conflict* is

$$c_i^*(c_j) = \sqrt{(y_i + y_j)c_j} - c_j,$$

which gives us the following equilibrium conflict expenditures and expected earnings:

$$c_i^* = \frac{y_i + y_j}{4} \text{ and } E[\pi_i^*] = \frac{y_i + y_j}{4}.$$

In *Decisive Conflict*, player i's best response in the first stage is to outspend the other player by an arbitrarily small amount, $c_i^*(c_j) = c_j + \epsilon$. By continuity, conflict expenditures increase until, in equilibrium, the poor player can no longer match the rich player's expenditures, $c_R^* = y_P + \epsilon$ and $c_P^* = y_P$. This implies that the rich player wins the contest with certainty and earnings are equal to $\pi_R^* = y_R - y_P - \epsilon$ for the rich player and $\pi_P^* = 0$ for the poor player.

Since in both games the one-shot game has a unique equilibrium, by backward induction, these predictions hold if the game is repeated a known number of times.

In the experiment, rich players were endowed with 500 units and poor players with 300 units. Given these parameters, Table 1 presents the predicted conflict expenditures and earnings per period for each game. This analysis leads to two interesting hypotheses for the experiment.

Hypothesis 1 [Conflict expenditures]: *On average, conflict expenditures are higher in Decisive Conflict compared to Noisy Conflict.*

Table 1 – Nash equilibrium predictions per period for each game

Note: Nash equilibria assuming risk neutrality and own-payoff maximization.

	Noisy Conflict			*Decisive Conflict*		
	Rich player	Poor player	Total	Rich player	Poor player	Total
Endowment	500	300	800	500	300	800
Conflict expenditures	200	200	400	301	300	601
Take rate	100%	100%	100%	100%	100%	100%
Expected earnings	200	200	400	199	0	199
Share of total endowments	63%	37%		63%	37%	
Expected share of total earnings	50%	50%		100%	0%	

Hypothesis 2 [Inequality]: *In Decisive Conflict, rich players obtain a higher share of the total earnings compared to their share of the total endowments, while in Noisy Conflict, on average, rich players obtain a lower share of the total earnings compared to their share of the total endowments.*

It is worth noting that these hypotheses are not restricted solely to the parameters used in our experiment. Hirshleifer (1991; 2000) demonstrates that increases in the decisiveness parameter generally lead to increases in equilibrium conflict expenditures.[4] Similarly, Hirshleifer (1991) shows that for low values of m the so-called *paradox of power* holds and conflict reduces initial inequalities, while for high values of m the opposite is true.[5]

3.4. Experimental procedures

The experiment took place at the CREED laboratory of the University of Amsterdam using z-Tree (Fischbacher, 2007). In total, 76 undergraduate students participated in the experiment. The experiment lasted around one hour. At the end of the experiment, subjects were paid based on an exchange rate of 100 units for 1€.

After arrival to the laboratory, subjects drew cards to be randomly assigned to a cubicle. Once everyone was seated, the instructions for the experiment were read aloud. Thereafter, subjects

[4] Specifically, on average, equilibrium conflict expenditures when $m < 2y_P/(y_R - y_P)$ are always below those when $m \geq 2y_P/(y_R - y_P)$. Moreover, if $m < 2y_P/(y_R - y_P)$ holds, then marginal increases in m always lead to increases in average conflict expenditures.

[5] With endowments of 500 and 300 units for rich and poor players respectively, it is straightforward to calculate that the paradox or power applies as long as $m < 5.219$.

Table 2 – Descriptive statistics for each game

Note: Means across all periods and their corresponding standard deviations in parenthesis.

	Noisy Conflict	*Decisive Conflict*
Conflict expenditures	200	171
	(96)	(111)
Take rate	80%	74%
	(25%)	(26%)
Earnings	200	229
	(96)	(111)
Rich player's share of total earnings	58%	72%
	(10%)	(12%)

completed a few exercises to confirm their understanding of the game. Subjects then played one of the two games, either *Noisy Conflict* or *Decisive Conflict*, for 15 periods. Throughout the experiment, subjects were always matched with the same opponent (i.e., we used partners matching). At the beginning of the experiment, subjects were told which role, either the rich player or the poor player, they had been randomly assigned to. In every period, rich players received 500 units and poor players received 300 units as their endowment. We stressed that they would play against the same person, that their role would not change, and that the number of periods was fixed. A translation of the instructions can be found in the Appendix.

4. Results

Throughout this section, we use nonparametric tests to evaluate the statistical significance of our findings. Specifically, we use Wilcoxon-Mann-Whitney (WMW) tests when testing for differences between the subjects' behavior in *Noisy Conflict* and *Decisive Conflict*, and Wilcoxon signed-rank tests when testing for differences between the behavior of rich and poor types or between the subjects' behavior in one of the games and a theoretical benchmark. In all tests, we use as units the average across all periods for each pair of subjects. All the reported p-values correspond to two-sided tests. In total, 17 pairs (34 subjects) participated in *Noisy Conflict* and 21 pairs (42 subjects) in *Decisive Conflict*.

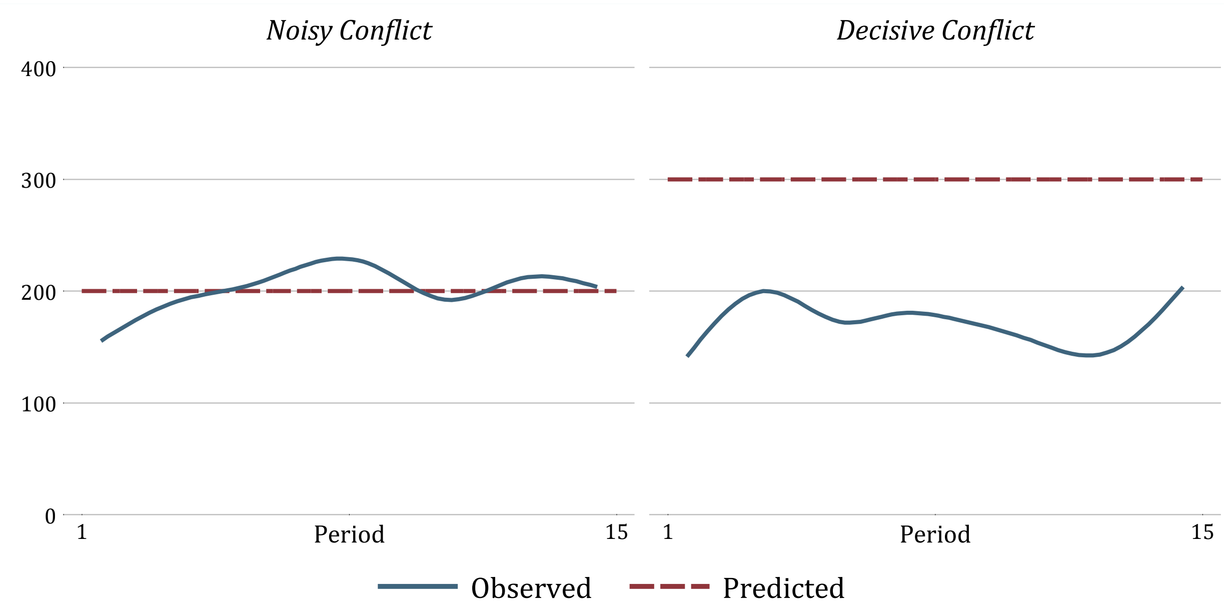

Figure 1 – Conflict expenditures over periods in each game

Note: Two-period moving average of the observed conflict expenditures in each game. Predicted conflict expenditures correspond to the Nash equilibrium predictions described in Table 1.

For each game, Table 2 displays summary statistics of the amount spent on conflict per period, the take rate chosen by contest winners, the subjects' earnings per period, and the share of total earnings obtained by the rich player. Next, we compare the subjects' behavior to the equilibrium predictions described in Table 1 and evaluate the veracity of Hypotheses 1 and 2 by looking at differences in conflict expenditures and the share of earnings accrued by rich players.[6]

We can see that average conflict expenditures in *Noisy Conflict* are in line with the theoretical prediction of 200 units (WSR test, $p = 0.723$). By contrast, subjects in *Decisive Conflict* spend considerably less (171 vs. 300 units; WSR test, $p < 0.001$).[7] This result is also clearly observed in Figure 1, which depicts the mean conflict expenditures in each game over the 15 periods. Contrary to Hypothesis 1, conflict expenditures do not increase as the contest success function becomes more

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[6] Regarding the take rate, we find that the mean take rate is below 100% in both games (WSR tests, $p < 0.001$) and are similar to take rates in the literature. For example, Lacomba et al. (2014) find a mean take rate of 81% in a *Noisy Conflict* with homogenous players. We find no significant difference in take rates between *Noisy Conflict* and *Decisive Conflict* (WMW test, $p = 0.539$).

[7] Obviously, these results are also reflected in to subjects' the mean earnings. While in *Noisy Conflict* mean earnings are in line with predicted earnings, in *Decisive Conflict* they are significantly higher.

Table 3 – Descriptive statistics by player type for each game

Note: Means across all periods and the corresponding standard deviations in parenthesis.

	Noisy conflict		*Decisive conflict*	
	Rich player	Poor player	Rich player	Poor player
Conflict expenditures	227	173	189	153
	(113)	(84)	(120)	(108)
Fraction of contests won	60%	40%	77%	23%
	(16%)	(16%)	(20%)	(20%)
Take rate	75%	91%	68%	83%
	(26%)	(13%)	(31%)	(20%)
Earnings	240	161	313	145
	(131)	(74)	(123)	(112)

decisive. In fact, mean conflict expenditures are slightly higher in *Noisy Conflict* compared to *Decisive Conflict* (WMW test, $p = 0.490$).

To better understand why we do not find support for Hypothesis 1, we take a closer look at the behavior of rich and poor players. For each player type and game, Table 3 displays summary statistics of the amount spent on conflict per period, the fraction of contests won, the take rate chosen by the contest winner, and the subjects' earnings.

In line with the aggregate statistics, the mean conflict expenditures of rich and poor players are close to the theoretical prediction in *Noisy Conflict* (WSR tests, $p > 0.308$) but are substantially below in *Decisive Conflict* (WSR test, $p < 0.001$).[8] Hence, we do not find support for Hypothesis 1 either among the rich or the poor players.[9] The fact that rich players spend markedly less than 301 units in *Decisive Conflict*—i.e., the amount that guarantees them a win—is revealing because it shows that below-equilibrium conflict expenditures in this game are not simply the result of indifferent poor players who know that the rich player can always win. We summarize these findings as our first result.

[8] Many authors find that subjects overinvest in Tullock contests, where decisiveness is low (see Dechenaux et al., 2015). However, our findings are consistent with Lacomba et al. (2014), who find that overspending on conflict when cooperation on a peaceful outcome is possible occurs only under random matching and not under partners matching.

[9] There is no significant difference between *Noisy Conflict* and *Decisive Conflict* in the conflict expenditures of rich players (WMW test, $p = 0.386$) or poor players (WMW test, $p = 0.692$).

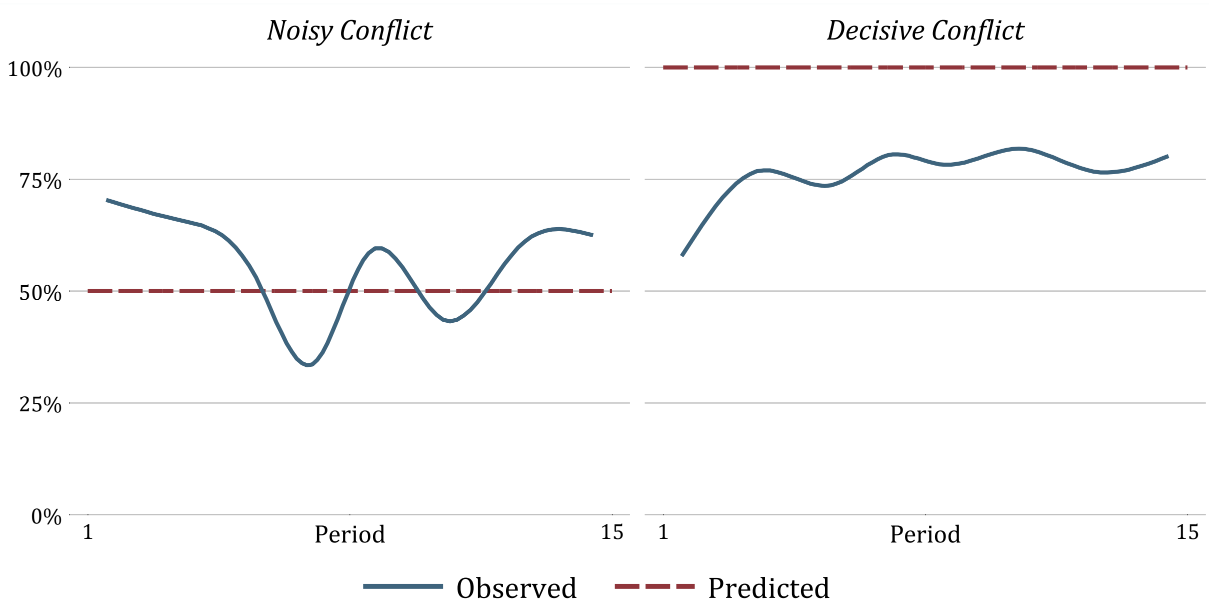

Figure 2 – Share of total earnings gained by the rich player over periods in each game

Note: Two-period moving average of the observed share of total earnings gained by the rich player in each game. The predicted share of total earnings correspond to the Nash equilibrium predictions described in Table 1.

Result 1 [Conflict expenditures]: *Conflict expenditures of rich and poor players are not significantly different in Decisive Conflict compared to Noisy Conflict. The main reason is that, while conflict expenditures in Noisy Conflict are close to the predicted ones, in Decisive Conflict rich and poor players spend substantially less than the predicted amount.*

Next, we turn to the distribution of earnings between rich and poor players. As seen in Figure 2, which depicts the rich players' share of earnings over the 15 periods, the share of total earnings obtained by the rich player deviates from the predicted one in both games. In *Noisy Conflict*, rich players obtained 58% of total earnings, which is more than their predicted share of 50% (WSR test, $p = 0.007$) but is less than 67%, their share of total endowments (WSR test, $p = 0.052$). Conversely, in *Decisive Conflict*, rich players obtained 72% of total earnings, which is less than their predicted share of 100% (WSR test, $p < 0.001$) but is more than their share of total endowments (WSR test, $p = 0.010$). The rich players' share of earnings is also significantly higher in *Noisy Conflict* compared to *Decisive Conflict* (WMW test, $p = 0.001$). In other words, even though the effect is not as extreme as predicted, the qualitative prediction in Hypothesis 2 holds.

Table 3 reveals that the rich players' share of total earnings diverges from the predicted share in both games because of the fraction of times each type of player wins the contest (conditional on there being one). In *Noisy Conflict*, although rich players are predicted to win only half the time, they win significantly more often (60% of the time; WSR test, p = 0.015). Conversely, in *Decisive Conflict*, rich players are predicted to win all the time, but they win significantly less often (77% of the time; WSR test, p < 0.001). This difference, partly explains why the rich players' share of total earnings diverges from the predicted share in both games.[10] We summarize these findings as the following result.

Result 2 [Inequality]: *As predicted, compared to their share of total endowments, the rich players' share of total earnings increases in Decisive Conflict and decreases in Noisy Conflict. Compared to the predicted change in their share, the increase in Decisive Conflict is smaller because rich players win too infrequently while the decrease in Noisy conflict is smaller because rich players win too frequently.*

Next, we turn to a more detailed analysis of the subjects' individual behavior. In particular, we are interested in understanding the deviations from the equilibrium predictions observed in *Decisive Conflict*. One of the main reasons that Hypothesis 1 fails is that it does not take into account that players who interact repeatedly can try to avoid the contest altogether by not spending any resources in conflict. The top two rows of Table 4 displays how often subjects attempt and succeed in attaining a peaceful outcome. Specifically, it shows the fraction of periods in which the subjects' conflict expenditures are exactly zero, to which we refer to as *peaceful attempts*, and the fraction of periods in which pairs of subjects avoided the contest because they both spent zero units in conflict, to which we refer to as *peaceful outcomes*. These fractions are also depicted over the 15 periods in Figure 3.

We find that higher decisiveness is associated with more peaceful behavior. While the fraction of peaceful attempts is 20% in *Noisy Conflict* (16% for rich players and 24% for poor players), it is 32% in *Decisive Conflict* (28% for rich players and 37% for poor players). Moreover, in *Noisy Conflict,*

[10] Differences in take rates also play a role explaining in the rich players' share of earnings. In particular, when they win, poor players tend to take a larger share of the losers remaining units compared to rich players (WSR tests; p = 0.003 in *Noisy Conflict* and p = 0.251 in *Decisive Conflict*). This difference in behavior affects the mean share of total earnings obtained by rich players, but the effect is modest. For example, if we recalculate the rich players' share of earnings assuming all players choose a take rate of 100%, we find that rich players would earn 62% of total earnings in *Noisy Conflict* and 71% in *Decisive Conflict* (cf. 58% and 72% respectively).

Table 4 – Fraction of peaceful and equilibrium play and outcomes

Note: Means across all periods and the corresponding standard deviations in parenthesis.

	Noisy conflict			*Decisive conflict*		
	Rich player	Poor player	Overall	Rich player	Poor player	Overall
Fraction of peaceful attempts	16%	24%	20%	28%	37%	32%
	(32%)	(33%)	(32%)	(42%)	(39%)	(39%)
Fraction of peaceful outcomes			13%			24%
			(32%)			(40%)
Fraction of equilibrium play	9%	9%	9%	41%	35%	38%
	(13%)	(17%)	(12%)	(34%)	(33%)	(30%)
Fraction of equilibrium outcomes			2%			23%
			(3%)			(30%)
Fraction of periods with similar conflict expenditures			27%			57%
			(31%)			(32%)

peaceful attempts result in a peaceful outcome in 13% of all periods while in *Decisive Conflict* the fraction is 24% of all periods, almost twice as much.[11] As Lacomba et al. (2014), we find that the majority of peaceful attempts and outcomes occur within a subset of pairs. For example, if we follow Lacomba et al. (2014) and classify *peaceful pairs* as those where at least half of all behavior corresponds to peaceful attempts, we find 2 such pairs in *Noisy Conflict* and 6 in *Decisive Conflict*. In *Noisy Conflict*, peaceful pairs account for 59% of all peaceful attempts and 85% of all peaceful outcomes. In *Decisive Conflict*, they account for 79% of all peaceful attempts and 100% of all peaceful outcomes.

Interestingly, we find that higher decisiveness is not only associated with more peaceful behavior, but also with the propensity to play according to equilibrium predictions. This finding can be seen in Table 4, which displays the fraction of periods in which the subjects' conflict expenditures equal the expenditures predicted in equilibrium (see Table 1), to which we refer to as *equilibrium play*, and the fraction of periods in which pairs of subjects both played according to the equilibrium predictions, to which we refer to as *equilibrium outcomes*.

[11] Although the difference between games in peaceful attempts and outcomes is large in magnitude, we do not find that it is statistically significant (WMW tests; $p = 0.311$ for peaceful attempts and $p = 0.431$ for peaceful outcomes). As discussed subsequently, this is most likely due to the extreme behavior observed in *Decisive Conflict* where pairs tend to choose either very high or very low conflict expenditures.

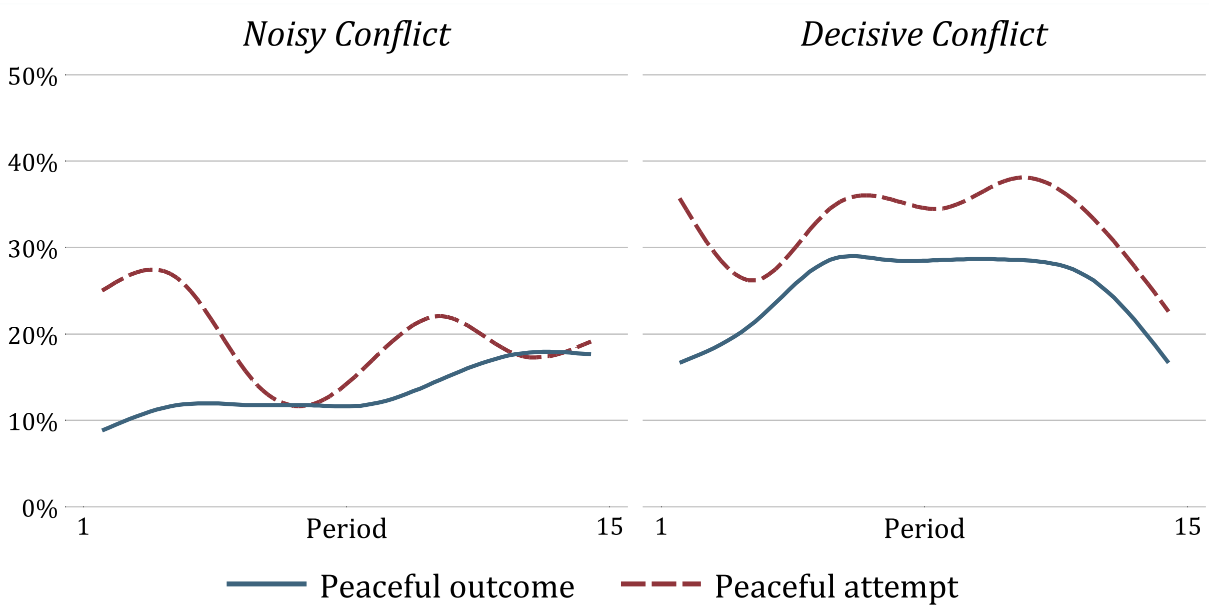

Figure 3 – Fraction of peaceful attempts and outcomes over periods in each game

Note: Two-period moving average of the fraction of peaceful attempts (i.e., subjects with zero conflict expenditures), and peaceful outcomes (i.e., pairs of subjects who avoid the contest by both choosing zero conflict expenditures).

The fraction of equilibrium play is only 9% in *Noisy Conflict* (9% for both rich and poor players) while it is 38% in *Decisive Conflict* (41% for rich players and 35% for poor players). As a result, in *Noisy Conflict*, the Nash equilibrium was observed in only 2% of all periods. By contrast, in *Decisive Conflict*, the Nash equilibrium occurred in 23% of all periods.[12] In the same way as for peaceful behavior, the majority of equilibrium play and outcomes occur within a subset of pairs. Classifying *equilibrium pairs* as those where at least half of all behavior corresponds equilibrium play gives no such pairs in *Noisy Conflict* and 7 pairs in *Decisive Conflict*. In the latter game, these pairs account for 64% of all equilibrium play and 84% of all equilibrium outcomes.

In other words, unlike in *Noisy Conflict*, behavior in *Decisive Conflict* tends to be either peaceful or very aggressive. In this game, these two extremes account for 48% of all outcomes and 70% of all individual decisions (69% for rich players and 72% for poor players). Moreover, they describe well the dynamics within pairs in that a majority of pairs (62%) are classified as either a peaceful pair or an equilibrium pair. These findings lead to two additional results.

[12] The differences between *Noisy Conflict* and *Decisive Conflict* in equilibrium pay and equilibrium outcomes are statistically significant (WMW tests; $p = 0.002$ both for equilibrium play and for equilibrium outcomes).

Result 3 [Individual behavior in Noisy Conflicts]: *Low decisiveness results in erratic behavior. Consequently, although mean behavior in Noisy Conflict is in line with equilibrium predictions, individual behavior is not.*

Result 3 is true even if we broaden the scope of what constitutes equilibrium play. For instance, if we define equilibrium play as either choosing the equilibrium conflict expenditures, best responding to their opponent's chosen conflict expenditures, or myopically best responding to their opponent's past conflict expenditures, we nonetheless find that equilibrium play only accounts for 10% of choices in *Noisy Conflict* (compared to 40% in *Decisive Conflict*). Moreover, in spite of the fact that marginal incentives to spend resources in conflict are the same for both players, it does not appear that subjects are converging towards symmetric outcomes. This can be observed by looking at the bottom row of Table 4, which shows the fraction of periods in which the absolute difference in conflict expenditures within a pair is less than or equal to 5 units. In *Noisy Conflict*, this fraction is 27% while in *Decisive Conflict* it is 57%.

Result 4 [Individual behavior in Decisive Conflicts]: *Behavior in Decisive Conflict tends to be one of the two extremes: either completely peaceful or very aggressive. The high frequency of peaceful behavior helps to explain why* ***c****onflict expenditures in Decisive Conflict are substantially below the equilibrium prediction.*[13]

5. Discussion

So far, we have described Nash equilibria assuming players are risk-neutral and maximize solely their own earnings. This is a useful benchmark as it gives us precise predictions. However, there is considerable evidence that these assumptions do not hold in many games, including ours. For this reason, we briefly discuss whether our results can be better explained if we consider common departures from the standard assumptions. Namely, risk-aversion, other-regarding preferences, and, more importantly, reputation building in repeated-games.

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[13] If we exclude peaceful pairs, mean conflict expenditures move closer to equilibrium predictions: 230 units (256 units for rich players and 205 for poor players). If, in addition, we exclude the remaining peaceful attempts, mean conflict expenditures equal 251 units (262 units for rich players and 242 for poor players).

5.1. Risk aversion

There is plenty of evidence that individuals display risk averse behavior even for the stakes involved in laboratory experiments (e.g., Holt and Laury, 2002). In *Noisy Conflict*, allowing for risk averse players increases the equilibrium expenditures in conflict, with more risk-averse players spending relatively more (see Skaperdas, 1991). The basic intuition is that risk-averse players are willing to spend more in order to insure themselves against a loss. Since in *Decisive Conflict*, risk aversion does not play a role, higher levels of risk aversion imply a smaller difference in conflict expenditures between the two games, which weakens Hypothesis 1. For example, if subjects possess a CRRA utility function $U_i\ (\pi_i) = \pi_i^{1-r}/1 - r$ and a common coefficient of relative risk aversion, then equilibrium conflict expenditures in *Noisy* equal $c_i^* = c_j^* = \left(y_i + y_j\right)/(4 - 2r)$. Consequently, equilibrium conflict expenditures in *Noisy Conflict* equal those in *Decisive Conflict* when $r = 0.667$ and will exceed them for higher degrees of risk aversion.

However, even though very high degrees of risk aversion can predict no difference between *Noisy Conflict* and *Decisive Conflict*,[14] it does so because conflict expenditures in *Noisy Conflict* increase compared to the traditional theoretical benchmark. What we find instead is that that the lack of a difference between games is driven by a reduction in conflict expenditures in *Decisive Conflict*.

5.2. Other-regarding preferences

There is also a large amount of evidence that individuals possess other-regarding preferences (e.g., see Bruhin et al. 2016). In particular, even in anonymous settings with no repeated interaction, individuals are willing to forgo earnings in order to sanction those who treat them unkindly and reward those who treat them kindly.[15] In games of conflict, models of other-regarding preferences introduce two opposing effects, each of which can narrow the difference between *Noisy Conflict* and *Decisive Conflict*.

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[14] A mean CRRA coefficient of 0.667 would imply that our mean subject pool is much more risk averse compared to other populations. For example, only around 10% of subjects in Holt and Laury (2002) have coefficients this high.

[15] Commonly cited explanations for these behaviors include inequality aversion, maximin preferences, and reciprocity (for a review see Fehr and Schmidt, 2006).

First, in some models of other-regarding preferences individuals can find it optimal to spend zero units in conflict if they are almost certain that the other player will do the same. If this occurs in both games, then clearly the difference between them narrows down. That being said, since this type of cooperation occurs only when both players have strong other-regarding preferences, it requires either common knowledge of the players' preferences, which is a strong assumption in an anonymous setting like ours, or the expectation that a clear majority of subjects possess strong other-regarding preferences, which is not consistent with the findings from most experiments designed to elicit such preferences (e.g., see Charness and Rabin, 2002; Engelmann and Strobel, 2004; Blanco et al. 2010). Moreover, cooperation on the peaceful outcome is not the prediction of the most popular models of other regarding preferences, namely inequity aversion (Fehr and Schmidt, 1999; Bolton and Ockenfels, 2000) and maximin preferences (Charness and Rabin, 2002). The reason these models fail to predict peaceful outcomes in our setting is that peace implies a high degree of earnings inequality. Hence, in both models, individuals with other-regarding preferences prefer the outcome where the rich player spends zero units in conflict, the poor player spends a minimal amount, wins the contest, and then equalizes earnings by appropriating some of the resources of the rich player. We do not observe this type of cooperation in any of the pairs in either game.

Second, if there are positive conflict expenditures, a willingness to reciprocate behavior that treats them unkindly implies that individuals with other-regarding preferences will spend more on conflict compared to individuals with only self-regarding preferences. However, since equilibrium conflict expenditures are already maximal for the poor player in *Decisive Conflict*, including other-regarding preferences can narrow the gap between the two games as conflict expenditures increase in *Noisy Conflict* but not in *Decisive Conflict*, again, weakening Hypothesis 1.[16] As mentioned above, however, higher conflict expenditures in *Noisy Conflict* is not the reason why there is no difference in conflict expenditures between the two games.

[16] For example, if we apply the model of inequity aversion proposed by Fehr and Schmidt (1999) with their proposed distribution of types, then we find that the predicted difference in conflict expenditures between the two games narrows from 100 units to 47 units.

On a separate note, it is worth noting that take rates below 100% are predicted by models of other-regarding preferences that include motivations to redistribute income (e.g., Fehr and Schmidt, 1999; Bolton and Ockenfels, 2000; Charness and Rabin, 2002).

5.3. Repeated game effects

Although introducing risk aversion and other regarding preferences can have noticeable effects on the predicted conflict expenditures, a more dramatic effect is obtained if we consider repeated interaction. Specifically, if repeated game effects facilitate the attainment of peaceful outcomes, then considerable reductions in conflict expenditures ensue.

It is straightforward to see that, if either game is played only once, then avoiding the contest by choosing $c_i = c_j = 0$ is not an equilibrium since both players have an incentive to marginally increase their conflict expenditures, win the contest with certainty, and take their rival's entire production. Moreover, as mentioned in Section 3.3, with standard assumptions, this prediction applies to every period of a repeated game with a known end. Contrary to these predictions, however, we find that some pairs of subjects consistently cooperate on the peaceful outcome. [17]

Arguably, the best-known model that rationalizes cooperation in finitely repeated games is that of Kreps et al. (1982). This model can be applied to our setting if we assume that both players believe that there is a probability that the other player is using the following "tit-for-tat" strategy: spend zero units in conflict as long as the other player spent zero units in conflict in the previous period, otherwise spend the amount prescribed by the Nash equilibrium.[18] If this is the case, selfish individuals have an incentive to mimic the tit-for-tat player for a while and enjoy the benefits of cooperation before switching to positive conflict expenditures towards the end of the repeated game.

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[17] Evidence that finitely repeated interaction increases cooperation is found in many different games; for example, in bribery games (Abbink 2004), principal-agent games (Cochard and Willinger 2005), trust games (Huck et al. 2012), prisoner's dilemma games (Duffy and Ochs, 2009; Reuben and Suetens, 2016), gift-exchange games (Gächter and Falk, 2002), public good games (Croson 1996; Keser and van Winden 2000), and the same conflict game we use in this paper (Lacomba et al., 2014).

[18] Holding such a belief is reasonable. There is plenty of evidence that individuals are willing cooperate in social dilemmas as long as others also cooperate (see Keser and van Winden, 2000; Fischbacher and Gachter, 2010).

Within this framework, there are two reasons why we can expect more peaceful cooperation in *Decisive Conflict* compared to *Noisy Conflict*. The first reason follows directly from the difference in equilibrium outcomes between games. In the model of Kreps et al. (1982)., cooperation is sustained for a while because the long-term payoff loss implied by a permanent switch to the Nash equilibrium is greater than the short-term benefit of not cooperating. Since, the difference in total earnings between the peaceful outcome and the Nash equilibrium outcome is larger in *Decisive Conflict* than in *Noisy Conflict* (600 units vs. 400 units respectively), cooperation in the peaceful outcome should be easier to sustain in the former game. The second reason is based on the arguments of Bereby-Meyer and Roth (2006). If we think that in complex games such as this one, players need some time to learn what the optimal strategies are, then it is reasonable to think that it is easier to learn how to cooperate in *Decisive Conflict*, where there is a strong link between choices and outcomes, compared to *Noisy Conflict*, where there is much more noise.[19]

These arguments are consistent with the below-equilibrium conflict expenditures observed in *Decisive Conflict* and, broadly-speaking, with the individual behavior of subjects in that game.

6 Conclusions

This paper investigates the impact on behavior of how decisive conflict expenditures are in determining the probability of winning in a conflict game with asymmetrically endowed players. Contrary to the standard theoretical predictions, our results indicate that increases in decisiveness are *not* associated with an increase in conflict expenditures. The reason is that with a highly decisive contest success function, subjects increase their effort to avoid the conflict altogether and form long-lasting peaceful relations. Our results are consistent with the intuition behind the model of Kreps et al. (1982), which rationalizes cooperation in finitely repeated games, and the argument proposed by Bereby-Meyer and Roth (2006), who claim that in settings where the relation between actions and payoffs are noisy, the players' capacity to learn to cooperate is substantially diminished.

[19] There is a well-established literature within psychology that argues that actions that are rewarded only sometimes, so-called partial reinforcement, slows learning compared to actions that are rewarded every time (for a review, see Donald Robbins, 1971).

Our study provides an interesting contribution to our understanding of how to avoiding potential conflicts. In this respect, this study highlights the importance of the decisiveness of the battle on the likelihood of conflict avoidance. Further work, both theoretical and empirical, is needed to develop and test mechanisms aimed at avoiding potential conflicts. A natural question that arises from this study would be to analyze the robustness of these results to having equally-endowed players, larger group sizes, or different contest functions.

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Appendix

Below are the instructions for the Noisy Conflict game. Instructions for Decisive Conflict game are very similar and are available upon request.

Instructions

There are 15 periods of decision making. In each period, you will interact with one other participant. For convenience, we will refer to this other participant as simply Other.

At the beginning of each period, you will get 300 tokens as endowment. Other will get 500 tokens as endowment.

Each period consists of two phases.

Phase 1:

In this phase, you as well as Other will distribute your endowment into two projects. Tokens can be allocated to project P1 (P1-tokens) or to project P2 (P2-tokens). Any distribution of tokens is allowed, including putting all tokens into only one project. Choices are made simultaneously. In other words you will not know what Other chooses until after you have made your choice and vice versa.

Each P1-token held by you after phase 2 increases your earnings by 1 token. The number of tokens that you and Other allocate to P2 determines the winner and loser of phase 1.

Phase 2:

In this phase, only the winner of phase 1 makes a decision. It consists of choosing a percentage. This percentage determines the share of P1-tokens of the loser that are transferred to the winner. The percentage must be an integer between 0 and 100 (inclusive).

Example

For example, suppose that, in phase 1, you allocate 225 tokens to P1 and 75 tokens to P2. Furthermore, Other allocates 300 tokens to P1 and 200 tokens to P2.

Assume that Other is the winner, and then, in phase 2, Other decides that 40% of your P1-tokens are to be transferred to him or her. In this case, your earnings in this period would equal: 225 (your P1-tokens) - 90 (transfer to Other) = 135 tokens. Other's earnings would equal: 300 (Other's P1-tokens) + 90 (transfer from you) = 390 tokens.

Next we will describe in detail how the winner is determined.

Determining the winner

The winner of phase one is determined by a lottery. Your probability of winning depends on the amount of tokens you and Other allocate to P2. Specifically, it is given by the following formula:

Your probability of winning = Your P2-tokens / (Your P2-tokens + Other's P2-tokens)

Similarly, Other's probability of winning is:

Other's probability of winning = Other's P2-tokens / (Your P2-tokens + Other's P2-tokens)

For example, if you allocate 20 tokens to P2 and Other allocates 60 tokens to P2, your probability of winning the lottery equals: 20/(20+60) = 20/80 = 1/4 (25%), and Other's probability of winning equals: 60/80 = 3/4 (75%).

Note that, for any given number of tokens that Other allocates to P2, your probability of winning increases the more tokens you allocate to P2. In our example, if you allocate 60 tokens to P2 instead of 20, your probability of winning becomes: 60/(60+60) = 60/120 = 1/2 (50%).

If neither you nor Other allocates any tokens to P2 (you both allocate all the endowment to P1) then the lottery does not take place. In this case phase 2 is skipped and your earnings in that period equal your endowment.

Example

We illustrate with an example how earnings in a period are calculated.

Suppose that, in phase 1, you allocate 150 tokens to P1 and 150 tokens to P2, while Other allocates 450 tokens to P1 and 50 tokens to P2. This means that your probability of winning the lottery equals 150/(150+50) = 3/4 (75%), while Other's probability equals 1/4 (25%).

Assume that you win the lottery, and in phase 2, you decide that 70% of Other's P1-tokens are to be transferred to you. The transfer from Other to you is then equal to 315 tokens (70% of 450 tokens).

Your earnings for this period would equal: 150 (your P1-tokens) + 315 (transfer from Other) = 465 tokens. Other's earnings would equal: 450 (Other's P1-tokens) – 315 (transfer to you) = 135 tokens.

Once you are done reading, click on Next to answer a few questions. Once everyone has correctly answer the questions, the experiment will start.