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Conflict Without Misperceptions or Incomplete Information: How the Future Matters

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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 and similar open forms of conflict are often attributed to misperceptions, misunderstandings, or simply to irrationality and base instincts. Within economics, where irrationality and instinctual behavior are ruled out by assumption, 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

[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. For modeling under incomplete information of such forms of conflict, see Brito and Intrilligator (1985) and more recently Bester and Warneryd (1998).

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 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, in 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 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. 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 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. Briefly, the difference in the findings is due to the stationary 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 analyze a model in which each party makes choices between guns and butter; it is of the type examined by Hirshleifer (1988) and others. 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 similar to that of Skaperdas and Syropoulos (1996), who emphasize the different 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.[2] There are two risk neutral parties, indexed by $i = 1, 2$. Each one is endowed with an initial resource, R_i, which can be

[2]There 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.

converted into guns, G_i, or butter, B_i, according to the following constraint:

$$R_i = B_i + G_i \tag{1}$$

for $i = 1, 2$. Both parties consume only butter. 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 (W) or to settle (S).

The possible outcomes given the choices of the two parties are depicted in Figure 1. As shown in the figure, war (W) emerges as an outcome if only one side chooses to fight, whereas both sides must choose to settle for settlement (S) 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 $1 - p(G_1, G_2)$. 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 are respectively as follows:

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

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

These are the payoffs that each side would expect in the outcomes (cells) labeled W in Figure 1.

WHY SETTLEMENT IS PREFERABLE

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, whereby each could enjoy a greater consumption of butter. If, for example, each party were to receive a share of output that equals its winning probability, it would have a certain payoff which is higher than the expected payoff shown in (2a) or (2b). However, this particular division of output is not the only one that would be preferable to war. As shown in Figure 2, all divisions of output along the line segment AC yield at least as high a payoff as that under war, which is indicated by W. Note that the smaller ϕ is, the closer is W to the origin and the greater is the set of divisions of output that are preferable to war.

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. As mentioned above, dividing output in accordance with the winning probabilities would be one particular rule of settlement; point P in Figure 2 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, given the linearity of the frontier as shown in Figure 2, all symmetric axiomatic bargaining solutions prescribe the midpoint M as the appropriate outcome.

The payoffs under settlement (S) with this *split-the-surplus* rule of division, [3] are as follows:

$$U_1^s(G_1, G_2) = [\phi p(G_1, G_2) + (1-\phi)/2](R_1 - G_1 + R_2 - G_2) \quad \text{(3a)}$$
$$U_2^s(G_1, G_2) = [\phi(1 - p(G_1, G_2)) + (1-\phi)/2](R_1 - G_1 + R_2 - G_2) \quad \text{(3b)}$$

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, $p(G_1, G_2)$:

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

[3]This rule can be found as the solution to $\max_\alpha (U_1^s - U_1^w)(U_2^s - U_2^w)$ for any given G_1, G_2 where U_i^w is as given in (2a) and (2b) for $i = 1, 2$ respectively and $U_1^s = \alpha(R_1 - G_1 + R_2 - G_2)$ and $U_2^s = (1-\alpha)(R_1 - G_1 + R_2 - G_2)$. 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).

This specification is the one most commonly adopted in the literature.[4]

WHEN THERE IS WAR

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—

$$\frac{\partial U_1^w}{\partial G_1} = \frac{\phi G_2}{(G_1+G_2)^2}[R_1 + R_2 - G_1 - G_2] - \frac{\phi G_1}{G_1+G_2} = 0 \qquad (5a)$$
$$\frac{\partial U_2^w}{\partial G_2} = \frac{\phi G_1}{(G_1+G_2)^2}[R_1 + R_2 - G_1 - G_2] - \frac{\phi G_2}{G_1+G_2} = 0 \qquad (5b)$$

The first term in both expressions 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.[5]

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:

$$G_1^w = G_2^w = \frac{R_1 + R_2}{4} \qquad (6a)$$
$$U_1^w = U_2^w = \frac{1}{4}\phi(R_1 + R_2) \qquad (6b)$$

As revealed by this solution, the two sides make the same choice of guns and receive the same payoffs even though the distribution of the initial resource might be asym-

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

[5] As 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: $1/3 \leq R_1/R_2 \leq 3$. 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 greater notational and computational burden, we focus only on cases where an interior solution obtains.

metric.[6] 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 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, (4) for agent 1 and (5) for agent 2, subject to (6) 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—

$$\frac{\partial U_1^s}{\partial G_1} = \frac{\phi G_2}{(G_1 + G_2)^2}[R_1 + R_2 - G_1 - G_2] - \left[\frac{\phi G_1}{G_1 + G_2} + \frac{1-\phi}{2}\right] = 0 \quad (7a)$$
$$\frac{\partial U_2^s}{\partial G_2} = \frac{\phi G_1}{(G_1 + G_2)^2}[R_1 + R_2 - G_1 - G_2] - \left[\frac{\phi G_2}{G_1 + G_2} + \frac{1-\phi}{2}\right] = 0 \quad (7b)$$

assuming an interior solution.[7] 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

[6]The 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 assumption 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.

[7]In 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. Note, that the condition here is weaker: if $\phi < 1$, this condition is satisfied whenever as an interior solution obtains under war [see footnote (5)]

avoiding the destruction of war. When $\phi < 1$, the anticipation of settlement induces less arming (8a) than does the anticipation of war (6a).[8] Therefore, within this static setting, it would appear that settling is overwhelmingly better than going to war for both parties.

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. If the past and the expected future were similar but unrelated to the present, then the model of the previous section could be considered to be an adequate representation of the incentives to settle or go to war.[9] If, however, the present affects the future in ways that fundamentally change the initial conditions of the future, then the incentives for war and settlement can change fundamentally as well.

When it comes to conflictual environments, there is an obvious channel through which today's outcomes can affect the future. Specifically, doing well relative to your opponent today will enhance your chances of doing better in the future. Through this channel, 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

[8] If war were not destructive ($\phi = 1$), the level of arming and the equilibrium payoffs under war and settlement would be identical. Hence, the destructive element of war is an essential feature of this analysis where the parties are assumed to be risk neutral and production exhibits neither diminishing returns nor complementarities in its inputs.

[9] Of course, in such stationary environments, there is the possibility of cooperation through the long-term relationships that have been amply examined in game theory [see, for example, Fudenberg and Tirole (1991)] and political science [Axelrod (1984)]. These arguments, though, only demonstrate the possibility of cooperation, not its necessity [Garfinkel (1990)]. Moreover, once we allow for non-stationarities of the type examined in this section, a longer "shadow of the future" can aggravate conflict [Skaperdas and Syropoulos (1996)].

the first period, U_{i1}:

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

for $i = 1, 2$. This expression implies that, if one of the two sides were to receive nothing in the first period, then it would have no resources in the second period; in this case, the other party would be able to enjoy its resources in the second period without having to arm.[10]

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 as indicated in Table 1. 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 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 concept 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

[10]Strictly 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.

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

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

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—

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

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 by[11]

$$V_i = U_{i1} + U_{i2} \tag{12}$$

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

Letting p_1 denote side $1's$ probability of winning in period $t = 1$, the war payoffs are:

$$\begin{aligned} V_1^w &= p_1[\phi(R_{11} - G_{11} + R_{21} - G_{21}) + \gamma\phi(R_{11} - G_{11} + R_{21} - G_{21})] \\ &= p_1\phi(1+\gamma)(R_{11} - G_{11} + R_{21} - G_{21}) \qquad (13a) \\ V_2^w &= (1-p_1)[\phi(R_{11} - G_{11} + R_{21} - G_{21}) + \gamma\phi(R_{11} - G_{11} + R_{21} - G_{21})] \\ &= (1-p_1)\phi(1+\gamma)(R_{11} - G_{11} + R_{21} - G_{21}) \qquad (13b) \end{aligned}$$

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 negotiated division of output in the first period under settlement, in turn, determines the amount each party receives in the second period. Let $\alpha \in (0, 1)$

[11]The 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. In a model that does not allow for a distinction between war and settlement but which has a similar structure to the one here, Skaperdas and Syropoulos (1996) examine the effect of the discount factor in detail.

denote the share received by side 1 (in stage 2 of the first period, given G_{i1}). Then, the two-period payoffs under settlement, using (10) and (12), can be written as

$$\begin{aligned} V_1^s &= \alpha(R_{11} - G_{11} + R_{21} - G_{21}) + \frac{\gamma}{2(1+\phi)}(R_{11} - G_{11} + R_{21} - G_{21})] \\ &= (\alpha + \frac{\gamma}{2(1+\phi)})(R_{11} - G_{11} + R_{21} - G_{21}) \qquad (14a) \\ V_2^s &= (1-\alpha)(R_{11} - G_{11} + R_{21} - G_{21}) + \frac{\gamma}{2(1+\phi)}(R_{11} - G_{11} + R_{21} - G_{21})] \\ &= (1 - \alpha + \frac{\gamma}{2(1+\phi)})(R_{11} - G_{11} + R_{21} - G_{21}) \qquad (14b) \end{aligned}$$

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 $p_1 = 1/2$ and[12]

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

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

[12]As shown below, $p_1 = \frac{1}{2}$ always in equilibrium. When $p_1 \neq 1/2$ the conditions for finding such an α are even more stringent.

than $\hat{\phi}(\gamma)$, (15) is satisfied. This critical value is given by—

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

Figure 3 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 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 3, 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.

For combinations of parameters below $\hat{\phi}(\gamma)$ in Figure 3, 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, our analysis has 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 versify that the Nash equilibrium gun choices and payoffs are given respectively by

$$G_{11}^w = G_{21}^w = \frac{R_{11}+R_{21}}{4} \tag{17a}$$

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

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).[13]

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_1, it can be shown[14] that

$$\alpha = \tfrac{1}{2}[1+(2p_1-1)\phi(1+\gamma)]$$

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

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

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

assuming an interior solution.[15]

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[13]This is true in similar models—see, for example, Hirshleifer (1991).

[14]As in the one period model, this value of α maximizes the product of the difference between the payoffs under settlement and those under war for the two players for any given G_{11} and G_{21}, $(V_1^s - V_1^w)(V_2^s - V_2^w)$.

[15]The 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 footnote7]. But, it is stronger than the analogous condition under war only if the inequality in equation (15) holds, in

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—

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

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 horizons to additional periods would, if anything, increase 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 3 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

which case $G_{i1}^{s} > G_{i1}^{w}$.

of a more general production structure would augment the rewards to having more resources, thereby making the incentives to go to war similarly stronger.

References

Axelrod, Robert. 1984. *The evolution of cooperation.* New York: Basic Books.

Bester, Helmut, and Karl Warneryd. 1998. Conflict resolution under asymmetric information. Working paper.

Brito, Dagobert L. and Michael D. Intriligator. 1985. Conflict, war, and redistribution. *American Political Science Review.* 79:943-57.

Fudenberg, Drew, and Jean Tirole. 1991. *Game theory.* Cambridge, MA: MIT Press.

Garfinkel, Michelle R. 1990. Arming as a strategic investment in a cooperative equilibrium. *American Economic Review.* 80:50-68.

Grossman, Sanford, and Oliver Hart. 1986. The costs and benefits of ownership. *Journal of Political Economy.* 94:691-719.

Hirshleifer, Jack. 1988. The analytics of continuing conflict. *Synthese.* 76:201-33.

Hirshleifer, Jack. 1989. Conflict and rent-seeking success functions: ration vs. difference models of relative success. *Public Choice.* 63:101-12.

Neary, Hugh M. 1997. Equilibrium structure in an economic model of conflict. *Economic Inquiry* 35:480-94.

Roth, Alvin. 1979. *Axiomatic models of bargaining.* New York: Springer Verlag.

Skaperdas, Stergios. 1991. Conflict and attitudes toward risk. *American Economic Review.* 81:160-64.

Skaperdas, Stergios, and Constantinos Syropoulos. 1996. Can the shadow of the future harm cooperation? *Journal of Economic Behavior and organization.* 29:355-72.

Skaperdas, Stergios, and Constantinos Syropoulos. 1997. The distribution of income in the presence of appropriative activities. *Economica.* 64:101-17.

Tullock, Gordon. 1980. Efficient rent seeking. in J.M. Buchanan, R.D. Tolllison, and G. Tullock (eds.). *Toward a theory of the rent seeking society.* College Station: Texas A&M University Press.

		Party 2	
		W	S
Party 1	W	*W*	*W*
	S	*W*	*S*

Figure 1: The breakout of war vs. peaceful settlement

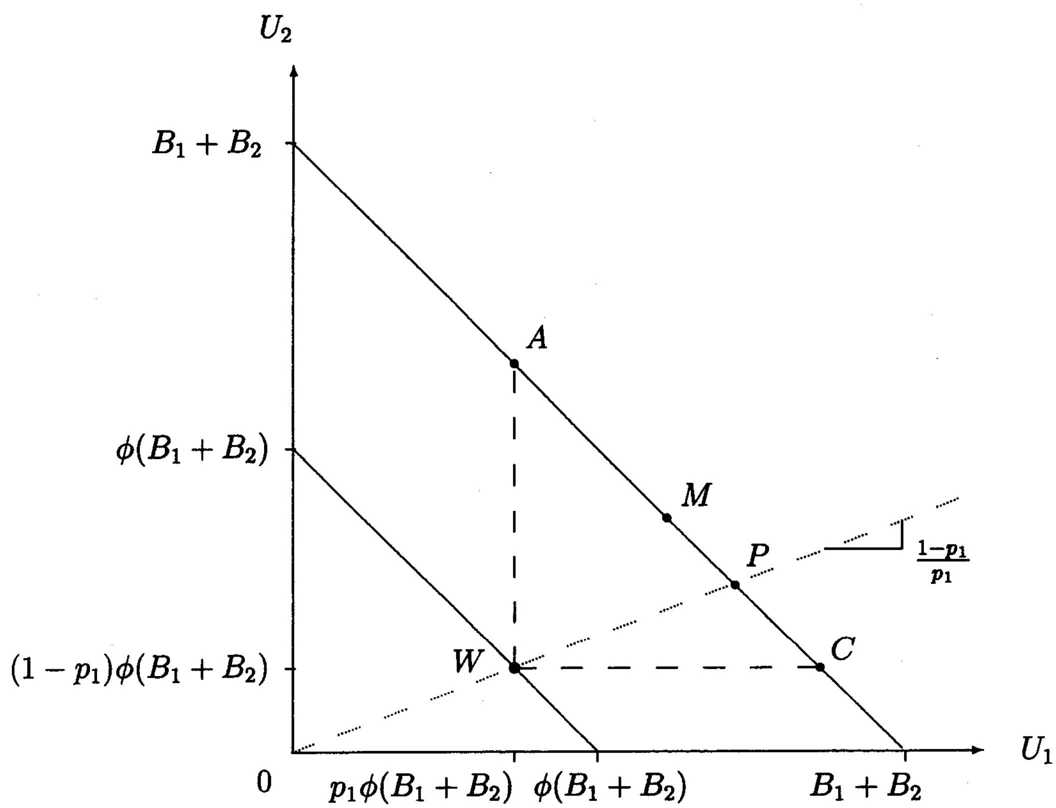

Figure 2: War and settlement outcomes

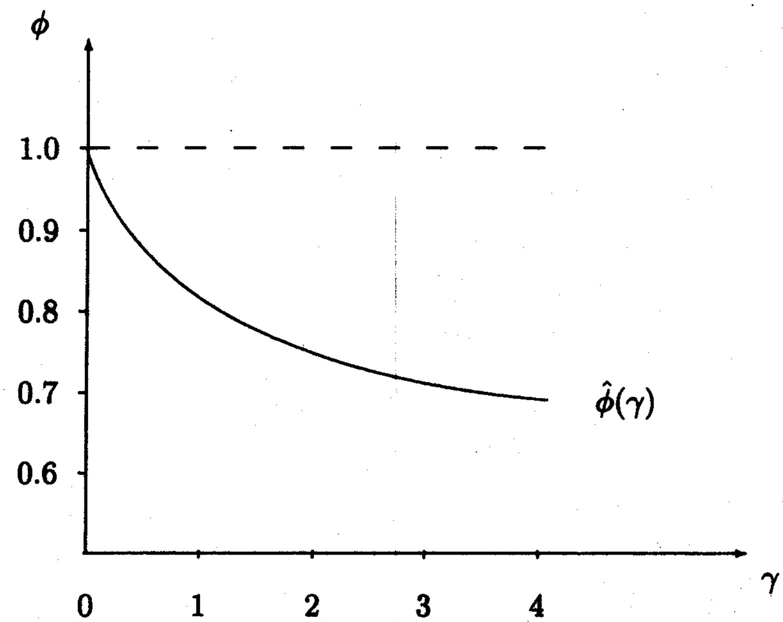

Figure 3: The critical value of ϕ