The Costs of Conflict*

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Abstract

Violent conflict destroys resources. It generates "destruction costs." These costs have an important effect on individuals' decisions to cooperate or conflict. We develop two models of conflict: one in which conflict's destruction costs are independent of individuals' investments in "arms"—the tools of conflict—and another in which conflict's destruction costs depend on those investments. Our models demonstrate that when conflict's destruction costs are arms-dependent, conflict is more costly, making cooperation more likely. We test this prediction with a laboratory experiment in which subjects first choose how heavily to invest in arms and then choose whether to cooperate or conflict in an environment where interaction is repeated. In one set of treatments conflict's destruction costs are arms-independent. In another they are arms-dependent. Our experimental results support our models' predictions. Compared to when conflict's destruction costs are arms-independent, when those costs are arms-dependent, cooperation increases by nearly a third.

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1 Introduction

Violent conflict destroys resources. It generates “destruction costs.” These costs have an important effect on individuals’ decisions to cooperate or conflict.

With the notable exception of Chang and Luo (2013), existing models of conflict treat conflict’s destruction costs as independent of individuals’ decisions to invest in “arms”—the tools of conflict. These models introduce conflict’s destruction costs through a “destructiveness parameter.” This parameter measures the amount of a contested resource violent conflict destroys. But it’s unconnected to individuals’ decisions about how many resources they devote to fighting (see, for instance, Grossman and Kim 1995; Anderton 2003; Garfkinkel and Skaperdas 2000, 2007; McBride and Skaperdas 2010).[1]

In disconnecting the destructiveness parameter from individuals’ arms investments, existing models of conflict make an important and unusual assumption: conflicting individuals destroy as many resources when they devote everything to fighting as when they devote almost nothing to this purpose. Fights with fists are as destructive as fights with tanks and missiles. This assumption comports poorly with reality. Further, it has an important effect on existing models’ predictions about the scope for cooperation.

Consider McBride and Skaperdas’ (2010) work. These authors develop and experimentally test a model of conflict in which the possibility of repeated interaction between individuals increases the likelihood of conflict rather than reduces it as conventional folk theorem-type reasoning would suggest. As in other models of conflict, in theirs too, conflict’s destruction costs are arms-independent. The height of individuals’ arms investments doesn’t influence conflict’s destruction costs. But the height of those investments does influence individuals’ decisions to cooperate or conflict. Higher arms investments make conflict more likely, reducing the scope for cooperation.

The intuition behind this result is sensible. When individuals invest in more arms, an armed peace is more expensive. Thus individuals are more likely to conflict.

[1] In earlier models of conflict violent clashes never occur. “[T]here is coercive taking but no actual battle” (Hirshleifer 1988: 204). Because of this, conflict destroys no resources. So conflict’s destruction cost is zero (see, for instance, Hirshleifer (1988, 1991, 1995).

But this intuition is incomplete. Its incompleteness stems from its assumption of arms-independent destruction costs. If conflict's destruction costs are arms-dependent, a countervailing force emerges.

As Chang and Luo (2013) show, when individuals invest in more arms, conflicts that occur are more destructive. This makes conflict more costly, inducing individuals to cooperate more.[2] The additional cooperation that heavier arms investments induce by raising the price of an armed clash may completely offset the additional conflict they induce by raising the price of an armed peace.[3]

Our paper follows this line of reasoning. We argue that by ignoring destruction costs' arms-dependence, existing studies of conflict overpredict the likelihood of conflict. If instead, more reasonably, we allow conflict's destruction costs to be arms-dependent, cooperation is more likely.[4]

We develop two competing models of conflict—one with arms-independent destruction costs and another with arms-dependent destruction costs—to demonstrate this. Unlike conventional models of conflict whose arms-independent destruction costs assumption, in Grossman and Kim's (1995: 1279) words, precludes "an internal explanation for violence and destruction," our model of conflict with arms-dependent destruction costs provides one.

We test our competing models of conflict with a laboratory experiment in which subjects choose whether to cooperate or conflict. Our experiment builds on McBride and Skaperdas (2010). Paired subjects engage in a repeated game. Subjects choose to "Cooperate," by splitting a resource of fixed value, or to "Conflict," in which case one subject receives the entire resource according to a fixed probability distribution. But before making that choice, subjects choose arms investments.

[2] Leeson (2009: 500) makes this point in the context of the Anglo-Scottish border reivers—a society of persons bent on plundering each other as a way of life. As he points out, "instead of this situation preventing decentralized institutions from emerging to govern them, if anything, it seems that these bandits' animosity enhanced the importance of developing a system to oversee intergroup interactions and, thus, both groups' incentive to devise institutions for regulating their predatory inclinations." See also, Leeson and Nowrasteh (2011).
[3] A similar effort by Amegashie and Runkel (2012) shows how the desire for revenge may have the countervailing effect of decreasing the likelihood of conflict. Their argument, echoing the logic of our own, is that the increased future cost of revenge-laden conflict may reduce the desire for conflict in the present.
[4] Though we do not pursue this line of reasoning, it is plausible that this would complement other cooperation-inducing parameters used to enhance simpler models of conflict. See, for example, Kimbrough and Sheremeta (2013) for an analysis of the role of side-payments in inducing cooperative outcomes.

In one set of treatments we follow McBride and Skaperdas' model and experimental environment: conflict's destruction costs are arms-independent. In another set of treatments we modify that environment to make those costs arms-dependent. In these treatments, when subjects invest in more arms, more resources are destroyed when they clash and vice versa.

Our experiment's results support our models' predictions. When conflict's destruction costs depend on subjects' arms investments, subjects cooperate more. When conflict's destruction costs are independent of subjects' arms investments, subjects cooperate less. The change in cooperation that going from arms-independent to arms-dependent destruction costs generates is substantial. Compared to when conflict's destruction costs are arms-independent, when those costs are arms-dependent, cooperation increases by nearly a third.

To further explore the relationship between arms investments and individuals' decisions to cooperate or conflict we consider two additional treatments that vary the price of investing in arms and thus the level of arms investments that subjects make. We find that when arms are cheaper, and thus subjects are better armed, they're more likely to cooperate. When arms are more expensive, and thus subjects invest less in arms, they're more likely to conflict. This finding is consistent with the reasoning our models describe. By making for better armed individuals, cheaper arms raise conflict's destruction costs when conflict occurs. In doing so cheaper arms promote cooperation.

2 Two Models of Conflict

2.1 Background

A growing literature tests models of conflict experimentally (for surveys of this literature, see Abbink 2012; Dechenaux, Kovenock, and Sheremeta 2013). But most of the models this literature tests assume that conflict destroys no resources (see, for instance, Durham, Hirshleifer, and Smith 1998; Carter and Anderton 2001; Duffy and Kim 2005). Its destruction cost is zero.

McBride and Skaperdas' (2010) work is an exception to this. So, too, is Lacomba et al.'s (2013) work. Although our experimental design most closely follows McBride and Skaperdas, the question Lacomba et al. study is most closely related to ours.

Lacomba et al. conduct an experiment where subjects compete for a resource. In two treatments, a conflict's loser may choose to destroy part or all of the resource before the conflict's winner claims it. Lacomba et al. find that when losers can increase conflict's destruction costs, subjects cooperate more.

Our experimental environment extends Lacomba et al.'s insight by making conflict's destruction costs arms-dependent. Lacomba et al. (2013) consider how post-conflict distributional decisions influence cooperation and conflict. We consider how pre-conflict arming decisions influence these decisions. In doing so our analysis emphasizes the interactive consequences of conflict itself rather the consequences of decisions individuals may make after violent clashes are over.

2.2 Arms-Independent Destruction Costs

We begin with a conventional model of violent conflict where conflict's destruction costs are arms-independent. We consider a model of conflict based on McBride and Skaperdas (2010). In this model there are two parties, i and j, who compete over a resource, Y, in n rounds of interaction. They do so by investing in arms.

First, i and j decide how many arms to invest in, a_i and a_j, respectively. Their arms levels are common knowledge.[5] Next they decide whether to cooperate by splitting the contested resource according to their relative arms strengths or to conflict to try to obtain a greater share of the resource. Cooperation requires both parties' consent. If either party chooses to not cooperate, the result is conflict.

Parties choose their arms levels and whether to cooperate or conflict in the first round of interaction only. Their decisions to cooperate or conflict in round one carry forward to all subsequent rounds. To enforce an armed peace, parties must maintain their arms levels in each round of interaction. Thus, if they cooperate in round one, they incur the cost of their arms investments in each subsequent round. Any deviation from this arms level would, of course, invite conflict from the other party.

[5] For the sake of parsimony, we assume that the chosen arming level is the same whether the parties choose to cooperate or engage in conflict. While this assumption is perhaps unrealistic (see Levento-lu and Slantchev 2007), we use it to focus the reader's attention on the principal variable of interest, destruction costs. Further, we relax the assumption in the experiment below and derive optimal arming levels under both cooperative and conflictual conditions, given the parameters of the experimental design. Note that relaxing the assumption does not change the expected outcome of greater conflict when destruction is arms-dependent.

If the parties cooperate, they split Y according to their relative strengths.[6] Those strengths are determined by their relative arms levels. The following contest success function describes i's share of Y, $P_{i,j}$:

$$P_{i,j} = \frac{a_{i,j}}{a_{i,j} + a_{j,i}}. \tag{1}$$

Thus, if the parties cooperate, i earns:

$$EV_{i,j} = n\left[Y\left(\frac{a_{i,j}}{a_{i,j} + a_{j,i}}\right) - a_{i,j}\right], n \in (1, \infty). \tag{2}$$

Conflict destroys part of the contested resource. How much of that resource it destroys depends on an exogenously determined destructiveness parameter, $\phi \in (0, 1)$. Resources destroyed in the first round of conflict remain destroyed in subsequent rounds.[7]

If the parties conflict in round one, the contest success function $P_{i,j}$ describes the probability that i is victorious over j. The conflict's winner remains arms-superior, and so victorious, in all subsequent rounds. Thus, in the event of conflict, parties incur the cost of their arms investments in the first round of interaction only. Unlike the cooperative outcome, they needn't maintain their arms levels in subsequent rounds because the conflict winner's first-round victory vanquishes his opponent permanently.

When parties conflict, in the first round of interaction the winner earns the value of the contested resource, less the value of what's been destroyed by the conflict, less the cost of his arms investment. For all subsequent rounds the conflict's winner earns the full value of the contested resource, less the value of the resource that was destroyed. In the first round of interaction the loser earns zero, less the cost of his arms investment. For all subsequent rounds he earns zero. Thus, if the parties conflict, i's earns:

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[6] There are, of course, other bargaining solutions that the parties may agree to. We adopt the "split the surplus" rule presented in Garfinkel and Skaperdas (2000) as it makes no assumption regarding prior commitments to less costly bargaining solutions by the parties. See Anbarci et al. (2002) for a discussion of alternative bargaining solutions that do make such an assumption.

[7] This assumption departs from McBride and Skaperdas (2010) who assume that resources destroyed in conflict in one round of interaction reappear in subsequent rounds of interaction. Since these resources now remain destroyed, the likelihood of conflict is lower in our model.

(3)

$$EV_{i,j} = n\left[Y[1-\phi]\left(\frac{a_{i,j}}{a_{i,j} + a_{j,i}}\right)\right] - a_{i,j}, \phi \in (0,1), n \in (1,\infty).$$

When conflict's destruction costs are arms-independent, *i* therefore cooperates when:

(4.1)

$$n\left[Y\left(\frac{a_{i,j}}{a_{i,j} + a_{j,i}}\right) - a_{i,j}\right] > nY\left(\frac{a_{i,j}}{a_{i,j} + a_{j,i}}\right)[1-\phi] - a_{i,j}.$$

This is when:

(4.2)

$$Y > \frac{(n-1)\left(a_{i,j} + a_{j,i}\right)}{n\phi}.$$

j's decision is symmetric. So (4.2) characterizes when he cooperates too.

Examining (4.2) we find that the destructiveness parameter is positively related to the likelihood of cooperation. The number of rounds of interaction is negatively related to the likelihood of cooperation. And, crucially, arms levels are negatively related to the likelihood of cooperation. The more parties invest in arms, the more likely they are to conflict.

The reason for this result stems from this model's assumption that conflict's destruction costs are arms-independent. Fighting with fists destroys as many resources as fighting with tanks and missiles. So conflict's destruction cost is the same no matter how many resources parties invest in arms as long as those investments are positive. Higher arms levels have no effect on conflict's cost. But they have a positive effect on cooperation's cost. When parties' arms levels are higher, an armed peace is more expensive. Thus higher arms levels make conflict more likely.

It's useful to see how adding a price scalar to arms may influence parties' decisions to cooperate or conflict when conflict's destruction costs are arms-independent. Consider a price scalar of arms $w > 0$. This price is the same for both parties.

Now if the parties cooperate, *i* earns:

(5)

$$EV_{i,j} = n\left[Y\left(\frac{a_{i,j}}{a_{i,j} + a_{j,i}}\right) - wa_{i,j}\right], n \in (1, \infty).$$

And if the parties conflict, *i* earns:

(6)

$$EV_{i,j} = n\left[Y(1-\phi)\left(\frac{a_{i,j}}{a_{i,j} + a_{j,i}}\right)\right] - wa_{i,j}, \phi \in (0,1), n \in (1, \infty).$$

Thus the parties cooperate when:

(7.1)

$$n\left[Y\left(\frac{a_{i,j}}{a_{i,j} + a_{j,i}}\right) - wa_{i,j}\right] > nY\left(\frac{a_{i,j}}{a_{i,j} + a_{j,i}}\right)[1-\phi] - wa_{i,j}.$$

This is when:

(7.2)

$$Y > \frac{(n-1)(a_{i,j} + a_{j,i})w}{n\phi}.$$

Examining (7.2) we find that the price parameter is negatively related to the likelihood of cooperation. This result stems from the influence that cheaper arms have on the price of an armed peace. When arms are cheaper, the relative price of an armed peace is lower. Cheaper arms therefore improve the likelihood of cooperation.[8]

This result illustrates the crucial difference between the demand for arming and the demand for conflict. Previous papers in the conflict literature (see Hirshleifer 1995, McBride

[8] We do not examine the secondary effects of this price scalar on the demand for arms. Since the demand for arms is negatively associated with its price, it is possible that a large enough scalar would sufficiently lower demand to negate the destructive cost of conflict we describe below. We consider this a fringe result, however, as the material cost of arming decreases with technological advancement and therefore the focus of our model—where destructive costs must be balanced against arms investment—would inevitably come into play. For a detailed account of technological advancement as it pertains to arming, see Rotte and Schmidt (2003).

and Skaperdas 2006) depict the relationship between the price of arms and the quantity of conflict as negative.[9]

Yet, the standard demand-curve relationship only applies of necessity to the relationship between the price of arms and quantity of arms demanded. It does not necessarily imply a corresponding negative relationship between the price of arms and the quantity of conflict demanded, unless the only constraint to conflict is the cost of arming.

When persons choosing conflict must not only reckon with the cost of arms but the cost of destruction as well, then it no longer follows that a decrease in the price of arms inevitably triggers more conflict.

Chang and Luo (2013) pursue this line of thought extensively with a model depicting various endogenous relationships between arms and destruction. For example, by assuming that resource destruction is an increasing function of arms investment, they find that cooperation dominates conflict once the cost of destruction outweighs the opportunity cost of an armed peace.[10]

Our purpose is to better understand how these costs map into the decision to engage in conflict. As we demonstrate in the next section—and later, test experimentally—how one models the relationship between these costs and the gains under conflict largely determines the likelihood of conflict's occurrence.

2.3 Arms-Dependent Destruction Costs

In this section we modify the foregoing model of conflict in one critical way: we permit conflict's destruction costs to be arms-dependent. We do this by connecting the destructiveness parameter, ϕ, to the level of arms parties choose to invest in, a_i and a_j. Now how much of the contested resource conflict destroys depends on parties' arms levels. Specifically, we assume that resource destruction in the event of conflict is given by $\phi(a_i + a_j)$.

If the parties cooperate, i earns the same as in (2). But if the parties conflict, i now earns:

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[9] A similar placement of the scalar w into the model presented in McBride and Skaperdas (2010) would, like our model, result in a positive relationship between the price of arms and conflict. The authors do not comment upon this implicit outcome.

[10] Again, Amegashie and Runkel (2012) provide one such input to these destruction costs: the notion of revenge. If the desire for revenge is relatively elastic with respect to destruction costs, then an escalation of conflict can ensue, further damaging the contested resource. Such a result would only increase the relevance of the framework we develop in Section 2.3.

$$EV_{i,j} = n\left[Y\left[1-\phi\left(a_{i,j} + a_{j,i}\right)\right]\left(\frac{a_{i,j}}{a_{i,j} + a_{j,i}}\right)\right] - a_{i,j}, \phi \in (0,1), n \in (1,\infty), 1 \geq \phi\left(a_{i,j} + a_{j,i}\right). \tag{8}$$

When conflict's destruction costs are arms-dependent, the parties therefore cooperate when:

$$n\left[Y\left(\frac{a_{i,j}}{a_{i,j} + a_{j,i}}\right) - a_{i,j}\right] > nY\left(\frac{a_{i,j}}{a_{i,j} + a_{j,i}}\right)\left[1-\phi\left(a_{i,j} + a_{j,i}\right)\right] - a_{i,j}. \tag{9.1}$$

This is when:

$$Y > \frac{(n-1)}{n\phi}. \tag{9.2}$$

j's decision is symmetric. So (9.2) characterizes when he cooperates too.

Examining (9.2) we find that, as in (4.2), the destructiveness parameter is positively related to the likelihood of cooperation. Further, the number of rounds of interaction is negatively related to the likelihood of cooperation.

However, unlike in (4.2), in (9.2) higher arms levels are no longer correlated with an increase in the likelihood of conflict. Here, arms levels have both a conflict-enhancing and cooperation-enhancing effect on the costs of conflict. The conflict-enhancing effect that higher arms investments have on the cost of an armed peace in the previous model—where conflict's destruction costs are arms-independent—is "cancelled out" by the cooperation-enhancing effect that higher arms investments have on conflict's cost in this model where conflict's destruction costs are arms-dependent. The reason for this "cancelling" is simple: when destruction costs are arms-dependent, conflict with higher arms levels destroys more resources. This mutes the effect that higher arms levels have on the price of an armed peace. Compared to the previous model with arms-independent destruction costs, this model with arms-dependent destruction costs predicts greater scope for cooperation.

It's useful to see how adding a price scalar to arms may influence parties' decisions to cooperate or conflict when conflict's destruction costs are arms-dependent. If the parties cooperate, *i* earns the same as in (5) above. But if the parties conflict, *i* earns:

(10)

$$EV_{i,j} = n\left[Y\left[1-\phi\left(a_{i,j}+\ a_{j,i}\right)\right]\left(\frac{a_{i,j}}{a_{i,j}+\ a_{j,i}}\right)\right]-wa_{i,j},$$
$$\phi\in(0,1), n\in(1,\infty), 1\geq\ \phi\left(a_{i,j}+\ a_{j,i}\right).$$

Thus the parties cooperate when:

(11.1)

$$n\left[Y\left(\frac{a_{i,j}}{a_{i,j}+\ a_{j,i}}\right)-wa_{i,j}\right]>nY\left(\frac{a_{i,j}}{a_{i,j}+\ a_{j,i}}\right)\left[1-\phi\left(a_{i,j}+\ a_{j,i}\right)\right]-wa_{i,j}.$$

This is when:

(11.2)

$$Y>\frac{(n-1)w}{n\phi}.$$

Examining (11.2) we find that *w* has the same effect on cooperation as (7.2). The price parameter is negatively related to the likelihood of conflict.[11] Thus, when arms are cheaper, cooperation is more likely. In this model, however, where conflict's destruction costs are arms-dependent, we may apply a different interpretation to this result than we did in the previous model where conflict's destruction costs are arms independent. That interpretation is this: when arms are cheaper, individuals invest in more of them. So, when conflict occurs, there's more destruction. That makes conflict more costly. This, in turn, encourages individuals to cooperate.

[11] Note that we assume that the specific arms bought do not change with the price parameter. In other words, more expensive arms are assumed to be no more destructive than cheaper arms. Instead, we use the price parameter strictly as a proxy for scarcity of arms. An interesting extension of our model would make room for heterogeneity in the choice of weapons. We thank an anonymous referee for this insight into our model.

3 Experimental Design

3.1 Experimental Parameters

We test the models developed above experimentally using four treatments. These treatments fall into two sets. In one set, conflict's destruction costs are arms-dependent. In the other, conflict's destruction costs are arms-independent.[12]

Our first treatment, *PRIME*, experimentally tests our model of conflict with arms-dependent destruction costs—the model in Section 2.3. Here subjects compete over a resource worth E$100 in repeated rounds of interaction. In Round 1 they make two decisions. First they decide what level of arms to invest in. Next they decide whether to "Cooperate" or "Conflict."[13]

We randomly pair subjects in eight matches using a computer program. This pairing changes every match. Before each match we provide each subject with an endowment of E$50 to compensate for potentially negative earnings. The number of rounds in which a pair of subjects interacts is randomly determined according to the fixed continuation probability of 0.75. Subjects are aware of this.

In Round 1 subjects choose to purchase between 0 and 5 arms units. Each unit costs a subject $E10. Subjects are then informed about the arms level that the other member of their pair has chosen. Next, subjects choose to cooperate or conflict.

Both subjects must choose to cooperate for cooperation to occur. A decision to cooperate carries forward into all subsequent rounds of interaction. If a pair of subjects cooperates in Round 1, in every round of interaction subject *i* earns a share of the contested resource's value (E$100), P_i, where P_i depends on his relative arms strength such that

$$P_i = \frac{a_i}{a_i + a_j},$$

less the cost of his arms purchases, a_i.

If a pair of subjects conflicts in Round 1, each arms unit either subject has purchased permanently destroys E$10 of the contested resource and thus reduces the contested resource's

[12] We borrow language from instructions presented in Lacomba et al. (2013). See the experiment instructions in the appendix.

[13] We use less provocative language in our instructions, such as "Option A" and "Option B" in place of "Cooperate" and "Conflict." See the experiment instructions in the Appendix.

total value by E$10*$(a_i + a_j)$ for each round of interaction. The conflict's winner and loser is decided in Round 1 by computer software programmed to determine the winner according to subjects' relative arms strengths where P_i is i's probability of victory. A decision to conflict carries forward into all subsequent rounds of interaction. So does the winner's and loser's identity from Round 1.

In Round 1 a conflict's winner earns the total value of the undestroyed resource, less his arms expenditures. In all subsequent rounds he earns the total value of the undestroyed resource. In Round 1 a conflict's loser earns zero, less his arms expenditures. In all subsequent rounds he earns zero.

3.2 Treatment Comparisons

We use three comparison treatments to isolate the effects of (1) making conflict's destruction costs arms-independent and (2) altering the price of arms on subjects' decisions to "Cooperate" or "Conflict." Together with our benchmark treatment, these comparison treatments form a box design presented in Table 1.

Table 1. Experiment Box Design

	Arms-Dependent Destruction Costs	Arms-Independent Destruction Costs
Low Arms Price	*PRIME*	*BASE*
High Arms Price	*PRIME PRICE*	*BASE PRICE*

In our first comparison treatment, *BASE*, we isolate the effect of disconnecting conflict's destruction costs from arms levels on subjects' decisions to cooperate or conflict. *BASE* follows the use of the destructiveness parameter in conventional models of conflict where conflict's destruction costs are arms-independent. It tests the model of conflict in Section 2.2. Thus this treatment follows *PRIME* with one modification. The value of the contested resource that conflict destroys is the same regardless of how many arms units subjects purchase. Conflict always destroys E$10 of this resource.

In our second and third comparison treatments, *PRIME PRICE* and *BASE PRICE*, we isolate the effect of changing the price of arms on subjects' decisions to cooperate or conflict. To do so we increase the price of arms units from E$10, their price in *PRIME* and *BASE*, to E$30. Thus *PRIME PRICE* is the same as *PRIME* and *BASE PRICE* is the same as *BASE* except that arms units cost E$30 in the "Price" treatments instead of E$10.

In our "Price" treatments it's possible for subjects to incur negative earnings for the match. To ensure that earnings in each match are independent, we implemented a rule in all treatments that informed subjects that any negative earnings would automatically be rounded up to zero.[14]

3.3 Procedures

We conducted nine sessions using 108 subjects from the at-large student body at George Mason University. Each session had 12 participants who participated in only a single session of this experiment. We seated subjects at visually isolated computer terminals where they interacted anonymously with other subjects. Sessions lasted approximately two hours including 25 minutes of instructions.

Subjects received instructions about how to participate in the experiment (see the Appendix). This was followed by a quiz of seven questions about how the experiment works to ensure subjects' understanding of the experimental procedures. Subjects received $7 for showing up on time in addition to what they earned in the experiment. Average earnings without the show-up payment were $20.97. We paid earnings privately at the experiment's conclusion.

In each session subjects participated in eight matches. And in each session we implemented two treatments. We implemented the first treatment in Matches 1 through 4. We implemented the second treatment in Matches 5 through 8.

To mitigate the end-game effects of a necessarily finite experiment, we didn't disclose the total number of matches to subjects. We used a within-treatment design where each treatment was conducted alongside its most closely related counterpart (i.e. *PRIME PRICE* with *PRIME* and *BASE PRICE* with *BASE*). This minimized the number of design changes within each

[14] Negative earnings occurred approximately 30% of the time in the *BASE PRICE* and *PRIME PRICE* treatments, ranging from 20.83% to 47.92%. Subjects were not informed if they received negative earnings in a given period. They simply received a $0 in earnings. We also ran a Probit regression to determine whether negative earnings had an effect on their subsequent choice to engage in conflict; that is, whether knowing that their earnings would be rounded up to zero caused them to make riskier decisions. We fail to reject the hypothesis that acquiring negative earnings had no influence on their subsequent conflict decision at the 95% confidence level (p-value = 0.073). Still, given the relatively low p-value, we do not rule out altogether the influence this may have had in instigating greater levels of conflict in our *PRICE* treatments.

session, reducing the cognitive burden imposed on our subjects. We randomized the order of treatments across sessions. Table 2 summarizes the ordering of treatments conducted for each session.

Table 2. Treatment Order by Session	
Session 1	*Prime:Prime Price*
Session 2	*Prime:Prime Price*
Session 3	*Prime:Prime Price*
Session 4	*Prime Price:Prime*
Session 5	*Prime Price:Prime*
Session 6	*Base Price:Base*
Session 7	*Base Price:Base*
Session 8	*Base:Base Price*
Session 9	*Base:Base Price*

4 Hypotheses

The competing models of conflict developed in Section 2 deliver competing predictions about the likelihood of cooperation and conflict. Together with the parameters our experimental treatments use, these models form the basis of our hypotheses for our experimental tests.

In *PRIME* our parameters are:

$$Y = 100, n = 4, w = 10, \phi = .10.$$

Plugging these parameters into (11.2) from above yields:

$$100 > \frac{(4-1)10}{4(.10)}.$$

Thus *PRIME* generates a cooperative equilibrium for all arms strategies. Table 3 presents the outcomes predicted for each possible combination of arms levels and conflict decision. Each of these outcomes reflects the Pareto-optimal strategy for each subject. In this and the following figure we italicize the subgame perfect equilibria.

Table 3. Expected Outcomes in *PRIME* and *PRIME PRICE*

		PRIME				*PRIME PRICE*			
		Player 1		Player 2		Player 1		Player 2	
Player 1 Arming Level	Player 2 Arming Level	*Coop*	*Conf*	*Coop*	*Conf*	*Coop*	*Conf*	*Coop*	*Conf*
0	0	200	200	200	200	200	200	200	200
	1	0	0	360	350	0	0	280	330
	2	0	0	320	300	0	0	160	260
	3	0	0	280	250	0	0	40	190
	4	0	0	240	200	0	0	-80	120
	5	0	0	200	150	0	0	-200	50
1	0	360	350	0	0	280	330	0	0
	1	160	150	160	150	80	***130***	80	***130***
	2	93	83	187	167	13	63	27	127
	3	60	50	180	150	-20	30	-60	90
	4	40	30	160	120	-40	10	-160	40
	5	27	17	133	83	-53	-3	-267	-17
2	0	320	300	0	0	160	260	0	0
	1	187	167	93	83	27	127	13	63
	2	***120***	100	***120***	100	-40	60	-40	60
	3	80	60	120	90	-80	20	-120	30
	4	53	33	107	67	-107	-7	-213	-13
	5	34	14	86	36	-126	-26	-314	-64
3	0	280	250	0	0	40	190	0	0
	1	180	150	60	50	-60	90	-20	30
	2	120	90	80	60	-120	30	-80	20
	3	80	50	80	50	-160	-10	-160	-10
	4	51	21	69	29	-189	-39	-251	-51
	5	30	0	50	0	-210	-60	-350	-100
4	0	240	200	0	0	-80	120	0	0
	1	160	120	40	30	-160	40	-40	10
	2	107	67	53	33	-213	-13	-107	-7
	3	69	29	51	21	-251	-51	-189	-39
	4	40	0	40	0	-280	-80	-280	-80
	5	18	-22	22	-28	-302	-102	-378	-128
5	0	200	150	0	0	-200	50	0	0
	1	133	83	27	17	-267	-17	-53	-3
	2	86	36	34	14	-314	-64	-126	-26
	3	50	0	30	0	-350	-100	-210	-60
	4	22	-28	18	-22	-378	-128	-302	-102
	5	0	-50	0	-50	-400	-150	-400	-150

In *PRIME* the subgame perfect equilibrium occurs when both subjects invest in two units of arms. This equilibrium is cooperative. Thus, while it behooves subject to arm, this doesn't necessitate conflict.

In *PRIME PRICE* we increase the price of arms in *PRIME* from 10 to 30. Plugging these new parameters ($Y = 100, n = 4, w = 30, \phi = .10$) into (11.2) yields:

$$100 < \frac{(4-1)30}{4(.10)}.$$

Thus *PRIME PRICE* generates a conflictual equilibrium for all arms strategies. Table 3 also predicts the outcome for each possible combination of arms levels and conflict decision given PRIME PRICE's parameters. Here the subgame perfect equilibrium occurs when both subjects invest in one unit of arms.

Compared to *PRIME*, subjects invest in fewer arms and engage in more conflict. Notably, increasing the price of arms doesn't increase the price of conflict. It decreases it. The opportunity cost of conflict—armed peace—is lower when the price of arms is higher. Subjects must maintain arms levels under cooperation to sustain an armed peace. But since after only one round of conflict the victor's and the vanquished's identities are permanently established, subjects can "disarm" after only one round of conflict. Compared to *PRIME*, then, where arms are cheaper, *PRIME PRICE* generates more conflict.

BASE uses the same parameters as *PRIME*:

$$Y = 100, n = 4, w = 10, \phi = .10$$

However, here both cooperative and conflictual outcomes are possible. Table 4 predicts outcomes for each possible combination of arms levels and conflict in *BASE* and *BASE PRICE*.

Table 4. Expected Outcomes in *BASE* and *BASE PRICE*

		BASE				*BASE PRICE*			
		Player 1		Player 2		Player 1		Player 2	
		Coop	*Conf*	*Coop*	*Conf*	*Coop*	*Conf*	*Coop*	*Conf*
Player 1 Arming Level	Player 2 Arming Level								
0	0	200	180	200	180	200	180	200	180
	1	0	0	360	350	0	0	280	330
	2	0	0	320	340	0	0	160	300
	3	0	0	280	330	0	0	40	270
	4	0	0	240	320	0	0	-80	240
	5	0	0	200	310	0	0	-200	210
1	0	360	350	0	0	280	330	0	0
	1	160	170	160	170	80	150	80	150
	2	93	110	187	220	13	90	27	180
	3	60	80	180	240	-20	60	-60	180
	4	40	62	160	248	-40	42	-160	168
	5	27	50	133	250	-53	30	-267	150
2	0	320	340	0	0	160	300	0	0
	1	187	220	93	110	27	180	13	90
	2	120	160	120	160	-40	120	-40	120
	3	80	124	120	186	-80	84	-120	126
	4	53	100	107	200	-107	60	-213	120
	5	34	83	86	207	-126	43	-314	107
3	0	280	330	0	0	40	270	0	0
	1	180	240	60	80	-60	180	-20	60
	2	120	186	80	124	-120	126	-80	84
	3	80	150	80	150	-160	***90***	-160	***90***
	4	51	124	69	166	-189	64	-251	86
	5	30	105	50	175	-210	45	-350	75
4	0	240	320	0	0	-80	240	0	0
	1	160	248	40	62	-160	168	-40	42
	2	107	200	53	100	-213	120	-107	60
	3	69	166	51	124	-251	86	-189	64
	4	40	140	40	140	-280	60	-280	60
	5	18	120	22	150	-302	40	-378	50
5	0	200	310	0	0	-200	210	0	0
	1	133	250	27	50	-267	150	-53	30
	2	86	207	34	83	-314	107	-126	43
	3	50	175	30	105	-350	75	-210	45
	4	22	150	18	120	-378	50	-302	40
	5	0	***130***	0	***130***	-400	30	-400	30

The subgame perfect equilibrium for *BASE* occurs when both subjects invest in the maximum number of arms units. This equilibrium is conflictual. Conflict's destruction costs are arms-independent. Thus conflict's cost is lower than it is in *PRIME*. The result is more conflict.

Finally, in *BASE PRICE* we increase the price of arms in *BASE* to 30. Table 4 also predicts outcomes using this treatment's parameters. Here the subgame perfect equilibrium occurs when both subjects invest in three units of arms. This equilibrium is conflictual. Compared to *BASE*, the higher price of arms here makes an armed peace more expensive. This promotes more conflict compared to *BASE*. Further, conflict's destruction costs are arms-independent here. This promotes conflict compared to *PRIME*.

The foregoing analysis delivers four hypotheses:

H1: Conflict's incidence will rank by treatment *BASE PRICE>BASE>PRIME PRICE>PRIME*.

H2: Arms investments will rank by treatment *BASE>BASE PRICE> PRIME>PRIME PRICE*.

H3: In *PRIME* and *PRIME PRICE* arms levels and cooperation will be uncorrelated.

H4: In *BASE* and *BASE PRICE* arms levels will be negatively correlated with cooperation.

5 Experimental Results

Table 5 presents the basic results of our experimental investigation.

Table 5. Summary of Experimental Results

Treatment	# of subjects	# of times conflict chosen	Average arms level	# of subjects who chose conflict only	# of subjects who chose conflict at least once
PRIME	60	90 (37.5%)	3.03	7 (11.7%)	41 (68.3%)
BASE	48	139 (72.4%)	3.85	21 (43.7%)	46 (95.8%)
PRIME PRICE	60	132 (55%)	1.99	14 (23.3%)	51 (85%)
BASE PRICE	48	134 (69%)	2.65	15 (31.3%)	47 (97.9%)

Result 1: When conflict's destruction cost is arms-dependent, there's less conflict.

Conflict is least frequent in *PRIME*, followed by *PRIME PRICE*, *BASE*, and *BASE PRICE*. We further compared the treatments using a series of nonparametric Wilcoxon rank sign tests. We firmly reject the null hypothesis that *PRIME* and *PRIME PRICE* display equal occurrences of conflict (z = 3.345, p-value = 0.0008). We also firmly reject the null hypothesis that *PRIME* and *BASE* display equal occurrences of conflict (z = 4.623, p-value = 0.0000).

This follows our predictions fairly closely, with the minor exception of *BASE* and *BASE PRICE*, which are indistinguishable (z = 0.773, p-value = 0.4395). Comparing *PRIME* and *BASE*, we find that the number of subjects who exclusively choose conflict nearly quadruples in percentage terms when the link between conflict's destruction costs and arms investments is severed.

Result 2: When the price of arms is higher, arms levels are lower.

Arms levels are lowest in *PRIME PRICE*, followed by *BASE PRICE*, *PRIME*, and *BASE*. This follows our predictions with the exception of *BASE PRICE*, which more closely follows its counterpart, *PRIME PRICE*, than predicted.

Result 3: When conflict's destruction cost is arms-dependent, arms levels and cooperation are uncorrelated.

To investigate how arms levels are related to subjects' decisions to cooperate or conflict we performed a Probit regression analysis of our results. In each session each subject makes eight decisions about whether to "Cooperate" or "Conflict." Four of these decisions occur in each of the two treatments tested in each session. If a subject chooses to conflict, we code this as a "1." If the subject chooses to cooperate, we code this as a "0." To create our dependent variable we average each subject's four decisions in each treatment.

We group our data by pooling *PRIME* with *PRIME PRICE* and *BASE* and *BASE PRICE*. The first Probit regression considers *PRIME* and *PRIME PRICE*. It estimates the effect of average arms levels by subject and a dummy for treatment comparison on the subsequent choice of conflict or cooperation. Consider Table 6.

Table 6. Results of Probit Test: *PRIME* and *PRIME PRICE*

Observations: 120

Variable	p-value	Coefficient	SE	df/dx
Arms Level	0.981	0.003	0.134	0.001
Treatment Dummy (Prime Price=1, Prime=0)	0.058	0.563	0.297	0.168

In the "Prime" treatments the coefficient on *Arms Level* is nearly zero and statistically insignificant. *Arms Level* has no effect on subjects' decisions to cooperate or conflict (see footnote 4).

Result 4: When the price of arms is higher, there's more conflict.

In the "Prime" treatments the coefficient on the *Treatment Dummy* is sizable and statistically significant. When arms are cheaper, subjects cooperate more. Going from *PRIME*, where arms cost $E10, to *PRIME PRICE*, where they cost $E30, increases the probability of conflict by more than 56 percent.

Result 5: When conflict's destruction cost is arms-independent, arms levels are negatively correlated with cooperation.

We analyze how arms levels are related to subjects' decisions to cooperate or conflict in *BASE* and *BASE PRICE* in the same manner that we do for *PRIME* and *PRIME PRICE* above. Consider Table 7.

Table 7. Results of Probit Test: *BASE and BASE PRICE*

Observations: 96

Variable	p-value	Coefficient	SE	df/dx
Arms Level	0.056	0.468	0.244	0.017
Treatment Dummy (Base Price=1, Base=0)	0.172	0.898	0.658	0.037

In the "Base" treatments the coefficient on *Arms Level* is sizable and statistically significant. *Arms Level* has a positive effect on subjects' decisions to conflict. Each additional unit of arms purchased increases the probability that a subject chooses conflict nearly 50 percent. The *Treatment Dummy* is positive but statistically insignificant. Arms prices are unrelated to subjects' decisions to cooperate or conflict.

Result 6: Establishing/severing a connection between arms investments and conflict's destruction cost has a larger effect on the prevalence of conflict than changing the price of arms.

To see which feature of our experiment is the more important determinant of whether subjects choose to cooperate or conflict—establishing/severing the connection between conflict's destruction costs and arms investments or changing the price of arms—we perform t-test comparisons.

A t-test comparison of the decision to cooperate or conflict in *PRIME* versus *PRIME PRICE* produces a mean difference of 17.08 percent. Compared to when arms cost $E30, when arms cost $E10, cooperation increases by approximately 17 percent. A t-test comparing the decision to cooperate or conflict in *PRIME* versus *BASE* produces a mean difference of 32.29 percent. Compared to when conflict's destruction costs are arms-independent, when those costs are arms-dependent, cooperation increases by nearly a third.

6 Conclusion

Violent conflict's destruction costs are a central aspect of its total cost. The more resources conflicting parties devote to "arms"—the tools of conflict—the more destructive conflict becomes. By ignoring this dependence and instead treating conflict's destruction cost as exogenous, conventional models of conflict imply that fights with fists are as destructive as fights with tanks and missiles. This has important ramifications for what conventional models predict about the likelihood of conflict. By rendering conflict cheaper than it really is, existing models significantly overpredict the probability of conflict.

In this paper we developed two models of conflict—one in which conflict's destruction costs are arms-independent and another in which those costs are arms-dependent—to show this. Our model with arms-independent destruction costs predicts more conflict than our model with arms-dependent destruction costs.

An experimental test of these models supports our theoretical predictions. In treatments where conflict's destruction costs were severed from subjects' arms investments, subjects engaged in substantially more conflict. In treatments in which conflict's destruction costs were linked to subjects' arms investments, subjects engaged in substantially more cooperation. Further, our experimental investigation demonstrated that when arms became cheaper, subjects cooperated more rather than less. This is consistent with the idea that when arms are less expensive, individuals invest more in them, making conflict more destructive when it occurs. The higher destructive costs of conflict that result encourage individuals to cooperate more.

These findings highlight the importance of unpacking the destructiveness parameter in models of conflict. In our arms-dependent model of conflict and corresponding experimental test, the destruction conflict creates interacts with individuals' arms investments. This is an advance over conventional models of conflict where there's no such interaction. However, our model's characterization of conflict's destruction cost, and thus the inferences one can draw from our experimental investigation, remains limited. In our model and experimental test, the destructive parameter itself remains exogenous. Future work should endogenize conflict's destruction cost fully by endogenizing the destructiveness parameter—i.e., characterizing ϕ as function of individuals' arms investments and perhaps other variables.

Our results suggest that in natural environments, where conflict's destruction costs are indeed linked to individuals' investments in the tools of conflict, cooperation is more likely than conventional models of violent conflict predict. Future research incorporating that link more fully therefore promises to deliver more refined insights about the prevalence of cooperation vs. conflict in natural environments.

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