

Conflict Without Misperceptions or Incomplete Information: How the Future Matters⁰

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Abstract. Conflict and war are typically viewed as the outcome of misperceptions, incomplete information, or even irrationality. We show that it can be otherwise. Despite the short-run incentives to settle disputes peacefully, there can be long-term, compounding rewards to going to war when doing better relative to one's opponent today implies doing better tomorrow. Peaceful settlement involves not only sharing the pie available today but also foregoing the possibility, brought about by war, of gaining a permanent advantage over one's opponent into the future. We show how war emerges as an equilibrium outcome in a model that takes these considerations into account. War is more likely to occur, the more important is the future.

War is often attributed to misperceptions, misunderstandings, or simply to irrationality and base instincts. Within economics, where irrationality and instinctual behavior are ruled out by assumption, violent conflict can arise as an equilibrium phenomenon when the players have incomplete information about the preferences or strategies of the other players.¹ Without incomplete information, however, it is difficult to generate open conflict as an equilibrium outcome. That is, the contending parties would prefer to settle under the threat of conflict and divide up whatever is at stake. Each party would still arm to maintain its negotiating position. But, once one accounts for the risk, destruction, additional expenditure of resources required in the event of war, and perhaps other considerations, a decision to go to war would appear to be irrational.

In this paper we show how war can occur despite the short-term incentives to settle peacefully in the shadow of war. The condition that generates this outcome is the dependence of tomorrow's resources on today's performance for each adversary. For example, a feudal lord or king who lost a war would also

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¹"Conflict" in the mainstream economics literature is typically of a rather benign form—the foregoing of a mutually advantageous exchange. There is a very large literature on games with incomplete information that shows how such conflict can take place. Fudenberg and Tirole (1991, Chapter 6) provide a textbook treatment of the topic. We take a more specific and darker view of conflict that may involve physical combat—i.e., violence. However, our model allows for alternative interpretations of conflict which need not involve violence—e.g., legal disputes, strikes and lockouts in which the outcome is probabilistic. See Hirshleifer and Osborne (1996) who discuss the application of models of conflict to legal disputes. For modeling under incomplete information of such forms of conflict, see Wittman (1979), Brito and Intrilligator (1985) and more recently Bester and Warneryd (1998).

lose territory and the associated productive resources. Such a loss would, in turn, make him weaker in future dealings with other lords or kings. Mafia dons, gangs, and warlords face similar conditions in today's Colombia, the former Soviet Union, and Somalia. The same dependence of tomorrow's resources on today's performance can be said to exist for nation-states as well, even though the numerous international institutions and norms of conduct that guard against the violent resolution of disputes might obscure that dependence. Empirically, then, this time dependence is considerably more accurate than is its absence, which is typically assumed for analytical simplicity in formal approaches to conflict and cooperation (for example, Axelrod 1984).

With today's outcome affecting future resources, the adversaries, in considering whether to fight or settle peacefully, have to weigh two opposing effects. On the one hand, because of destruction and other factors, fighting is more costly than settlement. This effect favors peaceful settlement. On the other hand, fighting provides each adversary with a chance to weaken his opponent well into the future, and thus a chance to reduce future arming costs, while securing bigger chunks of the pie. The downside of fighting is, of course, the possibility of defeat and, thus, being stuck in a weaker position relative to the other party in the future. Nevertheless, in expected terms, each side could perceive there to be a positive net benefit from fighting, because the asymmetry in the future could entail much less arming than when the parties are roughly equal. Overall, we find that the more salient is the future, the greater is the benefit of fighting relative to that of negotiation, and therefore the more likely is fighting and war to occur.

In view of our analysis, ethnic and national conflicts that take a destructive turn need not be the result of misunderstandings or irrationality. Rather, such conflict can be considered the outcome of calculated gambles as a consequence of the adversaries' concern for the future.² Similarly, gang or warlord warfare could well be the outcome of long planning horizons with the ultimate objective to eliminate the competition (other gangs or warlords).

As many readers may have noticed, the central result of our analysis contrasts sharply with that of Axelrod (1984) and much of game-theoretic thinking in economics and political science—that a “long shadow of the future” facilitates cooperation.³ Briefly, the difference in the findings is due to the stationary

²Fearon (1998) argues that the Croatian Serbs decided to fight in 1991 precisely because they feared that by simply admitting defeat (i.e., not seceding then) they would be in a relatively weaker position in the future. In particular, living as a minority group in Croatia, the Serbs believed that they would be stripped of their political and economic resources, implying an even smaller probability of a successful secession in the future.

³See also, for example, Fudenberg and Tirole (1991). Of course, these arguments only demonstrate the increased opportunity for cooperation, not its necessity (Garfinkel 1990). In

structure of the game examined by Axelrod and others, a structure which we argue does not adequately represent the situation for many disputes, historically and currently. We do not deny that adversaries who interact repeatedly over time eventually develop mechanisms to manage conflict. But, in a rapidly changing external environment in which the stronger can be expected to get even stronger like those of warlord competition and emerging ethnic disputes, a long shadow of the future is more likely to intensify conflict.

In what follows, we present and analyze a model in which each party chooses between guns and butter. In this model, which is of the type examined by Hirshleifer (1988) among others, the two adversaries cannot "commit" to reduce arms—arming is non-contractible,—but, they can settle under the threat of war. We first consider a static, one-period version of the model in which peaceful settlement is always the preferred outcome. We then move on to a two-period version of the model to establish the central result of our analysis. The dynamic structure of the model is the same as that in Skaperdas and Syropoulos (1996), who emphasize a similar effect of the future's salience on conflict. However, that analysis makes no distinction between fighting and negotiating under the threat of conflict; hence, in that paper, the intensity of conflict is indicated solely by the amount of arming. In this paper, by contrast, fighting and settling are distinct. Each side arms even when peaceful settlement is expected, because arming influences the negotiated outcome. But conflict is identified here only with actual fighting and war. In the concluding section, we briefly discuss the robustness of our findings—specifically, suggesting how relaxing some of the simplifying assumptions would tend to make our results even stronger.

SHORT-RUN INCENTIVES TO SETTLE: THE ONE-PERIOD MODEL

To illustrate the short-run incentives to settle, we first examine a simple one-period model in which actual conflict is destructive.⁴ There are two risk neutral parties, indexed by $i = 1, 2$. Each one is endowed with an initial resource, R_i , which can be converted into guns, G_i , or butter, B_i , according to the following constraint:

$$R_i = B_i + G_i, \quad (1)$$

any case, we have in mind here the sorts of situations where there is a potential problem of committing to the peaceful policy, rather than to the conflictual policy as in the case of terrorism (see, for example, Lapan and Sandler 1988).

⁴There are factors other than the destructiveness of conflict that can induce negotiation: risk aversion (Skaperdas 1991), diminishing returns or complementarity in production and exchange (see Skaperdas and Syropoulos 1997; and Neary 1997). We have chosen to concentrate on the destructiveness of conflict in this paper for simplicity only. Our findings in this and the next section would carry through despite these additional incentives to negotiate in the short-run, but at a great notational and computational expense.

for $i = 1, 2$. Both parties consume butter only. However, neither party has secure possession of its own output of butter, B_i . Rather, all output, $B_1 + B_2$, is contestable, giving each party an incentive to allocate some of the initial resource to guns.

Total output can be disposed in one of two ways: through war which has an uncertain outcome or through a peaceful and certain division in the shadow of war. Guns play a role in both cases. In the case of war, guns determine each side's probability of winning. In the case of settlement, they influence each side's negotiating position and, through that position, the share of butter that each side receives. In particular, the protocol of moves of the two sides can be decomposed into two stages within the single period:

Stage 1. Each side allocates its endowed resources to the production of guns and butter as described in equation (1).

Stage 2. Given these resource allocations, each side chooses whether to go to war or to settle.

We assume that war emerges as an outcome of the second stage if only one side chooses to fight, whereas both sides must choose to settle for settlement to emerge as the outcome. To proceed, we now specify precisely what occurs under war and what occurs under settlement.

IF WAR WERE TO OCCUR

Here we take as given that at least one of the two parties will choose to go to war in the second stage. Guns, in this case, determine each side's probability of winning. Following standard practice, we suppose that party 1's probability of winning is a function, $p(G_1, G_2)$, that takes a value between 0 and 1, is increasing in G_1 , and decreasing in G_2 . Party 2's winning probability is simply $1 - p(G_1, G_2)$. Assuming that both players have access to the same conflict technology, $p(G_1, G_2) = 1 - p(G_1, G_2) = \frac{1}{2}$ whenever $G_1 = G_2$. Furthermore, we suppose that war destroys a fraction, $1 - \phi$ where $\phi \in (0, 1)$, of the total output which, given (1), equals $R_1 - G_1 + R_2 - G_2$. Therefore, the output that remains after combat is $\phi(R_1 - G_1 + R_2 - G_2)$.

The winner of the war receives all that remaining output, whereas the loser receives nothing. For any given combination of G_1 and G_2 chosen by the two parties in the first stage, the expected payoffs for party 1 and for party 2 in the event of war respectively are as follows:

$$U_1^w(G_1, G_2) = p(G_1, G_2)\phi(R_1 - G_1 + R_2 - G_2), \quad (2a)$$

$$U_2^w(G_1, G_2) = [1 - p(G_1, G_2)]\phi(R_1 - G_1 + R_2 - G_2). \quad (2b)$$

These are the payoffs that each side would expect in the event of a war.

WHY SETTLEMENT IS PREFERABLE IN THE SHORT-RUN

The fact that war is destructive readily implies that, for any given allocation of the endowment in stage 1, both parties would prefer to settle. Specifically, having already chosen G_i , the two parties could bargain over the share of total output that each would obtain, α for party 1 and $1 - \alpha$ for party 2 where $\alpha \in (0, 1)$, without fighting to obtain a certain payoff which is higher than the expected payoff shown in (2a) or (2b) for $\phi < 1$. As shown in Figure 1, all divisions of output along the line segment AC yield at least as high a payoff for both parties as that under war, which is indicated by W . The smaller is ϕ , the closer is W to the origin and the larger is the set of divisions of output that are preferable to war.

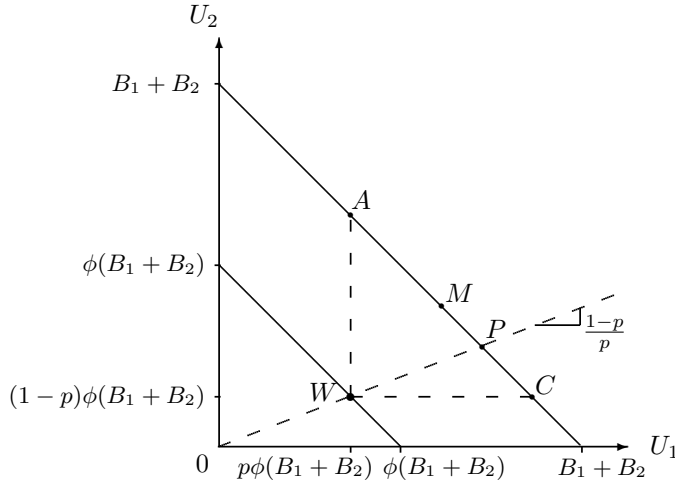


Figure 1: War and settlement outcomes

To fix ideas, we assume throughout the analysis a particular rule for dividing total output under settlement for a given choice of guns and butter. One possible rule would be to divide output in accordance with the winning probabilities; point P in Figure 1 shows the equilibrium payoffs under settlement with that rule. Such a rule, however, is arbitrary from the point of view of the long-standing literature on bargaining that studies precisely that problem. In particular, all symmetric axiomatic bargaining solutions prescribe, in cases of a linear frontier as shown in the figure, the midpoint M as the appropriate out-

come. The payoffs under settlement with this *split-the-surplus* rule of division⁵ are as follows:

$$U_1^s(G_1, G_2) = [\phi p(G_1, G_2) + \frac{1}{2}(1 - \phi)](R_1 - G_1 + R_2 - G_2), \quad (3a)$$

$$U_2^s(G_1, G_2) = [\phi(1 - p(G_1, G_2)) + \frac{1}{2}(1 - \phi)](R_1 - G_1 + R_2 - G_2). \quad (3b)$$

As shown in these expressions, each party's share of total output is a weighted combination of two possible rules: (i) the probabilistic contest success function, $p(G_1, G_2)$ and (ii) a 50-50 split of the output outright. The relative weights are determined by the destruction parameter $1 - \phi$. When ϕ is smaller implying that more output is destroyed in combat, the contest success function plays a smaller role in the determination of the distribution of output under settlement; hence, when ϕ is smaller, each side's choice of guns has a smaller impact on the settlement outcome. A comparison of the payoffs under settlement, (3a) and (3b), with those under war, (2a) and (2b), reveals immediately that for any given allocation of the initial resource, G_i for $i = 1, 2$, settlement is preferable to war. This relative preference is greater, the more destructive is war (i.e., the smaller is ϕ).

COMPARING EQUILIBRIA UNDER WAR AND SETTLEMENT

While it is clear that both parties would prefer to settle in the second stage of the game, it is still instructive to compare the Nash equilibria under the two possibilities: under war with the payoff functions in (2a) and (2b) and under settlement with the payoff functions in (3a) and (3b). In particular, these solutions reveal an additional benefit to settlement over war. To proceed, we assume a specific functional form for the contest success function, $p(G_1, G_2)$:

$$p(G_1, G_2) = \frac{G_1}{G_1 + G_2}, \quad (4)$$

This specification is the one most commonly adopted in the literature.⁶

WHEN THERE IS WAR

⁵This rule can be found by simply setting $U_1^s - U_1^w = U_2^s - U_2^w$ for any given G_1, G_2 where U_i^w is as shown in (2a) and (2b) for $i = 1, 2$ respectively and $U_1^s = \alpha(R_1 - G_1 + R_2 - G_2)$ and $U_2^s = (1 - \alpha)(R_1 - G_1 + R_2 - G_2)$: $\alpha = \phi p(G_1, G_2) + \frac{1}{2}(1 - \phi)$. See Roth (1979) for an overview of axiomatic bargaining theory. Among applied areas of economics that have employed the same split-the-surplus approach is the one on the property-rights theory of the firm that began with Grossman and Hart (1986).

⁶To our knowledge, it was first used by Tullock (1980). Hirshleifer (1989) discusses its properties.

In a Nash equilibrium, each party $i = 1, 2$ chooses its allocation, G_i , to maximize its individual expected payoff, (2a) for party 1 and (2b) for party 2, subject to (4) and taking the other party's allocation as given. Assuming an interior solution, the first-order conditions to party 1's and party 2's optimization problems are given respectively by

$$\frac{\partial U_1^w}{\partial G_1} = \frac{\phi G_2}{(G_1 + G_2)^2} [R_1 + R_2 - G_1 - G_2] - \frac{\phi G_1}{G_1 + G_2} = 0, \quad (5a)$$

$$\frac{\partial U_2^w}{\partial G_2} = \frac{\phi G_1}{(G_1 + G_2)^2} [R_1 + R_2 - G_1 - G_2] - \frac{\phi G_2}{G_1 + G_2} = 0. \quad (5b)$$

In both expressions the first term represents the marginal benefit of allocating one more unit of the endowment to appropriation in terms of the implied increase in the share of total output it yields for that party. The second term is the marginal cost of doing so in terms of the resulting decrease in total output weighted by party i 's share of total output. At the interior optimum where $G_1^w \in (0, R_1)$ and $G_2^w \in (0, R_2)$, this marginal cost is balanced against the marginal benefit.⁷

Simultaneously solving (5a) and (5b) yields the equilibrium choices of guns, G_i^w , and the expected payoffs of the two parties under war, U_i^w :

$$G_1^w = G_2^w = \frac{1}{4}(R_1 + R_2), \quad (6a)$$

$$U_1^w = U_2^w = \frac{1}{4}\phi(R_1 + R_2). \quad (6b)$$

As revealed by this solution, the two sides make the same choice of guns, implying $p = \frac{1}{2}$ and thus identical expected payoffs for the two parties even though the distribution of the initial resource might be asymmetric.⁸ In addition, notice from (6b) that the expected payoffs under war are lower than those in the "Nirvana" state in which all resources are converted to butter so that total output equals $R_1 + R_2$. This ranking of payoffs is hardly surprising, since in the event

⁷As one can easily verify using (6a) and (6b) below, an interior equilibrium obtains if the initial resources of the two parties are not too dissimilar: $\frac{1}{3} \leq R_1/R_2 \leq 3$. If this condition is not satisfied, then the side with the smaller endowment devotes all of its resources to guns, and the symmetric equilibrium summarized by equations (6a) and (6b) has no relevance. Because our findings carry through in this asymmetric case, but at a greater notational and computational burden, we focus only on cases where an interior solution obtains.

⁸The symmetry of this solution is not a general feature of (interior) equilibria in models of conflict when the players have different initial resources. Rather, it follows from the assumed production technology (1) and the assumption that the two parties are risk neutral. If these assumptions were relaxed, the outcome would be asymmetric: the player with the greater endowment would produce more guns and thereby obtain a greater payoff (see Skaperdas and Syropoulos 1997). Nevertheless, our central findings would remain intact. If anything, our findings would be stronger, because the dependence of each party's payoff on its own initial resources would be stronger.

of a war between the two parties, some of resources are used for arming and a fraction $(1 - \phi)$ of output is destroyed.

WHEN THERE IS SETTLEMENT

Anticipating settlement in the second stage, each party $i = 1, 2$ chooses $G_i = R_i - B_i$ to maximize its individual (certain) payoff, (3a) for agent 1 and (3b) for agent 2, subject to (4) and taking the other agent's allocation as given. The first-order conditions to party 1's and party 2's optimization problems are given respectively by—

$$\frac{\partial U_1^s}{\partial G_1} = \frac{\phi G_2}{(G_1 + G_2)^2} [R_1 + R_2 - G_1 - G_2] - \left[\frac{\phi G_1}{G_1 + G_2} + \frac{1 - \phi}{2} \right] = 0, (7a)$$

$$\frac{\partial U_2^s}{\partial G_2} = \frac{\phi G_1}{(G_1 + G_2)^2} [R_1 + R_2 - G_1 - G_2] - \left[\frac{\phi G_2}{G_1 + G_2} + \frac{1 - \phi}{2} \right] = 0, (7b)$$

assuming an interior solution.⁹ Solving (7a) and (7b) yields the following Nash equilibrium choices of guns, G_i^s , and payoffs, U_i^s , under settlement:

$$G_1^s = G_2^s = \frac{\phi}{2(1 + \phi)} (R_1 + R_2), \quad (8a)$$

$$U_1^s = U_2^s = \frac{1}{2(1 + \phi)} (R_1 + R_2). \quad (8b)$$

Given that $\phi < 1$, the payoffs under settlement (8b) are unambiguously higher than those under war (6b). But this preference for settlement is not simply a matter of avoiding the destruction of war. Recall from (3) that, by virtue of the split-the-surplus rule of division given $\phi < 1$, each side's gun allocation has less relevance for the outcome under settlement than under war. Hence, the anticipation of settlement induces less arming (8a) than does the anticipation of war (6a).¹⁰ Therefore, within this static setting, it would appear that settling is overwhelmingly better than going to war for both parties.

⁹In this case, an interior solution requires $\frac{\phi}{2 + \phi} < \frac{R_1}{R_2} < \frac{2 + \phi}{\phi}$. That is, as in the case of war, the initial resource endowments should not be too far apart. The condition here, however, is weaker: if $\phi < 1$, this condition is satisfied whenever an interior solution obtains under war (see footnote 7).

¹⁰If war were not destructive ($\phi = 1$), the level of arming and the equilibrium payoffs under war and settlement would be identical. We should mention that in other, more complex environments, the anticipation of settlement need not induce less arming than the anticipation of conflict. See, for example, Anbarci et. al. (1999) who, in examining the sensitivity of the adversaries' arming choices to the rule of division under settlement, demonstrate the possibility that some rules of division could induce more arming than would conflict. Of course, if arming were higher under settlement than under conflict in our model, settlement would be even less appealing than it is now, making the effect of the future that we examine below even stronger.

WHEN THE FUTURE MATTERS

Contrary to the timeless environment we have just examined, actual persons, organizations and states have both a history and a future horizon. Still, if the past and the expected future were similar but unrelated to the present, then the model of the previous section could be considered an adequate representation of the incentives to go to war. But, in conflictual situations, the present affects the future in ways that fundamentally change the initial conditions of the future. Specifically, doing well relative to your opponent today enhances your chances of doing better in the future. Through this intertemporal link, the uncertain but compounding rewards of war could very well swamp the (static) incentives for settlement identified in the previous section.

To explore this possibility, consider an extended version of the one-period model developed in the previous section. In particular, there are two periods. Let R_{it} denote the initial resource for each player $i = 1, 2$ in period $t = 1, 2$. The resources available at the beginning of the first period R_{i1} for $i = 1, 2$ are given as before. Second-period resources, however, depend on how well a side has done in the first period. For simplicity, suppose that the resources available to party i in the second period, R_{i2} for $i = 1, 2$, are positively related to the *realized* payoff received by that party in the first period, U_{i1} :

$$R_{i2} = \gamma U_{i1}, \quad \gamma > 0, \quad (9)$$

for $i = 1, 2$. This expression implies that, in the event of a war in the first period, the losing party receives nothing in the first period and, thus, has no resources in the second period.¹¹ In this case, the other party is able to enjoy its entire initial resource in the second period without having to arm.¹²

The sequence of actions within each period is as specified in the model of the previous section: In the first stage, each side allocates its resources among the production of guns and butter; and, in the second stage, they decide whether to go to war or settle. In this dynamic setting, actions taken in both stages of the first period influence the amount of resources available to them in the second period. Rational, forward-looking parties will take this influence into

¹¹In a more general setting such as Skaperdas and Syropoulos (1997) wherein the production technology exhibits diminishing returns and complementarity in the two parties' inputs, the qualitative results of this paper would follow through with a less extreme assumption. All that would be required is that the defeated side's second-period initial resource is sufficiently small relative to that of the victor as a result of combat.

¹²Strictly speaking, with the contest success function in (4), that party would have to devote some resources to arming. However, it need only devote an infinitesimal amount of resources to guns to gain full possession of the entire output of butter. But, to keep matters simple, we suppose that a party who receives nothing in the first period simply cannot participate in the second period of the game.

account when making their first-period choices. But, to do so, they need to know what would occur in the second period for each possible outcome (war and settlement) in the first period. This perspective accords with the notion of *subgame perfection*, an appropriate equilibrium concept for such dynamic games. We therefore solve the model backwards, starting from the second and final period.

PRELIMINARIES: THE SECOND-PERIOD OUTCOME

In the second and final period of the game, neither side has to consider the effects of their choices for the future; there is no future beyond that period. Hence, the conditions and constraints effective in the second period are identical to those in the single-period model of the previous section.

WHEN THERE IS SETTLEMENT IN THE FIRST PERIOD

When both sides have received positive payoffs in the first period the resources in the second period are positive as well [see equation (9)]. Since the conditions are identical to those described in section 2, it is clear that both sides would strictly prefer to settle. The level of arming and equilibrium payoffs in the second period would be those shown respectively in (8a) and (8b), where the amount of resources available at the beginning of the period, R_{i2} , is given by (9). Hence, by substituting (9) into (8b), we can write the second-period payoffs U_{i2} for $i = 1, 2$, given any realization of payoffs in the first period, as:

$$U_{12}(U_{11}, U_{21}) = U_{22}(U_{11}, U_{21}) = \frac{\gamma}{2(1 + \phi)}(U_{11} + U_{21}), \quad (10)$$

where $U_{11}, U_{21} > 0$.

WHEN THERE IS WAR IN THE FIRST PERIOD

By contrast, when there is war in the first period, the winning party enjoys all of its resources in the second period, whereas the loser receives zero payoff and, thus, cannot participate in the second period. In effect, the loser is eliminated. Consequently, given that war breaks out in the first period, the second-period payoffs are given by:

$$U_{i2}(U_{11}, U_{21}) = \gamma U_{i1}, \quad (11)$$

for $i = 1, 2$, where either $U_{11} = 0$ and $U_{21} > 0$ or $U_{11} > 0$ and $U_{21} = 0$.

SETTLEMENT OR WAR? FIRST-PERIOD CHOICES

In the first period, each party cares about the sum of the payoffs it will receive over the two periods. That is, party i 's two-period objective function is described by¹³:

$$V_i = U_{i1} + U_{i2}, \quad (12)$$

for $i = 1, 2$. As revealed by equations (10) and (11), second-period payoffs depend on first-period payoffs. In effect, then, the two-period payoffs, V_i , depend on what occurs in the first period only—that is, on the party's first-period arming and war-or-settlement decisions. As such, the war and settlement payoffs are not as they were in (2a) and (2b) and (3a) and (3b) respectively. In this dynamic setting, the two period payoff (12) must take the spillover effects of the players' first-period choices, captured by equations (10) and (11), into account.

WHEN THERE IS WAR

Using (11) and (12) and letting p denote side 1's probability of winning in period $t = 1$, the war payoffs are:

$$\begin{aligned} V_1^w &= p[\phi(R_{11} - G_{11} + R_{21} - G_{21}) + \gamma\phi(R_{11} - G_{11} + R_{21} - G_{21})] \\ &= p\phi(1 + \gamma)(R_{11} - G_{11} + R_{21} - G_{21}), \end{aligned} \quad (13a)$$

$$\begin{aligned} V_2^w &= (1 - p)[\phi(R_{11} - G_{11} + R_{21} - G_{21}) + \gamma\phi(R_{11} - G_{11} + R_{21} - G_{21})] \\ &= (1 - p)\phi(1 + \gamma)(R_{11} - G_{11} + R_{21} - G_{21}). \end{aligned} \quad (13b)$$

Keep in mind that these payoffs are *ex ante*: the two-period payoff realized by the winner of the first-period war weighted by the party i 's probability of winning.

WHEN THERE IS SETTLEMENT

The division of output negotiated in the first period under settlement determines the amount of resources each party receives in the second period. Let $\alpha \in (0, 1)$ denote the share received by side 1 in stage 2 of the first period, given G_{i1} and the sharing rule negotiated in the second period under settlement.¹⁴ Then, the

¹³The second period payoff is not discounted to keep the notation to a minimum. The role of the discount factor would be formally identical to that of γ . A higher discount factor (or, a longer "shadow of the future") would increase the range of parameters for which war is the equilibrium strategy in the first period. See Skaperdas and Syropoulos (1996) who examine the effect of the discount factor on the parties' incentives to arm in detail.

¹⁴The determination of this share, which is briefly discussed below, takes as given the share received by side 1 in the second period, which we now denote by $\tilde{\alpha}$: $\tilde{\alpha} = \phi p(G_{12}, G_{22}) + \frac{1}{2}(1 - \phi)$.

two-period payoffs under settlement, using (10) and (12), can be written as

$$\begin{aligned} V_1^s &= \alpha(R_{11} - G_{11} + R_{21} - G_{21}) + \frac{\gamma}{2(1+\phi)}(R_{11} - G_{11} + R_{21} - G_{21}) \\ &= \left(\alpha + \frac{\gamma}{2(1+\phi)}\right)(R_{11} - G_{11} + R_{21} - G_{21}), \end{aligned} \quad (14a)$$

$$\begin{aligned} V_2^s &= (1-\alpha)(R_{11} - G_{11} + R_{21} - G_{21}) + \frac{\gamma}{2(1+\phi)}(R_{11} - G_{11} + R_{21} - G_{21}) \\ &= \left(1-\alpha + \frac{\gamma}{2(1+\phi)}\right)(R_{11} - G_{11} + R_{21} - G_{21}). \end{aligned} \quad (14b)$$

In contrast to the two-period payoffs under war (13a) and (13b), the payoffs under settlement shown above are certain.

For any given combination of guns (G_{i1} , $i = 1, 2$), both sides would be willing to settle only if there exists at least one α such that $V_i^s \geq V_i^w$ for both $i = 1, 2$. No such α exists if $p = \frac{1}{2}$ ¹⁵ and

$$\phi(1+\gamma) > 1 + \frac{\gamma}{1+\phi}. \quad (15)$$

Note that this condition is always satisfied in the limiting case when war is not destructive ($\phi = 1$), since in this case the war and settlement payoffs in the first period are identical. Going to war in the first period, however, effectively eliminates one of the opponents in the second period and hence the need to arm in that period. In other words, in the special case where $\phi = 1$, waging war in the first period yields a net total and individual benefit in the first period. This benefit derives from the one-sided ‘‘pacification’’ resulting from the elimination of one of the two parties in the second period.

More generally, when $\phi < 1$, each party’s preference for war is limited by the destruction it causes. Nonetheless, the possibility of war remains. Its emergence depends on the sensitivity of second-period resources to first-period payoffs—i.e., the value of γ . There is a critical value of ϕ , call it $\hat{\phi}(\gamma)$, such that for ϕ strictly greater than $\hat{\phi}(\gamma)$, (15) is satisfied. This critical value is given by:

$$\hat{\phi}(\gamma) = \frac{\sqrt{4 + 8\gamma + 5\gamma^2} - \gamma}{2(1+\gamma)}. \quad (16)$$

Figure 2 shows the function $\hat{\phi}(\gamma)$. For combinations of ϕ and γ above $\hat{\phi}(\gamma)$, there is no division of the first-period output of butter that is preferable to war. Despite war’s destructive quality, both parties prefer the uncertain, but

¹⁵As shown below and as was the case in the one-period model, $p = \frac{1}{2}$ always holds in equilibrium. When $p \neq \frac{1}{2}$ the conditions for finding such an α are even more stringent.

compounded rewards of war to the certain payoffs obtained under settlement. Again, the key to this result is that war brings with it not simply the chance of taking the whole output that remains after combat, but also the potentially even more appealing chance of not having an opponent at all in the second period. As shown in Figure 2, the greater is the value of tomorrow’s resources R_{i2} given today’s payoffs U_{i1} , as indicated by the magnitude of γ , the larger is the set of values for ϕ that would be consistent with a preference for war over settlement. That is, a greater spillover effect means that each party has a greater tolerance for destruction of war.

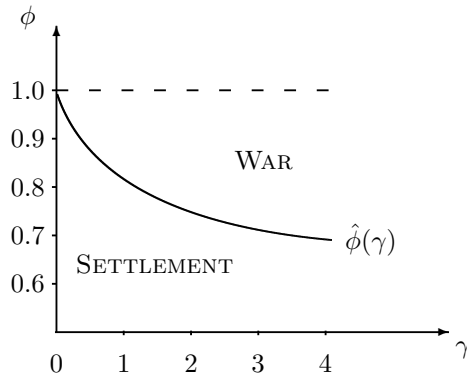


Figure 2: The critical value of ϕ

For combinations of parameters below $\hat{\phi}(\gamma)$ in Figure 2, settlement is preferable to war. Under such conditions, the destruction of output under war is sufficiently large and the future is sufficiently unimportant to make settlement preferable to war for both parties.

ARMING UNDER WAR AND UNDER SETTLEMENT

Our analysis of the incentives for going to war and those for settling makes no reference to the equilibrium choices of guns versus butter. Rather, we have shown how war or settlement would be induced in the first period for any given choice of G_{i1} , not for the equilibrium choices, G_{i1}^w and G_{i1}^s , which may differ. Hence, to complete our analysis, we now derive the Nash equilibrium choices under war and under settlement.

The optimizing choice of guns for each party, G_{i1} $i = 1, 2$, under war maximizes the party’s expected payoff, (13a) for $i = 1$ and (13b) for $i = 2$, taking the other side’s strategy as given. Based on the first-order conditions analogous to (5a) and (5b), one can easily verify that the Nash equilibrium gun choices

and payoffs are given respectively by

$$G_{11}^w = G_{21}^w = \frac{1}{4}(R_{11} + R_{21}), \quad (17a)$$

$$V_1^w = V_2^w = \frac{1}{4}\phi(1 + \gamma)(R_{11} + R_{21}). \quad (17b)$$

Indeed, these choices are identical to those under war in the one-period model [see equation (6a)], a consequence of the fact that the two-period payoffs under war, (13a) and (13b), are multiples of the one-period war payoffs, (2a) and (2b).¹⁶

To derive the equilibrium choices under settlement, we must specify the value of α in the payoff functions, (14a) and (14b). Suppose as before that the surplus is split between the two parties. Then, for each choice of guns and implied probability of winning for party 1, p , it can be shown¹⁷ that

$$\alpha = \frac{1}{2}[1 + (2p - 1)\phi(1 + \gamma)].$$

Using the payoff functions under settlement given by (14a) and (14b) with this value of α , one can verify that the equilibrium allocations, G_i^s , and payoffs, V_i^s , under settlement are given respectively by

$$G_{11}^s = G_{21}^s = \frac{\frac{1}{2}\phi(1 + \gamma)}{\frac{1+\phi+\gamma}{1+\phi} + \phi(1 + \gamma)}(R_{11} + R_{21}), \quad (18a)$$

$$V_1^s = V_2^s = \frac{\frac{1}{2}\left(\frac{1+\phi+\gamma}{1+\phi}\right)^2}{\frac{1+\phi+\gamma}{1+\phi} + \phi(1 + \gamma)}(R_{11} + R_{21}), \quad (18b)$$

assuming an interior solution.¹⁸

Comparing the equilibrium payoffs under settlement (18b) with those under war (17b) reveals that a necessary and sufficient condition for war to be preferred *ex ante* or before resources have been allocated is:

$$\left[\phi(1 + \gamma) - \frac{1 + \phi + \gamma}{1 + \phi} \right] \left[\phi(1 + \gamma) + \frac{2(1 + \phi + \gamma)}{1 + \phi} \right] > 0. \quad (19)$$

¹⁶This is true in similar models—see, for example, Hirshleifer (1988).

¹⁷As in the one period model, this value of α equates the difference between the payoffs under settlement and those under war for the two players for any given G_{11} and G_{21} : $V_1^s - V_1^w = V_2^s - V_2^w$.

¹⁸The condition ensuring an interior solution is

$$\frac{\phi(1 + \gamma)}{\frac{2(1+\phi+\gamma)}{1+\phi} + \phi(1 + \gamma)} < \frac{R_{11}}{R_{21}} < \frac{\frac{2(1+\phi+\gamma)}{1+\phi} + \phi(1 + \gamma)}{\phi(1 + \gamma)}.$$

This condition is stronger than that in the one-period case under settlement (see footnote 9). But, it is stronger than the analogous condition under war only if the inequality in equation (15) holds, in which case $G_{i1}^s > G_{i1}^w$.

One can easily verify that this expression holds if and only if (15) is true. Therefore, war is preferred to settlement *ex ante* if and only if war is preferred to settlement *ex post*—that is, in the second stage of the first period after resources have been allocated. In other words, the incentives to wage a war and those to settle before any resources have been allocated to guns and butter are identical to those after resources have been allocated.

CONCLUDING REMARKS

Despite the presence of incentives to settle in the short run, the future's salience and the compounding rewards that the winner of conflict can receive might actually induce all rational parties to choose war over settlement. Neither misperceptions nor incomplete information about the other side's preferences, capabilities, and other attributes are necessary.

To communicate the basic idea of this paper, we have kept the model as simple as possible. The findings, however, are general and they can become even stronger when the simplifying assumptions are relaxed. Extending the model's time horizon additional periods would, if anything, amplify the rewards to war relative to peaceful settlement. Such an extension would essentially amount to increasing the size of the growth parameter, γ , which as can be seen in Figure 2 increases the range of the destruction parameter, $-\phi$, for which war is an equilibrium outcome. Allowing for more complex production structures would make each party's equilibrium arming and payoff depend positively on its own resources as was the case with the simple production structure adopted here, but also depend negatively on the opponent's resources. Given the dependence of future resources on current payoffs, this property of a more general production structure would augment the rewards to having more resources, thereby making the incentives to go to war similarly stronger.

In the environment we have examined, settlements are based in part on the relative abilities of the two sides to prevail in the event of war, which in turn depend on the amount of arming undertaken by the adversaries. Of course, the problems of war and arming could disappear if the two sides could make an enforceable contract or a believable commitment not to arm in the future. What our model makes transparent is the importance of such long-term commitment devices for the avoidance of war and the reduction of arming. Hence, enforceable laws, courts, norms, and other institutions of conflict management at both the domestic and international levels should not be seen merely as a "veil" without any relevance for the choices made by the interested parties. To the contrary, these institutions play a critical role. How such institutions

evolve out of conditions like those we have examined here is obviously a very important topic, for research as well as of practical concern.

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