Proposing peace to belligerents with interdependent valuations

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This article investigates the efficiency of alternative forms of resolving disputes between two parties that are uncertain about the cost of war and win probability. We measure efficiency of peace promoting mechanisms by the *ex ante* probability of peaceful resolution of dispute. We present a model of bilateral conflict for opponents with private types that incorporates interdependent valuations and endogenously determined outside option. We show that there exists a best separating Bayesian equilibrium for the game induced by a cheap talk mechanism with partial disclosure of private types. We find the set of parameter values for which this peace talk game improves chances for peace upon the split proposal game.

1 Motivation

In this paper we examine the effect of interdependent ex ante valuations of the war outcome on the probability of peaceful resolution for bilateral conflicts. In many disputes that arise in practice, interdependent valuations are a more realistic assumption than private valuations. Typically, any state has a privately known fighting capacity and incomplete information about the value of winning an interstate war. Each of belligerents' fighting capacity affects both the relative balance of power and the prize for the prospective winner. Another setting where parties' valuations of winner's prize are interdependent is a litigation. The plaintiff and the defendant have private information about the expected judgement in a trial and the cost of obtaining it. The sources of asymmetric information that affects the expected judgement can be for instance "first-hand knowledge of the level of damage" which the plaintiff is suffering from, "first-hand knowledge of the level of involvement" in the accident for the defendant, the credibility of own witnesses, the quality of own layers etc. (see the discussion in [17]). The inefficiency of resolution methods for private disputes may result in costly trials. Out-of-court settlement of private civil disputes is in the interest of the society because litigation is wasteful: expensive, time consuming, and disturbing for the parties involved. This is one of the reasons for which overwhelming majority of filled cases in the US (see Langbein (2012)) are resolved through private dispute resolution mechanisms, in "the shadow of trial", in the same manner in which interstate disputes are settled in "the shadow of war".

To understand how the total cost resulting from interstate wars might be related to the fighting capacities of belligerents, we analyse data about the period 1816-2007. We use estimates of battle deaths in interstate wars provided by Meredith Sarkees and Frank Wayman in [24]. We also use data on states' fighting capacities that are assembled by Singer et al. in [25] and

expanded by Singer in [26] in the 4.0 version of the dataset. It contains the indicator Composite Indicator of National Capability (CINC) which is based on six components: the population size, total urban population, total steel and iron production, total primary energy consumption, total military personnel, and total military budget. We assume that the total cost of war is proportional to the human cost of war. The human cost of war comes in many forms. Weisiger emphasizes in [29] challenges posed by using war deaths data. Records of war related deaths are imprecise or unavailable, particularly for deaths that are not directly related to battlefields. Civilian fatalities in wars depend not only on the military strength of opponents but also on the autonomous government policy, such as civilian protection or genocide. Policy related civilian deaths might not be reported and might not be proportional to battlefield deaths. Given the concerns about quality of data, our study focuses on battle-related combatant fatalities as a measure of the human cost of war.

We argue that inter-state wars, where the aggregate fighting capacities of the two sides in the conflict are close to parity, generate higher cost than inter-state wars where there are significant disparity between belligerents. In order to test our theoretical expectation, we consider a model in which the dependent variable is the percentage of battle deaths in the total toll for the period 1816-2007. Some of these wars have been waged between military coalitions. Two of the independent variables in our analysis are the total CINC values for opponents on the two sides in the conflict, measured in the year preceding the outbreak of the war. We contend that a greater number of countries involved in a war is likely to increase the intensity of battles and the death toll. We use this number as an indicator of the scale of the conflict.

We find empirical support for these two predictions using observations about 94 inter-state wars[1]. Table in Appendix A shows the results of linear regression models that predict battle-related fatalities in inter-state wars for the period 1816-2007. The model results are consistent with our expectations about the determinants of the number of battle-related fatalities. In particular, the sum of fighting capacities alone explains less than 39% of the variation of the dependent variable while the product of fighting capacities alone explains more than 80% of this variation. Model 4 tests our hypotheses while controlling for two other determinants of battle-related fatalities: the sum of fighting capacities and the number of countries engaged in the war. According to estimates, the sum of fighting capacities has a negative

[1]We exclude from our sample the observations about the Chaco War (1932 -1935) fought between Bolivia and Paraguay. The national fighting capacities of the two countries at the time do not correspond to the resources used in this war. The Chaco War has been financed by Royal Dutch Shell backing Paraguay and Standard Oil supporting Bolivia. See 'The Chaco War: Bolivia and Paraguay', 1932-1935 by B.W. Farcau, (1996), Praeger.

Table 1: Outcomes of interstate wars for the period 1816-2007

Type	Frequency	Fraction
Higher CINC side wins	49	.52
Lower CINC side wins	28	.30
Stalemate	8	.08
Tie	2	.02
Transformed	8	.08

impact on the dependent variable. This result suggests that the death toll is relatively higher for wars between low capacity belligerents, where the difference in the fighting capacities is relatively lower.

The degree to which fighting capabilities of contestants are a noisy predictor of the war outcome is captured by the probability of win for the side with stronger capacity. The dataset provides a classification of the outcome of wars in 5 types. For example, in 49 wars the winner is the side with higher aggregate CINC value. Part of inter-state wars transform into intra-state or extra-state wars, for example when a state withdraws from an inter-state war, leaving one state in continuing combat with a non-state actor. Calculations in Table (1) show that the total number of interstate wars that have ended by one side winning is 77. Among these conflicts with decisive outcome, the percentage of wars for which belligerents with higher aggregate fighting capacities win is about 63%. This fraction is significantly lower than one and suggests a high level of uncertainty about the probability of win for the stronger opponent.

In following paragraphs we study a model of bilateral conflict in which the outside option is waging war and the uncertain prize is proportional to the product of the privately known fighting capacities of opponents. The aim of this model is to provide specification of the relationship between the conflict resolution method and the probability to avoid an inefficient outcome.

2 Results

The efficiency of peace promoting mechanisms in our model of conflict is measured by the ex ante probability of a peaceful settlement. We describe the set of Bayesian-Nash equilibria in the *crisis bargaining game* for two types of settlement procedures: a split proposal game and unmediated communication between parties. We provide an answer to the following question: For which type of conflicts a cheap talk mechanism increases the ex ante probability of peace compared to the split proposal game without communication?

The paper is organized as follows. Section 3 provides references to related

research on conflict resolution methods and on general assumptions employed in the design of optimal mechanisms in the case of interdependent valuations. In section 4 we present a model of conflict in which the loss of welfare in the case of war is proportional to the product of the private types of opponents. Section 5 provides estimates for the *ex ante* probability of peace in the case of exogenous split proposal and lack of communication between players. For example, under the assumption of common knowledge of parameters estimated in Section 1 for interstate wars, we find the upper bound for the probability of achieving peace by a split proposal mechanism to be 0.53. In Section 6 we construct a Bayesian incentive compatible and *ex post* individually rational peace talks mechanism. We describe the optimal unmediated cheap talk mechanism with partial disclosure of types from the perspective of a designer who maximizes the *ex ante* probability of peace. We provide the set of parameter values for which this cheap talk mechanism increases the ex ante probability of peace compared to the split proposal game without communication. The final section discusses some limitations of our approach. We suggest a type of mediation programme that might improve the chances for peaceful resolution over the unmediated communication in our model of conflict.

3 Related literature

The class of models that is central to current thinking about an international dispute between states is games with two-sided incomplete information. At any stage of negotiations each party can withdraw unilaterally and take up its war payoff. The theoretical literature on international conflict reveals the role of private beliefs of involved parties about the war payoff structure in the shaping of any settlement available through some peaceful process. The literature points out (see [11] by Garfinkel and Skaperdas (2007)) that the outcome of a military conflict between two parties is subject to much uncertainty. The general assumption is that the only source of vacillation are the probabilities of winning a war for each player, while in practice there are multiple sources of uncertainty. One of them is the value of the prize for the prospective winner. Fey and Ramsey (2011) investigate in [8] crisis bargaining games with two-sided incomplete information where either the relative power of opponents is uncertain or the win probabilities are common knowledge but there is uncertainty about the opponent's fixed cost of war. Authors find that the type of uncertainty that exists in the international environment can have important implications for the probability of war in the equilibrium of these games.

Application of mechanism design to resolution of conflicts was pioneered by Banks (1990), Fearon (1995), Warneryd (2003), Bester and Warneryd (2006), and Fey and Ramsay (2009). These authors study the design of

political and economic institutions to prevent or resolve any type of destructive conflict. A number of processes can be used to resolve a conflict, dispute or a claim. Dispute resolution processes are alternatives to having a war resolve the conflict or handling the dispute in the court system. These processes can be used to resolve conflicts in such areas as interstate relations, family matters, or workplace and contracting practices. Dispute resolution processes are cheaper and usually generate a solution faster than war resolution or litigation. The most common forms of dispute resolution processes are negotiation, mediation, and arbitration. The research on conflict resolution processes focus on conditions under which negotiation or mediation are chosen and the general effectiveness of these processes.

A part of negotiation is bargaining, which has been modelled and extensively studied in the economic literature in both cooperative and non-cooperative setups (extensive surveys are provided e.g. by Muthoo (1999) and by Napel (2002)). The equilibrium settlement is well understood in bargaining situations where parties' disagreement payoffs are common knowledge. In his seminal work on axiomatic bargaining theory, Nash (1950) provides a solution of the two-person bargaining problem where the disagreement payoffs are known to both players. The literature on bilateral bargaining in the environment with two-sided uncertainty about outside options is scarce (see e.g. [23] by Sanchez-Pages (2012)). An usual assumption in this literature is that a negotiator faces more than one candidate to reach an agreement with and an outside option for the negotiator become these alternative opponents and prizes. This is an appropriate model in the context of bilateral trade but certainly not a realistic model for all dispute resolution processes. Fey and Ramsey point out in [8] that for the case of crisis bargaining the "lack of "natural" game form limits the applicability of results derived from any particular choice of game form". The study of bargaining with incomplete information can be conducted in the framework of Bayesian mechanism design rather than modelled by a sequence of offers and counteroffers. The mechanism design provides a tool for characterization of the set of attainable outcomes for any particular environment and determines the optimal method for conflict resolution from the point of view of the designer.

Goltsman, Horner, Pavlov and Squintani (2009) study in [14] all three different classes of communication procedures: arbitration, mediation and negotiation, in the context of the Crawford and Sobel (1982) model of cheap talk with two players, the informed party and the decision-maker. In this setting, authors find that "mediation performs better than negotiation when the conflict of interest is intermediate, whereas a mediator is unnecessary and two rounds of communication suffice when the conflict of interest is low". These findings about the potential and the limitations of mediation and negotiations are confirmed by some empirical studies of outcomes of international negotiations and mediations, e.g. by Bercovitch and Jackson (2001). The authors find that parties are less likely to reach an agreement

without mediation when disputes are characterized by "high complexity, high intensity, long duration, unequal and fractionated parties, and where the willingness of the parties to settle peacefully is in doubt" [4]. Rauchhaus (2006) finds that a mediator who provides some information to parties is highly effective and provides an empirical support to the claim that asymmetric information is one of the root causes of war. Goltsman et al. pose the question about the relative efficiency of negotiations and mediation beyond the classical framework of Crawford and Sobel's model.

The paper which is closely related to ours is Horner's et al. (2011). In [15] authors study a role of mediation in the case of two parties with interdependent values and show that a mediator improves the probability of peace over direct communication by selectively shaping beliefs of players about the type of opponent. Our environment is more general due to continuous types and endogenously defined cost of war, although the disclosure policy in our mechanisms is restricted to finite set of verifiable types. We assume that the distribution of players' types is *ex ante* symmetric. This model specification is tractable but general enough not to yield any closed form solution for some range of parameter values. In principle, the cause of a peaceful resolution of conflict could be capacity heterogeneity. In the setting of Hoerner's et al. model it is the heterogeneity in *ex ante* expectations of the strength of opponent that softens the conflict and helps for recommendation of the public mechanism to be accepted. The present paper therefore disentangles the impact of types heterogeneity from the impact of uncertainty about the type of opponent and the cost of war.

Classical results about the optimal design of mechanisms in the independent values setting do not extend automatically to the interdependent values setting. In environments with quasilinear utility, independent private values and interdependent valuations, the result by Jehiel and Moldovanu (2001) shows that ex-post efficient social choice rules are not implementable for generic linear valuation functions. In the peace talks setting "payments" to agents can be made in two ways. One is by recommending a more generous share of the object and another is by increasing the probability that a peaceful split will be recommended. However, agents' utilities are not quasi-linear in the recommended share. Roughgarden and Talgam-Cohen (2013) establish in [22] some sufficient conditions under which positive results in the form of incentive compatible and ex post individual rational mechanisms can be obtained for environments with interdependent valuations. In the context of auction design, one restriction on type spaces that many researchers employ is correlation of types (e.g. Cremer and McLean (1985), McAfee and Reny (1992)). Another approach proposed by Mezzetti (2004) in the same context is to consider a two stage mechanism where after the announcement of the allocation agents are still not informed about the type profiles and are asked to report their realised utilities. This solution is not relevant to our setting where the value of the recommended split and

the peace probabilities cannot be disentangled in time.

The idea of including "rent shirking" possibility into a contest mechanism is not new. In [1] authors consider contests in which the size of the prize for the winner is endogenous. The expenditures of contestants in this model lower the value of the prize. The main difference between our models is that we consider a game with incomplete information. In our model the destruction of the prize for the prospective winner is a nonlinear function of the private values of the contestants.

4 The model

Two players contest the ownership of a perfectly divisible asset of common value one. The dispute may lead to a war or litigation. Only a peaceful settlement is efficient. The common value of the war prize is less than one. The probability of winning the war prize is determined by the relative strength of players. The strength t_i of player i in a potential military conflict is a realisation of a random variable that takes values in the interval T. This capacity is privately observed and referred to as type of the player.

Information is incomplete. There is a common prior over the types, with cumulative probability distribution function $F(t)$ on T. This function is symmetric in both arguments and summarizes the prior information of a player about the type of his opponent. Types are assumed to be independently and uniformly distributed and $F(t)$ has full support on $T = [0, 1]$. A uniform distribution of types is consistent with the assumption of lack of knowledge about opponent's type. It is assumed that the probability distribution of types after restricting the support is again uniform. In this symmetric setting players have the same conditional densities but their values may be different.

4.1 The outside option

After players privately observe their own type, an alternative of a peaceful agreement is only unilateral or bilateral initiation of an outright confrontation. The outcome of the confrontation is interpreted as probability of winning the whole prize and not as a split of the prize as in Rubinstein's alternating-offer bargaining game. We denote player i's probability of winning the prize by $p(t_i, t_j)$ and player j's probability of winning by $1-p(t_i, t_j)$. We consider the probability that contestant i gets the prize after his effort level has been exerted and the fighting capability t_i has been obtained. The fighting capability of contestants is a noisy predictor of the outcome of the war or, in a legal context, the litigation. The decision whom to give the prize is determined both by the relative strength of players and by the fair-

ness related type of the decision-making institution or process. The prize lottery faced by each contestant is given by probability measure $p(t_i, t_j)$ on $T \times T$:

$$p(t_i, t_j) = \begin{cases} p & \text{for} \quad t_i > t_j \\ \frac{1}{2} & \text{for} \quad t_i = t_j, \\ 1-p & \text{for} \quad t_i < t_j \end{cases}$$

where $p > 1 - p$, that is, $p > \frac{1}{2}$. Parameter p is interpreted as a degree to which the relative strength of players is a noisy predictor of the award decision. In a legal context, p is interpreted as a degree to which property rights are defined by the relative strength of arguments (see [5] by Bester and Warneryd (2006)). It is assumed that $p < 1$, that is, property rights are not perfectly defined.

We assume that each peaceful settlement is efficient. In order to limit the range of potential settlements that are acceptable by the opponents we assume that they are both risk averse. In the model with win probability $p(t_i, t_j)$, where $t_i > t_j$ and p is the payoff of player i, a peaceful split $(p, 1-p)$ would always be accepted if the relative strength of players was a common knowledge. However, each player has a constant, non decreasing in his type, incentive to misrepresent this type. According to Fey and Ramsay (2009) (see [10]), the combination of uncertainty about the other player's strength in war and the incentive to misrepresent private information has been identified in the literature as a central cause of war. Fearon (1995) points out in [7] that the bargaining might not prevent a war if the prize at stake is indivisible. The indivisible probability $p(t_i, t_j)$ of getting the prize can be considered as an additional war favouring condition to the indivisible prize.

4.2 War payoffs

Both players can take an unilateral action and induce war. Player's payoff from this activity is not known *ex ante*. The uncertainty about this option is twofold. Apart from the uncertainty about the probability of winning the prize, players are uncertain about the cost of conflict. A conflict shrinks the value of the prize. The standard assumption in the literature is that a conflict destroys a fixed part of the initial value (see [5] by Bester and Warneryd (2006) and [28] by Warneryd (2010)). This corresponds to the assumption that the war budget is fixed while in practice it is difficult to translate into financial terms and changes with the opportunity cost of doing something else. Hence, it is reasonable to assume that the loss, due to the overall resources expended, is a function of strengths of players involved in the conflict.

In both military and legal context, it is more costly to pick the winner when

players differ less in their strength. Hence, the lower is the difference, the more destructive is conflict. Additionally, the value of the prize $\theta(t_i, t_j)$ allocated to the winner is decreasing in both players' strength. We assume that the value of the prize $\theta(t_i, t_j)$ allocated to the winner satisfies conditions

$$\theta(t_i, t_j) > \theta(t_i', t_j) \quad if \quad t_i' > t_i, \quad and \quad \theta(t_i, t_j) > \theta(t_i, t_j') \quad if \quad t_j' > t_j.$$

It is easy to check that when the value of the prize depends solely on the difference $t_i - t_j$ in fighting capacities of opponents then for any feasible values of parameters the expected war payoff is sufficiently low for the peaceful split $(1/2, 1/2)$ to be unanimously accepted. That is why we make a more sound assumption that the destruction technology is given by some function

$$\theta(t_i, t_j) = 1 - \alpha t_i \; t_j, \tag{1}$$

where $0 < \alpha < 1$. This choice of technology reflects the observation that for any given distribution of fighting resources t_1 and t_2 a war between players of equal strength is the most destructive. This is the case because for any fixed total resource $S = t_1 + t_2$, the constrained maximum $max_{\{t_1+t_2=S\}}\{t_1 \; t_2\}$ is achieved when $t_1 = t_2$. Besides, a war between stronger opponents shrinks the value (1) more.

5 Welfare analysis for the split proposal game

Consider a designer whose objective is to maximize the *ex ante* probability of peaceful settlement in the Bayesian-Nash equilibria of a split proposal game. This mechanism does not solicit any private information and assumes that players do not communicate. The set of feasible outcomes in the split proposal game represents values of the prize allocated to players. In this paragraph we calculate the *ex ante* probability of peaceful settlement for some range of parameter values.

Definition 1. *The set of feasible outcomes is* $Y = \{(y_1, y_2) : y_1 + y_2 \leq 1\}$. *The set* Y^e *for which* $y_1 + y_2 = 1$ *is called the set of efficient outcomes.*

Players are proposed a split $(x, 1-x) \in Y^e$. At the time of proposal there is no common or private knowledge about the relative strength of players. After observing their own type, players simultaneously choose whether to agree or not to the given split proposal. We assume that no other peace promoting mechanism is available. If some of the players rejects the split then they fight.

A pure strategy $\sigma_i(x, t)$ of player i in the split proposal game specifies one of the two responses, 'accept' or 'reject', for each split proposal and each potential type. The choice criterion of a rational player is the maximization

of expected payoff. He compares the proposal with the conditional probability distribution of his war payoff using the prior probability distribution F. Beliefs of players about war payoffs are formed on the base of both parameters p and α.

The probability that proposal $(p, 1-p)$ or $(1-p, p)$ will be jointly accepted is zero, although with probability 1/2 the value $p > 1/2$ is proposed to the higher type. As we show in subsequent paragraphs, the reason is that $1-p$ is the minimal expected war payoff. Hence, there are no values of p and α for which proposal $(p, 1-p)$ or $(1-p, p)$ leads to voluntary peaceful settlement with positive probability.

Denote by $\pi(t)$ the expected war payoff for any player of type t.

Definition 2. *The assessment* $(x, \sigma_1(x, t_1), \sigma_2(x, t_2), \pi(t_1), \pi(t_2))$ *is a pure strategy Bayesian Nash equilibrium of the split proposal game if*

(i) given the split x, for each player i of type t, the response $\sigma_i(x, t)$ maximises the expected value of the allocated prize, given his belief $\pi(t_i)$,

(ii) for each x, each player's belief $\pi(t_i)$ satisfies Bayes' rule, that is,

$$\pi(t_i) = \int_0^1 p(t_i, t_j)\theta(t_i, t_j)\, dt_j.$$

The following claim is proved in the Appendix.

Proposition 1. *For parameter values satisfying condition $p(1-\alpha/3) \leq 1/2$, the ex ante probability of peace is 1 subject to opponents playing a Bayesian Nash equilibrium of the split proposal game with offer $(1/2, 1/2)$.*

Proposition (1) implies that parameter values for which an equal split proposal might not guarantee any peace satisfy condition

$$p(1 - \alpha/3) > \frac{1}{2}. \tag{2}$$

We will be using the following lemma.

Lemma 1. *Expected war payoff of type t is strictly increasing in t if and only if the parameter values satisfy condition*

$$a \leq \frac{4p - 2}{5p - 2}. \tag{3}$$

Proof: Since types of players are uniformly distributed, the expectation of truncated type t_j is

$$E\{t_j | a < t_j \leq b\} = \int_a^b \frac{t_j}{b - a}\, dt_j.$$

The expected war payoff for any player of type t_1 is given by

$$\pi(t_1) = \int_0^1 p(t_1, t_2)\theta(t_1, t_2)\, dt_2 = \tag{4}$$

$$= \int_0^{t_1} p(1 - \alpha t_1 t_2)\, dt_2 + \int_{t_1}^1 (1-p)(1 - \alpha t_1 t_2)\, dt_2 =$$

$$= 1 - p + \left(-1 - \frac{\alpha}{2} + 2p + \frac{\alpha p}{2}\right) t_1 + \left(\frac{\alpha}{2} - \alpha p\right) t_1^3. \tag{5}$$

We will show that expression (5) is strictly increasing in t_1 for $t_1 \in (0, 1)$ if and only if condition (3) holds.

Note that stationary points of $\pi(t_1)$ satisfy condition

$$\frac{\partial \pi(t_1)}{\partial t_1} = -2 - \alpha + 4p + \alpha p + 3\alpha t^2 - 6\alpha p t^2 = 0. \tag{6}$$

The coefficient in front of the cube of t_1 in expression (5) is negative because $\frac{\alpha}{2} - \alpha p = \alpha(1/2 - p)$ and $p > 1/2$. Moreover, $\pi(t_1)$ tends to $-\infty$ when t_1 tends to ∞ and vice versa. Hence, $\pi(t)$ is a concave function between the two inflection points. Then the negative stationary point $-\sqrt{\frac{4p+\alpha p-\alpha-2}{6\alpha p-3\alpha}}$ of $\pi(t_1)$ corresponds to a local minimum and the positive stationary point $\sqrt{\frac{4p+\alpha p-\alpha-2}{6\alpha p-3\alpha}}$ of $\pi(t_1)$ corresponds to a local maximum. Hence, the expected war payoff $\pi(t_i)$ is increasing for $t_i \in (0, 1)$ if and only if the positive stationary point is no lower than 1. We notice that

$$\frac{4p + ap - a - 2}{6ap - 3a} \geq 1 \Leftrightarrow a \leq \frac{4p - 2}{5p - 2}$$

which concludes the proof.

□

Figure (1) shows two subsets of the set of parameter values for which an equal split proposal might not secure any peace. The blue set represents the class of conflicts where condition (3) holds and the expected war payoff $\pi(t)$ is strictly increasing in t. The yellow subset represents the class of conflicts for which the expected war payoff is non-monotonic in the type of the player.

We call an acceptable split any element from the set of efficient outcomes Y^e that might be accepted with strictly positive probability by both players who observe privately their own type.This set of acceptable splits is denoted by X and can be represented by the share x for player 1 in recommendations. Note that the minimal expected payoff from war is $\pi(0) = 1 - p < \frac{1}{2}$ and the maximal expected payoff from war is

$$\pi(1) = p\left(1 - \frac{\alpha}{2}\right) > \frac{1}{2}.$$

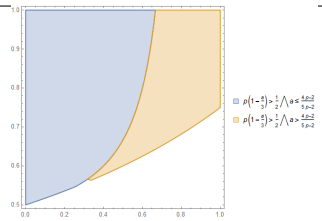

Figure 1: The subsets of values for p and α where the expected war payoff is strictly increasing or non-monotonic in player's type

Hence, by the symmetry of players, the set X is equivalent to the interval $[1-p, p]$.

Hereafter we consider conflicts where an equal split proposal might not secure a peace and where the expected war payoff is monotonic for all types of players, i.e., both conditions (2) and (3) hold. In subsequent paragraphs we assess the *ex ante* probability of peace in the Bayesian Nash equilibrium of the peace proposal game for any split $x \in X$. We shall determine the split proposal which maximizes this chance.

In order to convince the player of type t_i to accept a payoff x we set

$$x \geq \pi(t_i).$$

Denote by $\mathcal{P}(x, 1-x)$ the probability of peace with peaceful split $(x, 1-x)$. This probability is determined by the joint cumulative distribution function of random variables $\pi(t_1)$ and $\pi(t_2)$. These random variables are independent because t_1 and t_2 are independent. Hence, the joint cumulative distribution is a product of marginal distributions. Therefore,

$$\mathcal{P}(x, 1-x) = P(x \geq \pi(t_i) \wedge 1-x \geq \pi(t_j)) = P(x \geq \pi(t_i))P(1-x \geq \pi(t_j)).$$

The following claim is proved in the Appendix.

Proposition 2. *In the Bayesian Nash equilibrium of the split proposal game where condition* (3) *holds, the ex ante probability of peace with equal split is*

$$\mathcal{P}(1/2, 1/2) = -\frac{4}{3} r \sin^2 \left(\frac{\pi}{6} - \frac{1}{3} \arccos \left(\frac{3\sqrt{3} q \sqrt{-\frac{1}{r}}}{2r}\right)\right)$$

where r and q are given by

$$r = \frac{-2 - \alpha + 4p + \alpha p}{\alpha(1-2p)} \quad \textit{and} \quad q = \frac{1}{\alpha}. \tag{7}$$

This result shows that the probability of peace with equal split is lower than $1/2$ for some parameter values. For example, if $(p, \alpha) = (3/4, 1/4)$ then the

probability of peace with equal split is $\mathcal{P} \approx 0.310$, if $(p, \alpha) = (5/6, 1/8)$ then $\mathcal{P} \approx 0.267$, if $(p, \alpha) = (3/4, 1/6)$ then $\mathcal{P} \approx 0.286$.

We will find an upper bound for the probability $\mathcal{P}(x, 1-x)$ for any split proposal. The expected war payoff $\pi(t)$ is nonlinear in t and it seems difficult to calculate its cumulative distribution function. However, by Lemma (1) function $\pi(t)$ is monotonically increasing for $t \in [0, 1]$. Hence, a linear approximation of $\pi(t)$ over the interval $[0, 1]$ is appropriate and has the advantage of being uniformly distributed. By using a linear approximation which provides a lower bound for $\pi(t)$, we prove the following result.

Proposition 3. *The probability of peace $\mathcal{P}(x, 1-x)$ in the Bayesian Nash equilibrium of the split proposal game satisfies inequality*

$$\mathcal{P}(x, 1-x) \leq \frac{(2p-1)^2}{(4p-2-\alpha p)^2} \tag{8}$$

for parameter values that satisfy condition (3).

Proof: Let parameter values satisfy condition (3). Then function $\pi(t)$ is concave for $t \in [0, 1]$ (see the proof of Lemma (1)). Therefore, the linear function $f(t) = At + B$ which satisfies conditions $f(1) = \pi(1) = p(1 - \frac{\alpha}{2})$ and $f(0) = \pi(0) = 1 - p$ provides a lower bound for $\pi(t)$. Then $B = 1 - p$ and $A = p(1 - \frac{\alpha}{2}) - (1 - p) = 2p - 1 - \frac{\alpha p}{2}$.

Hence,

$$f(t) = At + B = (2p - 1 - \frac{\alpha p}{2})t + 1 - p.$$

The distribution of $f(t)$ is defined by the cumulative distribution function

$$F_f(x) = P(f(t) \leq x) = P\left(t \leq \frac{x - B}{A}\right) = \tag{9}$$

$$= P\left(t \leq \frac{x - (1-p)}{2p - 1 - \frac{\alpha p}{2}}\right) = F_t\left(\frac{x - (1-p)}{2p - 1 - \frac{\alpha p}{2}}\right).$$

For example, an upper bound for the probability that a payoff of 1/2 will be accepted in the equilibrium is given by inequality

$$P(1/2 \geq \pi(t)) \leq P(1/2 \geq f(t))$$

where

$$P(f(t) \leq 1/2) = P\left(t \leq \frac{\frac{1}{2} - (1-p)}{2p - 1 - \frac{\alpha p}{2}}\right) = F_t\left(\frac{p - 1/2}{2p - 1 - \frac{\alpha p}{2}}\right) = \frac{2p-1}{4p-2-\alpha p}.$$

Then the upper bound for the probability of peace with equal split is

$$\mathcal{P}(1/2, 1/2) \leq \left(\frac{2p-1}{4p-2-\alpha p}\right)^2 = \hat{\mathcal{P}}(1/2, 1/2).$$

The accuracy of this estimation is exemplified by the upper bounds $\hat{\mathcal{P}}$ for $(p, \alpha) = (3/4, 1/4)$, $(p, \alpha) = (5/6, 1/8)$, and $(p, \alpha) = (3/4, 1/6)$ which are approximately 0.379, 0.294, and 0.327.

Further, we can find the upper bound for the probability of peace with split $(y, 1-y)$ for any $y \in [0, 1]$. By substituting $x = 1 - y$ and $x = y$ in (9) we obtain

$$F_f(1-y) = F_t\left(\frac{(1-y)-(1-p)}{2p-1-\frac{\alpha p}{2}}\right) = F_t\left(\frac{p-y}{2p-1-\frac{\alpha p}{2}}\right) = \frac{p-y}{2p-1-\frac{\alpha p}{2}}$$

and

$$F_f(y) = F_t\left(\frac{y-(1-p)}{2p-1-\frac{\alpha p}{2}}\right) = \frac{y-1+p}{2p-1-\frac{\alpha p}{2}}.$$

Then

$$\mathcal{P}(y, 1-y) \leq \frac{(y-1+p)(p-y)}{(2p-1-\frac{\alpha p}{2})^2} = G(y).$$

Function $G(y)$ has a local maximum at $y = 1/2$ because $G'(y) = \frac{1-2y}{(2p-1-\frac{\alpha p}{2})^2}$ and $G''(y) = -2 < 0$. It is easy to check that this local maximum is also a global maximum for $y \in [0, 1]$. Hence, for any $y \in [0, 1]$ the probability of peace in the equilibrium of the split proposal game satisfies

$$\mathcal{P}(y, 1-y) \leq G(1/2) = \frac{(p-1/2)^2}{(2p-1-\frac{\alpha p}{2})^2} = \frac{(2p-1)^2}{(4p-2-\alpha p)^2} < 1.$$

Then

$$\mathcal{P}(x, 1-x) \leq \frac{(2p-1)^2}{(4p-2-\alpha p)^2}.$$

□

In Section 1 we have estimated the values of p and α for our model using observations about interstate wars in the period 1816-2007. Under the assumption that values $p = 0.63$ and $\alpha = 0.26$ are a common knowledge, inequality (8) implies that the upper bound for the probability of achieving peace by a split proposal mechanism is about 0.53.

There exists a wide set of parameter values where the *ex ante* probability of peace in the split proposal game is lower than 1/2.

Corollary 1. *In the split proposal game where parameter values satisfy conditions* (2), (3), *and inequalities*

$$\alpha < \frac{-2+2\sqrt{2}}{\sqrt{2}} \quad \wedge \quad p(4-4\sqrt{2}+\sqrt{2}\alpha) > 2-2\sqrt{2} \tag{10}$$

each split offer leads to peace with probability less than 1/2.

Proof: Let conditions (2) and (3) hold. Then by proposition (3) inequality

$$\mathcal{P}(x, 1-x) \leq \frac{(2p-1)^2}{(4p-2-\alpha p)^2}$$

holds as well. It is easy to check that inequality

$$\mathcal{P} \leq \frac{(2p-1)^2}{(4p-2-\alpha p)^2} < \frac{1}{2} \tag{11}$$

holds for parameter values that satisfy additionally inequalities (10).

□

This set of parameter values characterizes conflicts where opponents believe that the destruction level is lower than $\alpha = 0.5858$ and simultaneously the fighting capabilities are a fairly good predictor of the war outcome.

6 Unmediated peace talk game

We consider the class of conflicts for which the *ex ante* probability of acceptance of any split proposal is less than 1/2. In this paragraph we construct the optimal from designer's perspective unmediated peace talk game that may improve the chances for peace for these conflicts.

Consider a cheap talk where the message space is the product $\tau = M \times M$. After observing their own type, players publicly and simultaneously send costless messages $m_i \in M,\ i = 1, 2$. Denote the generic message profile by $m = (m_1, m_2)$. Messages sent in this mechanism are unverifiable, except for the case of war resolution.

For any given message profile m the mechanism may recommend to players either acceptable or unacceptable split. Recall that the set of acceptable splits is denoted by X, $X \subset Y^e$, and X is equivalent to the interval $[1-p, p]$. The probability of recommendation of acceptable split $x \in [1-p, p]$ when the message profile is m is denoted by $q(m),\ q(m) \in [0, 1]$. The probability of recommendation of unacceptable, war inducing split $x \notin X$, is denoted by $1 - q(m)$. A set of decisions is the product set $D = [1-p, p] \times [0, 1]$ with generic element (x, q).

Definition 3. *A peace talk mechanism is a pair (τ, f) where the decision rule $f : \tau \to D$ maps each pair of messages into a decision in $D = [1-p, p] \times [0, 1]$.*

We assume that no other peaceful mechanism is available. In this case any unilateral rejection of a split x proposed by mechanism (τ, f) leads to war with probability 1. The outcome induced by the mechanism (τ, f) is

either the efficient split x or, in the case of unilateral or bilateral rejection of recommendation, an inefficient outcome from the set $Y \setminus Y^e$ as a result of war.

We consider the game G induced by the mechanism (τ, f). In this game player i adopts a strategy $s_i : T \to M$ which maps each type to a message.

Preferences of players in the game G are given by utility functions $u_i : T \times M \to [0, 1]$. Utilities from a messages profile $m = (m_1, m_2)$ are

$$u_1(t, m) = q(m)x(m) + (1 - q(m))\pi_1(t)$$

and

$$u_2(t, m) = q(m)(1 - x(m)) + (1 - q(m))\pi_2(t)$$

where $\pi_1(t)$ and $\pi_2(t)$ denote expected war payoffs of players when the type profile is t. Let $b_0(.)$ be the uniform common prior probability distribution over type profiles T. The game G is described by $(\{1, 2\}, T, M, b_0, (u_1, u_2))$. Denote by $s(t_1, t_2) = (s_1(t_i), s_2(t_2))$ the pair of messages generated by the strategy profile (s_1, s_2) when realised types are (t_1, t_2).

A pure strategy Bayesian-Nash Equilibrium of G is a system of type-independent believes $b(.) = (b_1(.), b_2(.))$ at every information set and a pair of interim best response strategies (s_1, s_2). Let U_i be the expected payoff of player i with respect to the belief b_i from interim perspective, after player i learns his own type. Given the belief b_i, the expected payoff for player i of strategy profile s is

$$U_i^{b_i}(t_i) = \int_0^1 u(t_1, t_2, s(t_1, t_2))\, db_i(t_j),$$

where $i \neq j$.

A direct mechanism is a mechanism in which each player i fully or partially identifies himself by sending a message $m_i \in T$. If $M = T$ then a truth telling strategy for agent i is to reveal precisely its type, that is, $s_i(t_i) = t_i$.

Definition 4. *A direct mechanism (M, f) is interim incentive compatible (IC) if it has a Bayesian Nash equilibrium $(s_1^*(t_i), s_2^*(t_2))$ at the interim stage such that $s_1^*(t_1) = t_1$ and $s_2^*(t_2) = t_2$.*

We wish to find out if a decision rule f, where the expected value of q for the rule f is higher than $1/2$, can be implemented as a Bayesian Nash equilibrium of the game induced by some cheap talk mechanism. By the Revelation Principle for Bayesian equilibrium (see [16]), if a mechanism (τ, f) implements decision rule f in Bayesian equilibrium of the induced game, then the direct mechanism implementing f is Bayesian incentive compatible. Hence, we restrict our consideration to direct mechanisms (τ, f). Fix the equilibrium strategy profile s^* for mechanism (τ, f). Following the notation in [10], we denote by $q^*(m)$ the probability that, after observing each other's

message, both players accept the recommended split $x(m)$. Then the value of the prize for player 1 obtained from participation in the mechanism (τ, f) is $x^*(t) = x(s^*(t))$.

6.1 Designer's problem

The designer evaluates the quality of the mechanism (τ, f) by the probability $q^*(m)$ with which it is likely to avoid confrontation subject to opponents playing a Bayesian Nash equilibrium. It is assumed that players' beliefs are formed according to Bayesian rule and updated in the light of observed messages and the recommended split. In the *ex post* stage of the game (which might not be reached) the information is complete. We assume anonymity and no commitment of players to the mechanism, therefore in the equilibrium of the game G it must be optimal *ex post* to accept all peaceful splits proposed.

In an anonymous mechanism (τ, f) both functions $q(m)$ and $x(m)$ are symmetric with respect to players. This entails that

$$x(m_1, m_2) = x(m_2, m_1) \quad and \quad q(m_1, m_2) = q(m_2, m_1). \tag{12}$$

Hence,

$$x(y, y) = 1/2 \quad for\ any\ y \in M.$$

In a pooling equilibrium of the game each player sends the same message irrelevant to his type. The outcome in this equilibrium coincides with the equilibrium outcome of the agreement game without communication.

The designer's objective is to maximize the *ex ante* probability of peace

$$\mathcal{P} = max_{x(m),q(m)} \int_M \int_M q(m_1, m_2)\, dm_2\, dm_1 \tag{13}$$

across all mechanisms that satisfies the following two conditions. In the Bayesian-Nash equilibrium of the induced game G each player's strategy should satisfy the *interim* IC and the *ex post* individual rationality (IR) (participation) constraints that will be defined in subsequent paragraphs with respect to the message space M.

6.2 Full disclosure peace talk game

Let the message space be the type space $[0, 1]$. Consider anonymous mechanisms that satisfy conditions (12). The split $x(m_1, m_2)$ and probabilities $q(m_1, m_2)$ that maximizes the *ex ante* probability of peace

$$max_{x(m_1,m_2),q(m_1,m_2)} \int_0^1 \int_0^1 q(m_1, m_2)\, dm_2\, dm_1 \tag{14}$$

are subject to *interim* incentive compatibility (IC) and *ex post* individual rationality (IR) constraints.

Given the prior beliefs of players, the expected utility for type t_i of player i from participating in the induced game G and truthfully reporting $m_i = t_i$ is

$$U_i(t_i|t_i) = \int_0^1 q(t_i, t_j)x_i(t_i, t_j) + (1 - q(t_i, t_j))w_i(t_i, t_j)\, dt_j.$$

The expected utility from falsely reporting type $m_i' \neq t_i$ is

$$U_i(m_i'|t_i) = \int_0^1 q(m_i', t_j)x_i(m_i', t_j) + (1 - q(m_i', t_j))w_i(t_i, t_j)\, dt_j.$$

IC constraint states that for any $t_i, m_i' \in [0, 1]$

$$U_i(t_i|t_i) \geq U_i(m_i'|t_i) \quad \textit{and} \quad U_i(m_i'|m_i') \geq U_i(t_i|m_i'). \tag{15}$$

It must be optimal in the equilibrium of G to accept all peaceful splits proposed. Recall that if type profile is (t_1, t_2) then the war payoff of player i is $w_i(t_i, t_j) = p(t_i, t_j)\theta(t_i, t_j)$. Given that messages are public and truthfully reveal types, the *ex post* IR constraints are

$$x(m_1, m_2) \geq w_1(m_1, m_2) \quad \textit{and} \quad 1 - x(m_1, m_2) \geq w_2(m_1, m_2) \tag{16}$$

for all m_1, m_2.

Proposition 4. *Let $q(m_1, m_2)$ be the probability of recommendation of peaceful split in an interim incentive compatible and individually rational mechanism where $m_1, m_2 \in [0, 1]$. Then for every pair $m_1' \neq m_1$ there exists $m_2 \in [0, 1]$ such that $q(m_1', m_2) \neq q(m_1, m_2)$.*

Proof: Let the direct mechanism with decision rule $f(m_1, m_2) = (x(m_1, m_2), q(m_1, m_2))$ be interim incentive compatible. Let $m_1, m_1' \in [0, 1]$ and $m_1 \neq m_1'$. The interim IC constraint (15) for player 1 of type m_1 yields

$$\int_0^1 q(m_1, m_2)x(m_1, m_2)\, dm_2 + \int_0^1 (1 - q(m_1, m_2))w_1(m_1, m_2)\, dm_2 \geq \tag{17}$$

$$\geq \int_0^1 q(m_1', m_2)x(m_1', m_2)\, dm_2 + \int_0^1 (1 - q(m_1', m_2))w_1(m_1, m_2)\, dm_2.$$

For player 1 of type m_1' the interim IC constraint yields

$$\int_0^1 q(m_1', m_2)x(m_1', m_2)\, dm_2 + \int_0^1 (1 - q(m_1', m_2))w_1(m_1', m_2)\, dm_2 \geq \tag{18}$$

$$\geq \int_0^1 q(m_1, m_2)x(m_1, m_2)\, dm_2 + \int_0^1 (1 - q(m_1, m_2))w_1(m_1', m_2)\, dm_2.$$

Assume that $q(m_1', m_2) = q(m_1, m_2)$ for every $m_2 \in [0,1]$. Then inequality (17) yields that $\exists m_2^* \in [0,1]$ such that

$$x(m_1, m_2^*) \geq x(m_1', m_2^*),$$

while inequality (18) yields that $\exists m_2^{**} \in [0,1]$ such that

$$x(m_1', m_2^{**}) \geq x(m_1, m_2^{**})$$

holds. As m_1, m_1' are arbitrary, it implies $x(m_1, m_2) = x(m_2)$. Applying the same reasoning to player 2 we obtain $x(m_1, m_2) = x(m_1)$. Hence, $x(m_1, m_2) = const = K$. That is, all types expect the same share in the equilibrium without war. The *ex ante* IR constraint for the highest type of player 1 states

$$\int_0^1 x(1, m_2)\, dm_2 = K \geq \int_0^1 p\theta(1, m_2)\, dm_2 = p\int_0^1 (1 - \alpha m_2)\, dm_2 = \tag{19}$$

$$= p(1 - \frac{\alpha}{2}) > \frac{1}{2}.$$

Similarly, the *ex ante* IR constraint for the highest type of player 2 states

$$\int_0^1 x(m_1, 1)\, dm_1 = K \geq \int_0^1 p\theta(m_1, 1)\, dm_1 = p\int_0^1 (1 - \alpha m_1)\, dm_1 = \tag{20}$$

$$= p(1 - \frac{\alpha}{2}) > \frac{1}{2}.$$

Taking expectations we obtain the same constant

$$\int_0^1 \int_0^1 x(m_1, m_2)\, dm_2\, dm_1 = K.$$

Therefore, the IR constraint is violated because

$$K + K \geq 2p(1 - \frac{\alpha}{2}) > 1,$$

a contadiction. □

For an interim incentive compatible mechanism the truthful message m_1 maximises the value of

$$f(y) = \int_0^1 [q(y, m_2)x(y, m_2) + (1 - q(y, m_2))w_1(m_1, m_2)]\, dm_2.$$

The function under the integral sign is not continuous at the point (m_1, m_1). In particular,

$$f(y) = \int_0^{m_1} [q(y, m_2)x(y, m_2) + (1 - q(y, m_2))p(1 - \alpha m_1 m_2)]\, dm_2 +$$

$$\int_{m_1}^{1} [q(y,m_2)x(y,m_2) + (1-q(y,m_2))(1-p)(1-\alpha m_1 m_2)]\, dm_2.$$

For simplicity we only consider functions $q(y, m_2)$ that are piecewise continuously differentiable. Function q satisfies condition

$$\frac{\partial q(y,m_2)}{\partial y} = 0$$

for the optimal message y. The following property of probability $q(m_1, m_2)$ in an interim incentive compatible mechanism is proved in Appendix B.

Proposition 5. *Let $q(m_1, m_2)$ be the probability of recommendation of peaceful split in an interim incentive compatible mechanism where $m_1, m_2 \in [0, 1]$. Then for each messages profile (m_1, m_2) the following condition holds:*
(21)

$$q(m_1,1)x(m_1,1) - q(m_1,0)x(m_1,0) = \frac{3p-1}{2} - pq(m_1,0) + (1-2p)q(m_1,1) +$$
$$+(2p-1)\alpha m_1 \int_{m_1}^{1} \frac{\partial q(m_1,m_2)}{\partial m_1} m_2\, dm_2 - p\alpha m_1 \int_{0}^{m_1} \frac{\partial q(m_1,m_2)}{\partial m_1} m_2\, dm_2.$$

The survey by Miller et al. in [19] shows that for continuous types and interdependent private values, some positive implementation results are possible at the expense of imposing stochastic dependence of private signals. In general mechanism-design problems, the existence of ex post efficient and Bayesian incentive compatible mechanisms is limited to the settings with finitely many types.

In order to construct an efficient incentive compatible mechanism we restrict the precision of type revelation. Designer's choice to solicit partial revelation of types might be justified by the following two considerations. Acquisition of certificate of own type might be costly to the player. In the case of information about the military strength of a country, such estimate can be provided only relative to that of another country. In the presence of cost of precision it might not be an equilibrium strategy for any player to allow assessment of his own type as accurate as possible. In this case experts may observe some approximation of player's true type. Second, the problem of multiplicity of equilibria is particularly severe for mechanism design problems with a continuum of types. Apart from the sake of simplicity, these are the reasons for which in the following paragraph we study a mechanism with messages space $[h, l]$. This restriction minimises the multiple equilibrium problem for the induced game and increases the robustness of the mechanism to a wide range of behaviour.

6.3 Peace talk game with partial revelation of types

A partial type may be any subset of $T = [0, 1]$. In general, partial types may be overlapping. The partial types have to be exhaustive in order to

define incentive compatibility of a mechanism. We can define a truthful revelation with overlapping partial types in the following way.

Definition 5. *Let $\{T_0, T_1, ..., T_n\}$ be a finite set of messages such that $T_0 = 0$, $T_n < 1$, and $T_i < T_{i+1}$. We say that a report T_i, $0 \leq i \leq n-1$, of player j is truthful if the interval $[T_i, T_{i+1}]$ contains player' s true type t_j. Report T_n is truthful for player j if $T_n \leq t_j \leq 1$.*

Consider a mechanism that might reach a socially efficient outcome when revealed partial types are the least informative. This choice would meet the objective of minimizing the cost of participation in the mechanism and the objective of minimizing the set of equilibria of the induced game. This mechanism should reveal the type of the sender with precision up to two subintervals of $[0, 1]$. Let partial types divide the type space to two intersecting subintervals $[0, 1/2]$ and $[1/2, 1]$. Denote the message space by $M = [h, l]$. A truthful strategy for player i in the induced game is to report type l if $t_i \leq 1/2$ and h if $t_i \geq 1/2$. The symmetry of recommended splits $x(m_1, m_2)$ and probabilities $q(m_1, m_2)$ across players yields

$$x(l, l) = x(h, h) = 1/2 \quad \textit{and} \quad x \equiv x(h, l) = 1 - x(l, h).$$

The three unknown probabilities for the mechanism are

$$q_l \equiv q(l, l), \quad q_h \equiv q(h, h), \quad q_m \equiv q(h, l) = q(l, h).$$

Pooling equilibria are characterised by both types of players choosing the same message. There are many pooling equilibria of the game induced by $(M, (x, q))$. In order to construct one of them, assume that one of the players sends a message h with probability one. Assume that in the case of messages profile (h, h) the rule offers equal shares with probability $q(h, h) = 1$. Assume that for messages profile (h, l) the rule offers $\pi(1/2)$ to the player who sends a message l. Since each low type prefers to send a message h it means that only message h is sent by any type of each player in the Bayesian Nash equilibrium of the induced game. In each pooling equilibrium of the game induced by the mechanism the *ex ante* probability that the peace recommendation will be accepted by both players is the same as the probability of peace in some split proposal game. In a separating equilibrium the high type player sends a message h while the low type player sends a message l. The designer wishes to maximize the *ex ante* probability of peace in the separating equilibrium of the induced game. We will show that there exists a separating equilibrium of the game induced by $(M, (x, q))$.

The expected war payoff of an agent is decreasing in opponent's type in both cases of a low type and high type opponent. Moreover, the following lemma shows that a strong form of the single crossing property holds for the expected war payoffs. This lemma is proved in Appendix B.

Lemma 2. *The expected war payoffs in the mechanism $(M,(x,q))$, conditional on the type of the opponent, are strictly increasing in agent's own type for parameter values satisfying condition* (3)*. In particular,*

1. *the expected payoff $\pi_l(t_i)$ of a low type $t_i \leq 1/2$ from a war with low type is increasing and concave in t_i for $t_i \in [0,1/2]$,*
2. *the expected payoff $\pi_h(t_i)$ of a high type $t_i \geq 1/2$ from a war with high type is increasing and concave in t_i for $t_i \in [1/2,1]$.*

Hence, the best response of a player to an opponent reporting the same type is monotonic in its own type. In the construction of the optimal from designer's perspective mechanism we will employ the following properties of the expected war payoffs.

1. The expected payoff $\pi_l(t_i)$ of a low type $t_i \leq 1/2$ from a war with low type opponent satisfies

$$\pi_l(0) = \frac{1}{2}(1-p) \leq \pi_l(t_i) \leq \pi_l(\frac{1}{2}) = \frac{1}{2}p(1-\frac{\alpha}{8}) < 1/2. \tag{22}$$

2. The expected payoff $\pi_h(t_i)$ of a high type $t_i \geq 1/2$ from a war with high type opponent satisfies

$$\pi_h(1/2) = \frac{1}{2}(1-p)(1-\frac{3}{8}\alpha) \leq \pi_h(t_i) \leq \pi_h(1) = \frac{1}{2}p(1-\frac{3}{4}\alpha) < 1/2. \tag{23}$$

6.3.1 Objective function and constraints

In a Bayesian Nash equilibrium of the induced game, the peace maximizing splits and probabilities should solve the problem

$$max_{x,q_l,q_h,q_m} \left\{ \frac{1}{4}q_l + \frac{1}{2}q_m + \frac{1}{4}q_h \right\}, \tag{24}$$

that corresponds to problem (14) and is subject to the probability constraints

$$0 \leq q_l \leq 1,\ 0 \leq q_m \leq 1,\ 0 \leq q_h \leq 1 \tag{25}$$

and the following IC and IR constraints.

In a truthful mechanism messages reveal types. The *interim* expected prize in a war with reported low type is

$$\int_0^{1/2} (1-\alpha t_i m_2)\, dm_2 = \frac{1}{2} - \frac{\alpha t_i}{8} \tag{26}$$

while the expected prize in a war with reported high type is

$$\int_{1/2}^{1}(1-\alpha t_i m_2)\,dm_2 = \frac{1}{2} - \frac{3\alpha t_i}{8}. \tag{27}$$

Then the expected payoff of a high type from waging a war with reported low type is

$$p\int_{0}^{1/2}(1-\alpha t_i m_2)\,dm_2 = p(\frac{1}{2} - \frac{\alpha t_i}{8}).$$

We require that the share x of a reported high type makes war against a self-reported low type unprofitable. Hence, we require

$$x \geq p(\frac{1}{2} - \frac{\alpha t_i}{8})$$

for any $t_i > 1/2$. Then the *ex post* IR constraint for the high type share states

$$x \geq p(\frac{1}{2} - \frac{\alpha}{16}). \tag{28}$$

Similarly, the share $1-x$ of the low type should make it unprofitable to wage a war with reported high type. The expected payoff of a low type from waging a war with reported high type is

$$(1-p)\int_{1/2}^{1}(1-\alpha t_i m_2)\,dm_2) = (1-p)(\frac{1}{2} - \frac{3\alpha t_i}{8}).$$

Hence, we require

$$1-x \geq (1-p)(\frac{1}{2} - \frac{3\alpha t_i}{8})$$

for any $t_i \leq 1/2$. Then the *ex post* IR constraint for the low type share states

$$1-x \geq \frac{1}{2}(1-p). \tag{29}$$

Clearly, condition (2) implies that inequality $x = p(\frac{1}{2}-\frac{\alpha}{16}) > 1-x = \frac{1}{2}(1-p)$ is satisfied.

In the construction of the *interim* IC constraints we assume that misreporting is never followed by a failure to comply with the recommendation of the public randomization device. We check later in the section that the solution of the program gives no incentive for players to deviate by waging a war after misreporting.

Recall that $\pi_l(t_i)$ is the expected payoff of player i of type $t_i \leq 1/2$ from a war with low type and $\pi_h(t_i)$ is the expected payoff of player i of type

$t_i \geq 1/2$ from a war with high type. The *interim* IC constraint for a player i of type $t_i \leq 1/2$ is

$$\frac{1}{2}(\frac{q_l}{2} + (1-q_l)\pi_l(t_i)) + \frac{1}{2}(q_m(1-x) + (1-q_m)(1-p)(\frac{1}{2} - \frac{3\alpha t_i}{8})) \geq$$

$$\frac{1}{2}(q_m x + (1-q_m)\pi_l(t_i)) + \frac{1}{2}(\frac{q_h}{2} + (1-q_h)(1-p)(\frac{1}{2} - \frac{3\alpha t_i}{8})),$$

equivalent to

$$\frac{q_l}{2} - q_l\pi_l(t_i) + q_m(1-x) - q_m(1-p)(\frac{1}{2} - \frac{3\alpha t_i}{8}) \geq \tag{30}$$

$$\geq q_m x - q_m\pi_l(t_i) + \frac{q_h}{2} - q_h(1-p)(\frac{1}{2} - \frac{3\alpha t_i}{8})$$

for $t_i \leq 1/2$. The LHS is the expected payoff from sending a message l while the RHS is the expected payoff from exaggerating strength.

Similarly, the *interim* IC constraint for a player i of type $t_i > 1/2$ is

$$\frac{1}{2}(q_m x + (1-q_m)p(\frac{1}{2} - \frac{\alpha t_i}{8})) + \frac{1}{2}(\frac{q_h}{2} + (1-q_h)\pi_h(t_i)) \geq$$

$$\frac{1}{2}(\frac{q_l}{2} + (1-q_l)p(\frac{1}{2} - \frac{\alpha t_i}{8})) + \frac{1}{2}(q_m(1-x) + (1-q_m)\pi_h(t_i)),$$

equivalent to

$$\frac{q_h}{2} - q_h\pi_h(t_i) - q_m p(\frac{1}{2} - \frac{\alpha t_i}{8}) \geq \frac{q_l}{2} - q_l p(\frac{1}{2} - \frac{\alpha t_i}{8}) + q_m(1-2x) - q_m\pi_h(t_i) \tag{31}$$

for $t_i \geq 1/2$. The LHS is the expected payoff from sending a message h while the RHS is the expected payoff from hiding strength.

6.3.2 The optimal mechanism

Consider the game G induced by the mechanism $g = ([h,l] \times [h,l], f)$ where the decision rule f is determined by split function $x(m_1, m_2)$ and war probability function $q(m_1, m_2)$ that satisfy IC constraints (30) and (31), probability constraints (25), and solve problem (24).

The following proposition is proved in the Appendix.

Proposition 6. *The peace talk game induced by mechanism where mixed type dyads never fight is equivalent to the split proposal game.*

In the light of this result, we construct a peace talk mechanism where mixed dyads may fight with positive probability $1 - q_m$.

Proposition 7. *There is an unique best separating equilibrium of the game G. The ex ante probability of peace in this equilibrium equals*

$$\mathcal{P} = \frac{1}{2} + \frac{8 - 16p + 4\alpha p - 3\alpha}{2(2\alpha p - 3a - 8)}.$$

Proof: The proof is by construction. We calculate parameters of the direct mechanism and we show that both types have no incentive to deviate from recommendations of the public randomization device.

We rearrange the IC constraint (30) for the low type and we consider a relaxed problem: maximizing (24) subject to the high type *ex post* IR constraint

$$x \geq p(\frac{1}{2} - \frac{\alpha}{16}), \tag{32}$$

the probability constraints

$$q_l \leq 1,\ 0 \leq q_m \leq 1,\ q_h \leq 1, \tag{33}$$

and the low type *ex ante* IC constraint

$$q_l \left(\frac{1}{2} - \pi_l(t_i)\right) \geq q_m \left(2x - 1 - \pi_l(t_i) + (1-p)\left(\frac{1}{2} - \frac{3\alpha t_i}{8}\right)\right) + \\ + q_h \left(\frac{1}{2} - (1-p)\left(\frac{1}{2} - \frac{3\alpha t_i}{8}\right)\right). \tag{34}$$

1. By Lemma (2) inequality $\frac{1}{2} - \pi_l(t_i) > 0$ holds for any $t_i \leq 1/2$. Then setting $q_l = 1$ maximizes the LHS of (34) and does not affect the RHS. Simultaneously, it does not affect the high type *ex post* IR constraint (32).

2. As $\frac{1}{2} - (1-p)(\frac{1}{2} - \frac{3\alpha t_i}{8}) > 0$ for any $t_i \leq 1/2$, it follows that at the maximal feasible value of q_h the IC constraint (34) binds for some $t_i^* \leq 1/2$. In the light of step (1) we rewrite the IC constraint for the low type as

$$\frac{1}{2} \geq (1-q_m)\pi_l(t_i) + (q_h - q_m)(1-p)\frac{3\alpha t_i}{8} - (q_h - q_m)\frac{(1-p)}{2} + \\ + q_m(2x-1) + q_h\frac{1}{2}. \tag{35}$$

   Hence, t_i^* maximizes the value of $(1-q_m)\pi_l(t_i) + (q_h - q_m)(1-p)\frac{3\alpha t_i}{8}$.

3. We want to show that the high type *ex post* IR constraint (32) binds. Suppose that it is slack, that is, $x > p(\frac{1}{2} - \frac{\alpha}{16})$. Then it is possible to reduce x without violating the IC constraint (35) because x appears in the RHS of (35) with coefficient $2q_m \geq 0$. It makes the constraint (35) slack also for t_i^*, a contradiction with (2). Therefore, the high type *ex post* IR constraint (32) binds.

4. Steps (1) and (3) yield

$$x = p\left(\frac{1}{2} - \frac{\alpha}{16}\right) \quad \textit{and} \quad q_l = 1. \tag{36}$$

We want to show that $q_h \geq q_m$. In the light of equalities (36) the constraint (35) which is binding for $t_i = t_i^*$ becomes

$$\frac{1}{2} - \pi_l(t_i^*) = q_m\left(p(1-\frac{\alpha}{8}) - 1 - \pi_l(t_i^*) + (1-p)(\frac{1}{2} - \frac{3\alpha t_i^*}{8})\right) + \\ + q_h\left(\frac{1}{2} - (1-p)(\frac{1}{2} - \frac{3\alpha t_i^*}{8})\right). \tag{37}$$

As $\frac{1}{2} - (1-p)(\frac{1}{2} - \frac{3\alpha t_i^*}{8}) > 0$,

$$q_h = \frac{\frac{1}{2} - \pi_l(t_i^*)}{\frac{1}{2} - (1-p)(\frac{1}{2} - \frac{3\alpha t_i^*}{8})} + q_m \frac{1 - p(1-\frac{\alpha}{8}) + \pi_l(t_i^*) - (1-p)(\frac{1}{2} - \frac{3\alpha t_i^*}{8})}{\frac{1}{2} - (1-p)(\frac{1}{2} - \frac{3\alpha t_i^*}{8})} \tag{38}$$

is well defined. We rearrange (38) as

$$q_h = q_m \frac{\frac{1}{2} - (1-p)(\frac{1}{2} - \frac{3\alpha t_i^*}{8})}{\frac{1}{2} - (1-p)(\frac{1}{2} - \frac{3\alpha t_i^*}{8})} + \frac{q_m(1 - p(1-\frac{\alpha}{8}) - \frac{1}{2} + \pi_l(t_i^*)) + \frac{1}{2} - \pi_l(t_i^*)}{\frac{1}{2} - (1-p)(\frac{1}{2} - \frac{3\alpha t_i^*}{8})} = \\ = q_m + \frac{q_m(1 - p(1-\frac{\alpha}{8})) + (1-q_m)(\frac{1}{2} - \pi_l(t_i^*))}{\frac{1}{2} - (1-p)(\frac{1}{2} - \frac{3\alpha t_i^*}{8})}. \tag{39}$$

By lemma (2) inequality $\frac{1}{2} - \pi_l(t_i^*) > 0$ holds. Hence, the ratio on the RHS of (39) is positive for any $q_m \leq 1$. Therefore, $q_h \geq q_m$.

5. We want to show that the solution of the relaxed problem is $q_l = q_h = 1$ and $q_m = \frac{8-16p+4\alpha p-3\alpha}{2\alpha p-3a-8}$.

In the light of step (1) we rewrite the IC constraint (34) as

$$\frac{1}{2} \geq (1-q_m)\pi_l(t_i) + (q_h - q_m)(1-p)\frac{3\alpha t_i}{8} - (q_h - q_m)\frac{(1-p)}{2} + q_m(2x-1) + q_h\frac{1}{2}. \tag{40}$$

As $q_h - q_m \geq 0$ and $1 - q_m \geq 0$, lemma (2) implies that the value of $(1-q_m)\pi_l(t_i) + (q_h - q_m)(1-p)\frac{3\alpha t_i}{8}$ is maximal for $t_i = 1/2$. Therefore, the IC constraint (40) binds for $t_i^* = 1/2$. Then constraint

$$\frac{1}{2} \geq (1-q_m)\frac{1}{2}p(1-\frac{\alpha}{8}) + (q_h - q_m)(1-p)\frac{3\alpha}{16} - (q_h - q_m)\frac{(1-p)}{2} + \\ + q_m(2x-1) + q_h\frac{1}{2} \tag{41}$$

binds.

We substitute x in the binding constraint (41) and we obtain

$$(42)\quad 1 = (1-q_m)p(1-\frac{\alpha}{8}) + (q_h-q_m)(1-p)\frac{3\alpha}{8} - (q_h-q_m)(1-p) + \\ +q_m(p(2-\frac{\alpha}{4})-2)+q_h.$$

Clearly, $2\alpha p - 3a - 8 < 0$ for any feasible values of α and p. Hence,

$$(43)\qquad q_m = q_h\frac{3\alpha p - 8p - 3\alpha}{2\alpha p - 3a - 8} + \frac{8-8p+\alpha p}{2\alpha p - 3a - 8}$$

is well defined. In the light of step (1) we simplify the objective function (24) and maximize

$$(44)\qquad max_{q_h,q_m}\left\{2q_m + q_h\right\}.$$

Substituting q_m by the RHS of (43) we maximize expression

$$W = \frac{2(8-8p+\alpha p)}{2\alpha p - 3a - 8} + q_h\left(1 + \frac{2(3\alpha p - 8p - 3\alpha)}{2\alpha p - 3a - 8}\right).$$

We note that coefficient of q_h is positive and the maximization of W requires maximization of q_h. However, the value of q_h is constrained by inequality in (33). Setting $q_h = 1$ and solving for q_m in (43) yields

$$(45)\quad q_m = \frac{3\alpha p - 8p - 3\alpha}{2\alpha p - 3a - 8} + \frac{8-8p+\alpha p}{2\alpha p - 3a - 8} = \frac{8-16p+4\alpha p - 3\alpha}{2\alpha p - 3a - 8}.$$

It is easy to check that $0 < q_m \leq 1$ for any feasible values of p and α. Indeed, $2\alpha p - 3a - 8 < 0$ and inequality $8 - 16p + 4\alpha p - 3\alpha < 0$ holds for any values of parameters α and p that satisfy condition (2). The RHS of (45) achieves its maximal value of $\frac{8-\alpha}{8+\alpha} \leq 1$ for $p = 1$. Therefore, the solution $q_l = q_h = 1$ and $q_m = \frac{8-16p+4\alpha p-3\alpha}{2\alpha p-3a-8}$ is admissible.

6. We want to show that the solution constructed in step (5) satisfies all constraints of the initial problem. The *ex post* IR constraint(29) for the low type share is trivially satisfied when $x = p(\frac{1}{2} - \frac{\alpha}{16})$, as $1 - x = 1 - p(\frac{1}{2} - \frac{\alpha}{16}) \geq \frac{1}{2}(1-p)$. By substituting $q_l = q_h = 1$ the high-type *ex ante* IC constraint (31) becomes
(46)
$$\frac{1}{2} - \pi_h(t_i) + q_m x - q_m p(\frac{1}{2} - \frac{\alpha t_i}{8}) \geq q_m(1-x) - q_m\pi_h(t_i) + \frac{1}{2} - p(\frac{1}{2} - \frac{\alpha t_i}{8})$$

We will show that inequality (46) is satisfied for any $t_i \geq 1/2$.

Recall that by inequality (23) of lemma (2) inequality

$$(47)\qquad p(\frac{1}{2} - \frac{\alpha t_i}{8}) \geq \pi_h(t_i)$$

holds for $t_i \geq 1/2$. Then

$$(1-q_m)p(\frac{1}{2}-\frac{\alpha t_i}{8}) \geq (1-q_m)\pi_h(t_i) \tag{48}$$

because $q_m < 1$. We rewrite (48) as

$$-\pi_h(t_i) - q_m p(\frac{1}{2}-\frac{\alpha t_i}{8}) \geq -q_m\pi_h(t_i) - p(\frac{1}{2}-\frac{\alpha t_i}{8}). \tag{49}$$

We note that summing inequality (49) with inequality $q_m x > q_m(1-x)$, that holds because $x > 1-x$, we obtain (46), which had to be proved. The probability constraints (25) are obviously satisfied.

6.4 Welfare analysis

Proposition (7) shows that the *ex ante* probability of peace in the separating equilibrium of the peace talk game is higher than $\frac{1}{2}$ for any parameter values that satisfy inequalities (3). The proof of Proposition (7) implies that the optimal cheap talk mechanism achieves this result by persuading low type players not to fight with probability 1, i.e., $q_l = 1$. It suggests that some mediation programme might improve the probability of peace if it increases the probability q_m that mixed pairs do not fight.

By lemma (2) the value of split $x = p(\frac{1}{2} - \frac{\alpha}{16})$ implies that neither the low nor the high type has any incentive to deviate by waging a war after misreporting, learning the type of the opponent and receiving a peaceful recommendation by the mechanism. Hence, truthfully reporting type and following the recommendation is a Bayesian-Nash equilibrium in the game induced by the mechanism. This equilibrium is unique up to the strategy of the player with type $t_i = 1/2$ who can randomize between reporting h and l. Therefore, in the best separating equilibrium of the peace talk game the *ex ante* probability of peace is

$$\mathcal{P} = \frac{1}{4} + \frac{8-16p+4\alpha p-3\alpha}{2(2\alpha p-3a-8)} + \frac{1}{4}.$$

□

Corollary (1) implies that a peace talk reduces the *ex ante* probability of conflict compared to all equilibria of the split proposal game for conflicts where parameter values satisfy conditions (2), (3), and (10). Recall that this set includes conflicts where the level of destruction caused by war is below some threshold and the fighting capacities of opponents are relatively good predictor of the war outcome.

In the ex post stage, as a result of updated beliefs about the opponent's war capacity, parties might not follow a war recommendation and seek bilaterally another peaceful mechanism. However, the lack of commitment to fight after a war recommendation can only increase the ex ante probability of peace in the case of communication.

7 Mediated peace talk games

The designer may propose to parties to mediate the conflict. Typically, the mediator is a third party that has no private information but helps others to reach an agreement. The mediator who evaluates the case is often expected to adopt a neutral stance in his advisory role. Nevertheless, a typical mediator has his own agenda. The fundamental assumption in our model is that the objective of a mediator is to maximise the *ex ante* probability of peaceful resolution of the conflict and this objective is common knowledge. The mediator cannot enforce his recommendations. We assume that the mediator can fully commit to the outcome induced by the mechanism and that channels of communication of the privately informed players with the mediator are perfect and immune to disclosure of confidential information.

The basis for our analysis is the mediated communication game studied by Horner, Morelli and Squintani (2010) in [15]. The game induced by the mediator can be decomposed into four stages.

- Nature moves first and chooses types.
- At the first interim stage, players observe their own type and send a message to the mediator. When the mediator receives a pair of messages he chooses a lottery from a menu of lotteries. This lottery determines the final split recommended publicly to parties.
- At the second interim stage, opponents play an agreement game with the proposed split.

Parties believe that the mediator is committed to a policy rule that maximizes the probability of peace.

By the Revelation Principle for Bayesian equilibrium we restrict our consideration to direct mechanisms. In contrast to the peace talk game, messages sent by parties to the mediator are non publicly observed. The mediator randomly selects a split from a full menu, but his recommendation is made after he learns the messages profile m. Following the model by Horner, Morelli and Squintani (2010) presented in [15], we assume that a split $(y, 1-y)$is recommended according to some cumulative distribution function $F(y|m)$ over a set of possible splits where there is only one recommendation in the support of F leading to war, the split $(0, 1)$.

S. Baliga and T. Sjostrom (2011) express in [2] the view that 'the mechanisms are clearly not meant to be descriptive of real-world institutions. For example, they typically require the agents to report "all they know" before any decision is reached, an extreme form of centralized decision making hardly ever encountered in the real world.' Several papers study the impact of the alignment of preferences of the sender and the receiver on the

amount of information communicated in equilibrium (see [12] and [13] by Kamenica and Gentzkow (2009,2011)). The authors show that more aligned preferences can make the optimal signal either more or less informative depending on the default action of the receiver. In general, parties have some control over the precision of the information shared with the mediator. The mediator may relax the requirement of full disclosure of private information and solicit partial revelation of types.

Consider a mechanism with the same strategy set as the cheap talk game studied in Section 5. Messages sent in this mechanism reveal the type of sender with precision up to division of the type space to subintervals $[0, 1/2]$ and $[1/2, 1]$. Given the messages profile $m = (m_1, m_2)$ where $m_i \in \{h, l\}$, the mediator recommends a split chosen from a set of possibilities. In general, the mediator can assign a positive probability to a number of peaceful splits. For the sake of simplicity, we restrict the set of possible recommendations to the set $R = \{(1/2, 1/2), (x, 1-x), (1-x, x), (0, 1)\}$ where $x > 1 - x$. Clearly, the split $(0, 1)$ induces war with probability 1 while the other three recommendations might be accepted by both players with positive probability. Following the model of Horner et al., we consider direct mechanisms for which the recommendation rule is given by discrete and symmetric randomisation function $F : \{h, l\} \times \{h, l\} \to [0, 1]^4$.

Players use Bayes rule to update their beliefs after any history that allows to do so. After observing the publicly announced recommendation from the menu $F(y|m)$, players update their prior belief to an *interim* belief about the type of the opponent. The mediator has to decide how informative his recommendations for players should be. They can choose to go to war at any time. Hence, in the construction of the menu of lotteries, the mediator should avoid releasing unnecessary information about opponent's type to players. Following the recommendation should be optimal, given players' types and the updated beliefs about the opponent's type.

Note that for the mediation programme given by lotteries

$$F(h, h) = (q_h, 0, 0, 1 - q_h), \quad F(h, l) = (0, q_m, 0, 1 - q_m),$$

$$F(l, l) = (q_l, 0, 0, 1 - q_l), \quad F(l, h) = (0, 0, q_m, 1 - q_m)$$

the solution exactly reproduces the separating equilibrium of the cheap talk game. The reason is that the updated beliefs of players after the announcement of recommendation are the same as their posterior beliefs after observing the public messages in the cheap talk game. The proof of Proposition (7) shows that in the optimal cheap talk mechanism low type dyads do not fight with probability 1, i.e., $q_l = 1$. This suggests that a mediation programme might improve the probability of peace if it increases the probability that mixed pairs do not fight. This could be achieved by not always revealing to the high type player that he is facing a low type player. We infer that

in the optimal mediation programme the recommendation $(1/2, 1/2)$ might not be made only for messages profiles (h, h) and (l, l).

8 Conclusion

Our motivation in this paper was to understand how the choice of peace promoting mechanism influences the *ex ante* probability of peace in a bilateral conflict where both the win probability and the cost of war are uncertain. We use a simple model with two symmetric players where the privately known type describes player's fighting capacity. Players hold a common prior belief about the type of their opponent. We depart from the benchmark model by allowing for the possibility of uncertain cost of conflict and continuous types.

We calculated an upper bound for the probability of a peaceful split in the case of lack of communication and a simultaneous choice of players whether to agree to a given split proposal. We rank sets of Bayesian Nash equilibria that are achievable in games induced by some information sharing mechanisms. This Pareto ranking of sets is based on the *ex ante* probability of peace in the best separating equilibrium of the induced game.

We study the probability of peace achieved by mechanisms with partial disclosure of private information. We allow for some blurring of the boundaries between partial types. We found that an unmediated cheap talk between players improves chances for peace for some parameter values, even in the case of partial disclosure. We defined the problem of a strategic mediator without enforcement power in the case of a mediation game with the same discrete message space as the unmediated peace talk game.

Fey and Ramsay (2010) show in [9] that for a broad class of crisis bargaining games with no restriction on the motivation of the mediator any equilibrium outcome that is achievable through mediation is also achievable as an equilibrium outcome of an unmediated cheap talk game. Our analysis does not preclude the possibility for some mediation programmes with restricted message space to increase the *ex ante* probability of peace in the given setup. In order to determine a mediation program which can improve upon the unmediated communication, the welfare properties of mediation program where players reporting unequal types can be recommended an even split with positive probability should be studied. For this mediation programme the decision rule F is fully characterized by five probabilities and is given by lotteries

$$F(h,h) = (q_h, 0, 0, 1 - q_h), \quad F(h,l) = (q_m, p_m, 0, 1 - q_m - p_m), \tag{50}$$

$$F(l,l) = (q_l, 0, 0, 1 - q_l).$$

By symmetry $F(l,h) = (q_m, 0, p_m, 1-q_m-p_m)$. If the only available peaceful mechanism is given by programme (50) then it may be optimal for the players to share their information with the mediator in spite of imperfect alignment of interests. However, players who have the opportunity to choose a mediator may avoid mediators that offer this particular mediation program and seek the advice of mediators using different mediation programs.

A mediator seeking to improve the welfare of the opponents might face a tradeoff between minimization of destruction caused by a possible conflict and minimization of its probability. In the former case the decisive information for a mediator is the value of the prize for the winner in a potential war. This is an example of information that an opponent might be willing to share with a strategic mediator but is not willing to share with an adversary. It should be noted that the mediator could obtain the cost $\alpha t_i t_j$ of potential war without revealing types of the opponents.

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A Appendix

	(1) battledeaths	(2) battledeaths	(3) battledeaths	(4) battledeaths
productcinc	0.196***			0.257***
	(19.56)			(18.40)
numberstates		0.000805***		0.000397***
		(9.09)		(5.34)
sumcinc			0.0174***	-0.0178***
			(7.68)	(-8.36)
N	94	94	94	94
R^2	0.805	0.470	0.388	0.890
adj. R^2	0.802	0.465	0.381	0.886

t statistics in parentheses

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

B Appendix

Proof of Proposition 1

Consider three types of beliefs regarding the relative strength of players. Assume that both players believe that they are of the same type. The split $(\frac{1}{2}, \frac{1}{2})$ will be accepted by any player who beliefs the opponent to be of the same type because $\alpha > 0$ and $\frac{1}{2} \geq \frac{1}{2}(1 - \alpha t^2)$ for any $t \in T$. Assume that players' beliefs are different. Then the split will be anonymously accepted if it is accepted by the player who believes to be of higher type than the opponent. Let player i beliefs to be of the higher type. The expected war payoff of type i who believes to be of the higher type is

(51)

$$\pi(t_i) = \int_0^{t_i} p(1 - \alpha t_i t_j)\, dt_j \leq \int_0^{t_i} p(1 - \alpha t_j^2)\, dt_j = pt_i - p\alpha \frac{t_i^3}{3} = t_i p(1 - \alpha \frac{t_i^2}{3}).$$

It is easy to check that for $t_i \in (0, 1)$, $a \in (0, 1)$, and $p \in (1/2, 1)$, inequality $p(1 - \alpha/3) \leq 1/2$ is necessary and sufficient condition for inequality

$$t_i p(1 - \alpha \frac{t_i^2}{3}) \leq \frac{1}{2}$$

to hold for all $t \in (0, 1)$. Therefore, for parameter values satisfying condition $p(1 - \alpha/3) \leq 1/2$ a peaceful split $(\frac{1}{2}, \frac{1}{2})$ will be accepted by the player who believes to be of the higher type. Hence, the equal split will be accepted by both players, irrelevant of their beliefs about the type of the opponent. We conclude that peace can be attained with probability 1 when $p(1-\alpha/3) \leq \frac{1}{2}$.

□

Proof of Proposition 2

An offer of x does not affect the belief of player i about the unknown type t_j and player's expected war payoff $\pi(t_i)$. By Lemma (1), function $\pi(t_i)$ is strictly increasing in t_i on $[0,1]$. Hence, it has an inverse function, which we denote by $\varphi(.)$. The inverse function satisfies $\pi(\varphi(y)) = y$ for any $y \in [1-p, p(1-\frac{\alpha}{2})]$. The value of $\varphi(y)$ is the type of player who has an expected war payoff y. As a monotonic real-valued function, $\pi(t_i)$ is differentiable almost everywhere. Similarly, the inverse function $\varphi(.)$ is also differentiable almost everywhere. The inverse functions is monotonic and increasing in $[1-p, p(1-\frac{\alpha}{2})]$, so we keep the direction of inequality as

$$x \geq \pi(t_i) \Leftrightarrow \varphi(x) \geq t_i.$$

Therefore,

$$P(x \geq \pi(t_i)) = P(\varphi(x) \geq t_i) = \varphi(x).$$

First, we calculate the probability that an offer of $x \in [0,1]$ is accepted by player of type t. Inequality

$$x \geq \pi(t)$$

is equivalent to

$$(1-p-x) + (-1 - \frac{\alpha}{2} + 2p + \frac{\alpha p}{2})t + (\frac{\alpha}{2} - \alpha p)t^3 \leq 0.$$

Then we solve

$$(2-2p-2x) + (-2-\alpha+4p+\alpha p)t + \alpha(1-2p)t^3 \leq 0. \tag{52}$$

Recall that $1-2p < 0$. Dividing both sides by $\alpha(1-2p)$ we obtain

$$t^3 + \frac{-2-\alpha+4p+\alpha p}{\alpha(1-2p)}t + \frac{(2-2p-2x)}{\alpha(1-2p)} \geq 0. \tag{53}$$

Equation

$$t^3 + \frac{-2-\alpha+4p+\alpha p}{\alpha(1-2p)}t + \frac{(2-2p-2x)}{\alpha(1-2p)} = 0 \tag{54}$$

has three distinct real roots. Hence, although all roots are real, we require complex numbers to express them in radicals. That is why we express the root which belongs to the interval $[0,1]$ in terms of the cos and arccos functions. For simplicity of notation we denote

$$r = \frac{-2-\alpha+4p+\alpha p}{\alpha(1-2p)} \quad and \quad q = \frac{(2-2p-2x)}{\alpha(1-2p)}. \tag{55}$$

Then

$$t = 2\sqrt{-\frac{r}{3}}\cos\left(\frac{1}{3}\arccos\left(\frac{3q}{2r}\sqrt{\frac{-3}{r}}\right) - \frac{2\pi}{3}\right) =$$

$$= -2\sqrt{-\frac{r}{3}}\sin\left(\frac{\pi}{6} - \frac{1}{3}\arccos\left(\frac{3q}{2r}\sqrt{\frac{-3}{r}}\right)\right) \tag{56}$$

is a real root in the interval $[0,1]$ because $r < 0$ for any p and α satisfying condition (3). The left hand side of (52) is decreasing function, hence we change the direction of inequality and we obtain

$$P(x \geq \pi(t)) = P\left(t < -2\sqrt{-\frac{r}{3}}\sin\left(\frac{\pi}{6} - \frac{1}{3}\arccos\left(\frac{3q}{2r}\sqrt{\frac{-3}{r}}\right)\right)\right) = \tag{57}$$

$$= -2\sqrt{-\frac{r}{3}}\sin\left(\frac{\pi}{6} - \frac{1}{3}\arccos\left(\frac{3q}{2r}\sqrt{\frac{-3}{r}}\right)\right).$$

Next, we calculate the probability that a peaceful split $(\frac{1}{2}, \frac{1}{2})$ is accepted. The joint cumulative distribution function of random variables $\pi(t_1)$ and $\pi(t_2)$ is

$$P(1/2 \geq \pi(t_1) \wedge 1/2 \geq \pi(t_2)) = P(1/2 \geq \pi(t_1))P(1/2 \geq \pi(t_2)) = P^2(1/2 \geq \pi(t))$$

because $\pi(t_1)$ and $\pi(t_2)$ are independent and identically distributed. Hence

$$\mathcal{P}(1/2, 1/2) = P^2(1/2 \geq \pi(t)) = \varphi^2(1/2).$$

Substituting $x = 1/2$ in (55) we obtain $q = \frac{1}{\alpha}$. From (57) we obtain

$$P(1/2 \geq \pi(t)) = 2\sqrt{-\frac{r}{3}}\cos\left(\frac{1}{3}\arccos\left(\frac{3q}{2r}\sqrt{\frac{-3}{r}}\right) - \frac{2\pi}{3}\right)$$

where

$$r = \frac{-2 - \alpha + 4p + \alpha p}{\alpha(1-2p)} \quad \textit{and} \quad q = \frac{1}{\alpha}. \tag{58}$$

Hence,

$$\mathcal{P}(1/2, 1/2) = -\frac{4}{3}r\sin^2\left(\frac{\pi}{6} - \frac{1}{3}\arccos\left(\frac{3\sqrt{3}q\sqrt{-\frac{1}{r}}}{2r}\right)\right)$$

where r and q are given by (58).

□

Proof of Proposition (5)

By differentiating $q(y, m_2)$ with respect to y we obtain condition

$$\int_0^{m_1}\left[\frac{\partial q(y,m_2)}{\partial y}x(y,m_2) + q(y,m_2)\frac{\partial x(y,m_2)}{\partial y} - \frac{\partial q(y,m_2)}{\partial y}p(1-\alpha m_1 m_2)\right]dm_2 +$$

$$\int_{m_1}^{1}\left[\frac{\partial q(y,m_2)}{\partial y}x(y,m_2)+q(y,m_2)\frac{\partial x(y,m_2)}{\partial y}-\frac{\partial q(y,m_2)}{\partial y}(1-p)(1-\alpha m_1 m_2)\right]dm_2=0$$

for function q. By simplifying this equality we obtain

$$\int_0^1 \frac{\partial q(y,m_2)}{\partial y}x(y,m_2)+q(y,m_2)\frac{\partial x(y,m_2)}{\partial y}\,dm_2=$$

$$=\int_0^{m_1}\frac{\partial q(y,m_2)}{\partial y}p(1-\alpha m_1 m_2)\,dm_2+\int_{m_1}^{1}\frac{\partial q(y,m_2)}{\partial y}(1-p)(1-\alpha m_1 m_2)\,dm_2.$$

By rearranging the RHS we obtain

$$\int_0^1 \frac{\partial q(y,m_2)}{\partial y}x(y,m_2)+q(y,m_2)\frac{\partial x(y,m_2)}{\partial y}\,dm_2=$$

$$=\int_0^{m_1}\frac{\partial q(y,m_2)}{\partial y}p(1-\alpha m_1 m_2)\,dm_2+\int_{m_1}^{1}\frac{\partial q(y,m_2)}{\partial y}(1-2p)(1-\alpha m_1 m_2)\,dm_2.$$

Hence,

$$[q(y,m_2)x(y,m_2)|_{m_2=0}^{m_2=1}=p\int_0^{m_1}\frac{\partial q(y,m_2)}{\partial y}\,dm_2-p\alpha m_1\int_0^{m_1}\frac{\partial q(y,m_2)}{\partial y}m_2\,dm_2+$$

$$+\int_{m_1}^{1}\frac{\partial q(y,m_2)}{\partial y}(1-2p)\,dm_2-(1-2p)\alpha m_1\int_{m_1}^{1}\frac{\partial q(y,m_2)}{\partial y}m_2\,dm_2.$$

Therefore,

$$q(y,1)x(y,1)-q(y,0)x(y,0)=p(q(y,m_1)-q(y,0))-p\alpha m_1\int_0^{m_1}\frac{\partial q(y,m_2)}{\partial y}m_2\,dm_2+$$

$$+(1-2p)(q(y,1)-q(y,m_1))-(1-2p)\alpha m_1\int_{m_1}^{1}\frac{\partial q(y,m_2)}{\partial y}m_2\,dm_2.$$

By substituting $y=m_1$ for the optimal message we obtain an IC constraint for each $m_1\in[0,1]$:

$$q(m_1,1)x(m_1,1)-q(m_1,0)x(m_1,0)=p(q(m_1,m_1)-q(m_1,0))-p\alpha m_1\int_0^{m_1}\frac{\partial q(y,m_2)}{\partial y}m_2\,dm_2+$$

$$+(1-2p)(q(m_1,1)-q(m_1,m_1))-(1-2p)\alpha m_1\int_{m_1}^{1}\frac{\partial q(y,m_2)}{\partial y}m_2\,dm_2.$$

By conditions (12) $q(m_1,m_1)=1/2$. Hence,

$$q(m_1,1)x(m_1,1)-q(m_1,0)x(m_1,0)=p(1/2-q(m_1,0))-p\alpha m_1\int_0^{m_1}\frac{\partial q(m_1,m_2)}{\partial m_1}m_2\,dm_2+$$

$$+(1-2p)(q(m_1,1)-1/2)-(1-2p)\alpha m_1\int_{m_1}^{1}\frac{\partial q(m_1,m_2)}{\partial m_1}m_2\,dm_2.$$

By simplifying the RHS we obtain

$$q(m_1,1)x(m_1,1)-q(m_1,0)x(m_1,0)=\frac{3p-1}{2}-pq(m_1,0)-p\alpha m_1\int_0^{m_1}\frac{\partial q(m_1,m_2)}{\partial m_1}m_2\,dm_2+$$

$$+(1-2p)q(m_1,1)-(1-2p)\alpha m_1\int_{m_1}^{1}\frac{\partial q(m_1,m_2)}{\partial m_1}m_2\,dm_2.$$

□

Proof of Lemma (2)

To prove (1) we notice that the expected payoff of type $t_i \le 1/2$ from a war with type $t_j \le 1/2$ is

$$\pi_l(t_i)=\int_0^{1/2}p(t_i,t_j)\theta(t_i,t_j)\,dt_j=\int_0^{t_i}p(1-\alpha t_1t_2)\,dt_2+\int_{t_i}^{1/2}(1-p)(1-\alpha t_it_j)\,dt_j=$$

$$=\frac{1-p}{2}+\left(2p-1-\frac{\alpha(1-p)}{8}\right)t_i+\left(\frac{\alpha}{2}-\alpha p\right)t_i^3. \tag{59}$$

It is easy to check that for parameter values that satisfy condition (3) inequality

$$\frac{\partial\pi_l(t_i)}{\partial t_i}=\left(2p-1-\frac{\alpha(1-p)}{8}\right)+3\alpha\left(\frac{1}{2}-p\right)t_i^2>0.$$

holds for $t_i\in[0,1/2]$. Hence, $\pi_l(t_i)$ is increasing in t_i for $t_i\in[0,1/2]$.

To prove (2) we notice that the expected payoff of a higher type $t_i > 1/2$ from a war with higher type $t_j > 1/2$ is

$$\pi_h(t_i)=\int_{1/2}^{1}p(t_i,t_j)\theta(t_i,t_j)\,dt_j=\int_{1/2}^{t_i}p(1-\alpha t_it_j)\,dt_j+\int_{t_i}^{1}(1-p)(1-\alpha t_it_j)\,dt_j=$$

$$=1-\frac{3p}{2}+\left(2p-1-\frac{\alpha}{2}+\frac{5\alpha p}{8}\right)t_i+\left(\frac{\alpha}{2}-\alpha p\right)t_i^3. \tag{60}$$

It is easy to check that for parameter values that satisfy condition (3) inequality

$$\frac{\partial\pi_h(t_i)}{\partial t_i}=2p-1-\frac{\alpha}{2}+\frac{5\alpha p}{8}+3\alpha\left(\frac{1}{2}-p\right)t_i^3>0.$$

holds for $t_i\in[1/2,1]$. Hence, $\pi_h(t_i)$ is increasing in t_i for $t_i\in[1/2,1]$. Concavity of $\pi_l(t_i)$ and $\pi_h(t_i)$ follows from inequality $\frac{1}{2}-p<0$. □

Proof of Proposition (6)

We show that for $q_m = 1$ there are no meaningful values of x, q_l and q_h that satisfy both IC constraints. Let $q_m = 1$. Then

$$(61) \quad q_h(\frac{1}{2} - \pi_h(t_i)) \geq \frac{q_l}{2} - q_l p(\frac{1}{2} - \frac{\alpha t_i}{8}) + p(\frac{1}{2} - \frac{\alpha t_i}{8}) + 1 - 2x - \pi_h(t_i)$$

for $t_i \geq 1/2$,

(62)
$$q_l(\frac{1}{2} - \pi_l(t_i)) \geq (1-p)(\frac{1}{2} - \frac{3\alpha t_i}{8}) + 2x - 1 - \pi_l(t_i) + \frac{q_h}{2} - q_h(1-p)(\frac{1}{2} - \frac{3\alpha t_i}{8})$$

for $t_i \leq 1/2$.

Assume that $q_h < 1$ or $q_l < 1$. Then IC constraint

$$q_h \frac{1}{2} + (1 - q_h)\pi_h(t_i) \geq \frac{q_l}{2} + (1 - q_l)p(\frac{1}{2} - \frac{\alpha t_i}{8}) + 1 - 2x$$

binds for $t_i = 1/2$ because the value of the LHS is the least for $t_i = 1/2$ and the value of the RHS is the highest for $t_i = 1/2$. Similarly, IC constraint

$$q_l \frac{1}{2} + (1 - q_l)\pi_l(t_i) \geq (1 - q_h)(1 - p)(\frac{1}{2} - \frac{3\alpha t_i}{8}) + 2x - 1 + \frac{q_h}{2}$$

binds for $t_i = 0$ because the value of the LHS is the least for $t_i = 0$ and the value of the RHS is the highest for $t_i = 0$.

Hence,

$$q_h \frac{1}{2} + (1 - q_h)\frac{1}{2}(1 - p)(1 - \frac{3\alpha}{8}) = \frac{q_l}{2} + (1 - q_l)p(\frac{1}{2} - \frac{\alpha}{16}) + 1 - 2x$$

and

$$q_l \frac{1}{2} + (1 - q_l)\frac{1}{2}(1 - p) = (1 - q_h)(1 - p)\frac{1}{2} + 2x - 1 + \frac{q_h}{2}.$$

The sum gives

$$(1-q_h)\frac{1}{2}(1-p)(1-\frac{3\alpha}{8}) + (1-q_l)\frac{1}{2}(1-p) = (1-q_l)p(\frac{1}{2}-\frac{\alpha}{16}) + (1-q_h)(1-p)\frac{1}{2}$$

equivalent to

$$(1 - q_h)(1 - p)(1 - \frac{3\alpha}{8}) + (1 - q_l)(1 - p) = (1 - q_l)p(1 - \frac{\alpha}{8}) + (1 - q_h)(1 - p)$$

Denote $x = 1 - q_h$ and $y = 1 - q_l$.

$$x(1 - p)(1 - \frac{3\alpha}{8}) + y(1 - p) = yp(1 - \frac{\alpha}{8}) + x(1 - p)$$

$$-x(1-p)\frac{3\alpha}{8} = y(p(1-\frac{\alpha}{8}) - 1 + p)$$

Clearly, $LHS < 0$ and $RHS > 0$. The only feasible solution is $x = y = 0$, or $q_l = q_h = 1$. It implies $x = 1/2$. Hence, for $q_m = 1$ the peace talk is equivalent to the split proposal game with equal split.

□