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# Investing in the Peace: Economic Interdependence and International Conflict

Erik Gartzke, Quan Li, and Charles Boehmer

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Research appears to substantiate the liberal conviction that trade fosters global peace. Still, existing understanding of linkages between conflict and international economics is limited in at least two ways. First, cross-border economic relationships are far broader than just trade. Global capital markets dwarf the exchange of goods and services, and states engage in varying degrees of monetary policy coordination. Second, the manner in which economics is said to inhibit conflict behavior is implausible in light of new analytical insights about the causes of war. We discuss, and then demonstrate formally, how interdependence can influence states' recourse to military violence. The risk of disrupting economic linkages—particularly access to capital—may occasionally deter minor contests between interdependent states, but such opportunity costs will typically fail to preclude militarized disputes. Instead, interdependence offers nonmilitarized avenues for communicating resolve through costly signaling. Our quantitative results show that capital interdependence contributes to peace independent of the effects of trade, democracy, interest, and other variables.

Students of world politics have long argued that peace is a positive externality of global commerce. Theorists like Montesquieu and Kant and practitioners like Woodrow Wilson asserted that economic relations between states pacify political interaction. Mounting evidence in recent years appears to substantiate these claims. Multiple studies, many identified with the democratic peace, link interstate trade with reductions in militarized disputes or wars.<sup>1</sup> While we concur with the evolving consensus, we see existing analyses of economics and peace as incomplete. On the

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1. See McMillan 1997 for a review of the literature. See also the *Journal of Peace Research* 36 (4), July 1999.

one hand, a rich history of theorizing offers speculation addressing virtually every aspect of the relationship between economics and conflict. On the other hand, empirical studies of interdependence often adopt excessively narrow indicators of economic activity. It may be rewarding to take an intellectual step back—to briefly assess the broader theoretical question of how interdependence is likely to affect conflict behavior—and then to examine promising aspects of the relationship using more appropriate indicators.

We begin with a theory of disputes. A valid explanation for the effect of economics on peace must be placed in the context of an account of why most states occasionally resort to military violence. Using a theory of dispute onset based on work by James Fearon and others, we deduce conditions under which interdependence likely contributes to peace.<sup>2</sup> In contrast to conventional interpretations, we show that opportunity costs associated with economic benefits generally cannot *deter* disputes. Instead, interdependence creates the means for states to demonstrate resolve without resorting to military violence. Liberal states more ably address the informational problems that give rise to costly contests, credibly communicating through costly signals using nonviolent methods of conflict.<sup>3</sup>

Our analysis calls for a notion of interdependence involving aspects of economic activity besides trade. Most studies of interdependence and conflict focus solely on bilateral or aggregate trade flows, but interdependence through international capital is substantially larger than exchanges of goods and services. Capital markets link aspects of domestic economies that otherwise have little global exposure. A preoccupation with risk leads capital to react to political violence in ways that are arguably both more sensitive and more unwavering. States can trade with the enemy, but political shocks to capital market equilibria invariably imply capital flight and/or higher rents in the shadow of costly contests. Peace may be a positive political externality of commerce, but risk is clearly a negative economic externality of political contests. Other macropolitical aspects of international economics—such as the need for monetary policy coordination—are also omitted in previous studies of interdependence.

Thus, while accepting as valid the correlation between interdependence and peace, we seek to alter both the logic underpinning the observation and the scope of indicators used in assessing the relationship. Through a series of formal illustrations and models, we show that the opportunity cost conception cannot account for the impact of interdependence on peace. We also show that costly signaling offers a satisfactory alternative. We broaden empirical assessment of interdependence by introducing measures of other aspects of economy. We test our ideas by replicating the work of a prominent research program on liberalism and peace.<sup>4</sup> Results support

2. See Blainey 1973; Fearon 1995; Gartzke 1999; and Wagner 2000.

3. Morrow outlines an argument about trade interdependence that in important respects parallels our own. Morrow 1999. We develop our ideas independently, derive them formally, apply them more broadly, and offer empirical tests.

4. See Oneal and Russett 1997; and Russett, Oneal, and Davis 1998.

our broader interpretation of interdependence—monetary and financial indicators are typically significant while standard measures of trade and especially joint democracy are marginal in their impact or insignificant.

Together, these extensions form a comprehensive and theoretically satisfying account of the relationship between interdependence and peace. We review the relevant literature, discuss the theory, and derive predictions. We then outline our tests and present the results. We conclude with speculation about implications of signaling and interdependence for globalization and peace.

## Existing Arguments About Economics and Peace

The literature on interdependence, international conflict, and the nexus of these topics is vast. We survey work in four areas: the democratic peace, and trade, capital, and monetary interdependence.

### *The Democratic Peace*

Scholarly attention has focused in recent years on the “democratic peace,” the observation that liberal polities rarely fight each other<sup>5</sup> though appearing about as likely to engage in disputes generally.<sup>6</sup> Democracies behave differently toward each other than toward nondemocracies.<sup>7</sup>

Researchers initially sought to verify the statistical observation, but work increasingly focuses on augmenting theoretical bases for the democratic peace. A strong strain in the literature argues that domestic political factors explain the relative absence of military violence among liberal states. States sharing republican norms may be more willing to bargain, compromise, and fulfill contracts than states without these norms.<sup>8</sup> Alternately, democratic institutions may constrain leaders from using force against leaders who are likewise constrained.<sup>9</sup> Still others contend that in democracies domestic audiences or opposition groups force the revelation of private information responsible for costly contests, averting war.<sup>10</sup>

### *Trade Interdependence*

Democratic peace research was inspired by the Kantian prophesy of a “perpetual peace,” but Kant’s recipe (often called the “liberal peace”) consists of much broader

5. See Bremer 1992 and 1993; Bueno de Mesquita and Lalman 1992; Maoz and Russett 1993; Oneal and Russett 1997; Rousseau et al. 1996; Rummel 1997; Russett 1993; and Russett, Oneal, and Davis 1998.

6. See Benoit 1996; Ray 1997; Chan 1984; Rousseau et al. 1996; and Weede 1984.

7. The consensus is that the monadic effect of democracy on peace is at most much weaker than the dyadic effect.

8. Dixon 1993 and 1994.

9. See Babst 1972; Bueno de Mesquita and Lalman 1992; and Morgan and Campbell 1991.

10. On domestic audiences, see Fearon 1995; on opposition groups, see Schultz 1998 and 1999.

conditions, including republican government, a league of nations, and common markets.<sup>11</sup> Beginning in the 1970s, students of political economy began to evaluate evidence that interdependence inhibits conflict behavior. Debate continues, but consensus appears to be that interdependence is associated with peace.

Work by Robert O. Keohane and Joseph S. Nye, James A. Caporaso, Karl W. Deutsch, James M. Rosenau, and John A. Kroll made conceptual contributions by clarifying definitions of interdependence.<sup>12</sup> However, these studies lack theoretical precision and fail to delineate key processes. One is left to ponder the origins of interdependence. Exactly how do multiple channels alter incentives to compete? Also, complex interdependence appears to imply dyadic consequences, but the argument as posed is almost exclusively systemic.

There are many ways to conceive of interdependence. The central logic of most studies of conflict and interdependence is that states are less likely to fight if there exist additional opportunity costs associated with military force. "International commerce, being a transaction between nations, could conceivably also have a direct impact on the likelihood of peace and war: once again the [economic] interests might overcome the passions, specifically the passion for conquest."<sup>13</sup>

Evidence has mounted that trade interdependence reduces interstate disputes.<sup>14</sup> John R. Oneal and Bruce M. Russett argue that Kant was right—liberalism leads to peace.<sup>15</sup> In addition to interdependence, law, civil liberties, executive constraints, and a bargaining culture all reduce disputes. Interdependence has a greater effect than democracy, growth, or alliances in reducing conflict in contiguous states.

However, "theoretically, liberalism does not specify what types of conflict are most likely to decrease in the presence of high levels of interdependence."<sup>16</sup> Gartzke and Dong-Joon Jo find that while liberal dyads are less likely to engage in militarized conflict, they have more nonmilitarized conflicts.<sup>17</sup> Mark J. Gasiorowski finds that short-term capital flows increase conflict while trade reduces conflict.<sup>18</sup> Gasiorowski and Mary Ann Tetreault emphasize that the quantitative literature measures not interdependence but interconnectedness.<sup>19</sup> Trade flows alone may not be an optimal measure of interdependence.

Other recent work directly challenges the validity of research on the trade-conflict nexus. Using a measure of interdependence based on the salience of trade, Katherine

11. Kant [1795] 1957.

12. See Caporaso 1978; Deutsch 1978; Keohane and Nye 1989; Kroll 1993; and Rosenau 1984.

13. Hirschman 1977.

14. See Oneal et al. 1996; Oneal and Russett 1997 and 1999a; Polachek 1980; and Polachek, Robst, and Chang 1999.

15. See Oneal and Russett 1997 and 1999a. Though not directly related to our research, other studies assess the effect of conflict and alliances on trade. See Gowa and Mansfield 1993; Mansfield and Bronson 1997; and Pollins 1989.

16. McMillan 1997, 54.

17. Gartzke and Jo 2000.

18. Gasiorowski 1986.

19. See Gasiorowski 1986; and Tetreault 1980.

Barbieri finds that trade *increases* conflict.<sup>20</sup> Like others, we suspect that Barbieri's measure of interdependence is responsible for her findings.<sup>21</sup> Oneal and Russett assess differences between the two programs. They find that positive trade-conflict relationships are isolated to nonrelevant dyads.

Barbieri and Gerald Schneider are concerned about discrepant findings and warn that bias may be a product of tainted trade data. They question the reliability of existing empirical findings.<sup>22</sup> Barbieri and Jack S. Levy provide evidence that states often trade with the enemy while at war and suggest that liberalism and realism reconsider expectations regarding interdependence and conflict.<sup>23</sup> Han Dorussen demonstrates that trade has a pacifying effect on interstate conflict mainly when there are minimal barriers to trade and few states in the system.<sup>24</sup> Numerous potential trading partners combined with barriers increase the incentives to engage in military contests.

In a project that anticipates aspects of this study, James D. Morrow offers a coherent basis for questioning the statistical association between trade and conflict. He begins by outlining an explanation for the causes of international crises and disputes and provides two reasons why trade and conflict may not interact the way researchers typically expect.<sup>25</sup> First, because firms anticipate conflict between states with volatile relations, trade will be reduced *ex ante* where the risk of conflict is greatest.<sup>26</sup> Thus, trade and conflict are both endogenous; states will not be deterred from conflict if the threat of conflict deters trade. Second, the deterrent effect of trade should be modest. Any factor that discourages aggression by one party encourages aggression in others. States can use trade to signal, informing others by demonstrating a willingness to pursue costly acts (harming trade).

Finally, interdependence may affect conflict indirectly by transforming state preferences in such a way that states no longer desire to compete. Etel Solingen argues that domestic coalitions with internationalist preferences may forge cross-national bonds at the regional level, facilitating greater economic interdependence and prosperity. The efforts of domestic internationalist coalitions to act in concert may in turn improve their stability and influence in domestic politics.<sup>27</sup> State preferences will converge, producing regional zones of peace. Still, peace may not follow from interdependence between status quo and revisionist states. Paul A. Papayoanou contends economic linkages act as signals of resolve and credibility.<sup>28</sup> Because domestic economic actors in status quo states only support conflicts that

20. Barbieri 1996.

21. See Oneal et al. 1996; and Oneal and Russett 1999a.

22. Barbieri and Schneider 1999.

23. Barbieri and Levy 1999.

24. Dorussen 1999.

25. Morrow 1999.

26. Bueno de Mesquita found that during the Seven Weeks' War money markets signaled expectations about the risk of a contest as well as the probability that Prussia would win (and thus that Denmark would lose). Bueno de Mesquita 1990.

27. Solingen 1998.

28. Papayoanou 1999.

protect their interests, these states are more easily constrained from balancing against revisionist states with which they share economic relations. If confrontations arise, revisionist states may threaten to disrupt economic relations, increasing opportunity costs for status quo states.

### *Monetary Interdependence*

Monetary interactions may also be a source of interdependence. States may choose to subordinate monetary sovereignty to a foreign power through a fixed exchange-rate regime, pool sovereignty in a monetary union, or assert their own sovereignty under a floating exchange-rate regime.<sup>29</sup> Interstate monetary relations can be characterized by intermittent cooperation, competition, and coercion.<sup>30</sup> Attempts by one state to increase its monetary authority (a relative gain) may produce “public bads” that diminish absolute gains. Hence, monetary interaction may be considered as part of the general notion of economic interdependence.<sup>31</sup> Although they reduce state autonomy in monetary policymaking, higher levels of monetary dependence raise the incentives to cooperate.

### *Capital Interdependence*

In *Spirit of the Laws*, Montesquieu argues that “movable wealth” encourages peace between and within states. Mobile capital constrains the sovereign domestically. “The richest trader had only invisible wealth which could be sent everywhere without leaving any trace . . . [so that] rulers have been compelled to govern with greater wisdom than they themselves would have thought.”<sup>32</sup>

Trade is only one manifestation of the global spread of capitalism.<sup>33</sup> Since capital markets dwarf the exchange of goods and services, firms should weigh the risks of investment much more heavily than trade. Foreign production facilities are vulnerable to nationalization in a way that trade is not. Further, even the threat of lost revenues makes investors skittish. Globalization has increased capital mobility and monetary cooperation even as it redefines the terms on which states compete.

State policies aim to preserve political autonomy, but states are faced with a dilemma when seeking to influence interstate finance. Vittorio Grilli and Gian Maria Milesi-Ferretti suggest that states impose capital controls for four reasons: limiting volatile short-term capital flows, retaining domestic savings, sustaining structural reform and stabilization programs, and maintaining the tax base.<sup>34</sup> States engage in

29. Cohen 1998.

30. Kirshner 1995.

31. See Hamada 1976; and Suzuki 1994.

32. Montesquieu [1748] 1989, 389. Montesquieu also discusses the political effects of currency market speculation.

33. Andrews 1994.

34. Grilli and Milesi-Ferretti 1995.

financial repression for similar reasons.<sup>35</sup> However, states may find capital controls less useful when facing integrated capital markets and pressures to liberalize from powerful interest groups such as multinational corporations and financial institutions.<sup>36</sup> Edward L. Morse points out that when states fail to reduce their vulnerability and solve the crises that arise through interdependence, they may seek to externalize problems.<sup>37</sup> Interdependence may even transmit economic crises.<sup>38</sup> Thus, the literature suggests that interdependence could increase conflict between states while decreasing the chances of violent, militarized behavior.

## Theory: Economic Interdependence and Peace

The literature generally reports that states that trade are less likely to fight. Still, there is substantial room to expand and to better account for the processes linking interdependence to disputes. Our argument follows in three stages. We first offer a theory of contests based on recent developments in the literature on war.<sup>39</sup> Discussions of this logic appear elsewhere, so we focus here on intuition. We use simple formal examples in the text and provide rigorous formal proofs in the appendix. We then use the theory of contests to demonstrate how interdependence affects militarized behavior. We show that conventional opportunity cost accounts of the effect of interdependence on disputes are inconsistent with a logic of costly contests, but that an alternative explanation based on signaling does anticipate pacific effects. Discussion is again informal, with a proof in the appendix. Finally, we cover supporting topics needed to link signaling to capital and monetary processes.

## Why States Fight: A Theory of Costly Contests

Explanations for war are legion. However, work by James Fearon and others shows that most purposive theories of war are internally inconsistent in that they do not account for the behavior of interest.<sup>40</sup> Fearon points out that theories of war commonly conflate the motives for conflict with the choice of method for conflict resolution. Costly contests involve at least two elements. First, there is zero-sum

35. Leblang 1997.

36. See Frieden 1991; and Goodman and Pauly 1993.

37. Morse 1976.

38. *Ibid.*, 129.

39. See, for example, Fearon 1995; Gartzke 1999; and Wagner 2000. Morrow offers a parallel account. Morrow 1999.

40. Fearon identifies three explanations why purposive, unitary states in conflict fail to achieve bargains *ex ante* that they accept *ex post*. We address only the first explanation here. For a more detailed discussion, see Gartzke 1999.

competition for an excludable good.<sup>41</sup> States differ over issues or territory that each cannot possess simultaneously. Second, states choose a settlement method. The choice of method is non-zero-sum. Transaction costs deprive “winners” of benefits and increase the burden for “losers” so that all are better off selecting methods that minimize costs. Since war is expensive, fighting makes sense only if equivalent settlements cannot be obtained using cheaper methods. A theory of war, then, explains why efficient settlements are at times unobtainable *ex ante*.

Fearon follows Geoffrey Blainey in arguing that wars result from uncertainty about conditions likely to influence eventual settlements as well as incentives states have to misrepresent these conditions.<sup>42</sup> States possess private information about strategic variables (capabilities, resolve, and so on). If states could credibly share private information, efficient *ex ante* bargains could be identified. Instead, uncertainty provides weak or unresolved states an opportunity to conceal weakness even as competition creates incentives to bluff. States “pool,” claiming to be resolved and capable regardless of their true nature. Such “cheap talk” claims do not allow observers to differentiate resolved or capable opponents from the weak or unresolved. Only by imposing costly contests—by fighting or similar acts—can states distinguish resolute opponents from those seeking to bluff. States fight largely because they cannot agree on bargains that each prefers to what each expects to obtain from fighting. If states can agree about the nature of eventual settlements, then there is always some mutually preferable bargain. Therefore, uncertainty about the allocation of spoils from the contest accounts for the contest itself.

Imagine that two states compete over a sum of money (say \$100).<sup>43</sup> States keep any division of the stakes but pay a fee for fighting (say \$20). Suppose that the winner gets all the money (minus costs) and the loser gets nothing (again minus costs). For simplicity, assume that states have equal chances of victory. Thus, fighting has an expected value of  $[0.5(\$100) + 0.5(\$0) - \$20]$  or \$30. If states are risk neutral, then any offer yielding each side at least \$30 is at least as valuable as fighting. Negotiated settlements from (\$31, \$69) to (\$69, \$31) are available and preferred to war.<sup>44</sup>

Suppose instead that war costs remain \$20 for one state (*A*) but that the other state (*B*) has private information about its costs (*c*). Suppose that war costs for states like *B* range from \$0 to \$40. Obviously, if *B*'s costs are high, then *A* can make a demanding proposal. *B* thus has an incentive to bluff. *A* in turn recognizes that *B* will

41. Excludability means that property rights are enforceable. To the degree that a good is nonexcludable, states stand to internalize benefits regardless of whether they fight. There are few incentives to engage in costly contests to obtain what cannot be denied even the loser. Realism implies that rivalry is not necessary for conflict. States that care about relative gains still have incentives to fight even if one actor's consumption does not diminish the consumption of others.

42. Blainey 1973. For a brief and highly intuitive account of the argument, see also Morrow 1999.

43. Proofs in the appendix are more general. Examples in the text are meant only to illustrate the arguments.

44. Risk propensity affects the size of the Pareto space (the range over which bargains are preferable to the lottery of war). Risk aversion increases the range of acceptable bargains, while risk acceptance reduces the Pareto space.



claim low costs whether or not  $B$ 's costs are modest.  $A$  thus cannot infer anything meaningful from  $B$ 's "cheap talk" claims.<sup>45</sup>

For simplicity, imagine that  $A$  makes a demand ( $d$ ) that  $B$  either accepts (giving  $A$   $[\$100 - d]$ ) or rejects, leading to war. If  $A$  knows  $B$ 's cost, then  $A$ 's optimal offer is one that  $B$  just prefers to fighting. If  $A$  is uncertain what  $B$  prefers, then  $A$ 's optimal offer is the best demand of each type of  $B$ , weighted by the odds that a given type is the real opponent. Technically,  $A$ 's demand equals the integral over the distribution of types of  $B$ 's marginal product for fighting.  $A$ 's offer is thus linked to the central tendency of opponent types.<sup>46</sup> If  $B$ 's costs are distributed uniformly, this implies that  $A$  offers \$30. Types  $B$  with lower than average costs fight, whereas high-cost types  $B$  accept  $A$ 's offer.

Fearon's reassessment renders a finite set of necessary conditions for costly contests. States must have incentives to compete. This first set of conditions is widely recognized and is referred to by several labels (opportunity and willingness, capability and resolve, probability and utility).<sup>47</sup> Yet, while the first set of conditions implies conflict, these conditions do not determine the method by which conflict is resolved. Costly contests only follow when states are also uncertain about likely consequences of contests. The second set of conditions requires that states possess private information about some aspect of the first set of conditions and that states be unable to credibly dissipate uncertainty.

Now that we have identified conditions leading to costly contests, explaining the absence of such contests in certain dyads is tantamount to removing a necessary condition. In the model wars are unlikely if fighting is *prohibitively* expensive (wars are anticipated to cost more than the payoffs) or if information about strategic variables is revealed. Interdependence can contribute to peace by making costly contests more costly than the stakes or by revealing private information for at least one of the actors. We show later that revelation of private information is the likely mechanism.

## Why Some States Do Not Fight: Contribution(s) of Interdependence to Peace

For interdependence to promote peace, economic processes must either remove incentives for states to engage in conflict or reduce the uncertainty states face when

45. Cheap-talk signals can be informative if costs are applied conditionally. See Fearon 1994; Sartori 1996; and Smith 1998. Sartori points out that states *do* appear to communicate credibly through cheap talk (diplomacy, and so on). Yet diplomats are notorious for bluffing (someone once referred to a diplomat as a gentleman who lies for his country). While reputation or audience costs add to the credibility of cheap talk, credible communication is clearly problematic. Here, we adopt the useful fiction that the effects of cheap-talk signaling can be normalized to zero while noting that our results are general.

46. Gartzke 1999.

47. Rationalist theories can motivate costly contests with full information by imposing restrictive assumptions about actors' ability to bargain. Examples include Bueno de Mesquita 1981; and Bueno de Mesquita and Lalman 1992.

bargaining in the shadow of costly contests. Since removing incentives to act aggressively only increases incentives for opponents, the former explanation must typically occur in special “boundary” conditions (discussed later). We argue that interdependence makes it easier to substitute nonviolent contests for militarized disputes in signaling resolve. States that possess a range of methods of conflict resolution have less need to resort to the most destructive (and costly) techniques. Liberal dyads can damage mutually valuable linkages to communicate credibly. States without linkages must choose between a very limited set of options, including—more often—war. The conflict model with uncertainty shows why this is so.

Recall that *A*’s best response is an offer that an opponent weakly prefers to fighting. If the opponent (*B*) has private information about its war costs (*c*), then *A*’s optimal offer derives from a rational guess (the distribution of reservation prices for different types of player *B*). *A* calculates its offer as the best demand it can make to each opponent weighted by the odds that a given opponent “type” is the actual adversary. Players *B* whose war costs are high accept, whereas those with low costs fight.

Conventional descriptions of interdependence see war as less likely because states face additional opportunity costs for fighting. The problem with such an account is that it ignores incentives to capitalize on an opponent’s reticence to fight. If an opponent (*B*) is reluctant, then state *A* can make larger demands without risking war. Assume that interdependent dyads are those that derive some benefit from economic linkages (*h*, say  $h = \$10$ ). If *A* and *B* avoid a fight, then each receives the settlement plus the benefit ( $\$100 - d + \$10$  and  $d + \$10$ , respectively). *B*’s war costs are again between \$0 and \$40. Conventional explanations for interdependence identify the fact that *B* receives ( $d + \$10$ ) instead of (*d*) for accepting *A*’s demand as leading to peace. If demands are the same, then not fighting is more beneficial in interdependent dyads, and *B* should more often prefer *A*’s demand to fighting. Yet unless we assume that *A* is ignorant of its own interdependence with *B* (not very plausible), *A*’s demand *must be different*. *A*’s best offer is one that *B* just prefers to a fight. Since benefits increase under interdependence, *A* simply demands commensurately more. In the previous example, *A* offers \$30 (*A* receives  $\$100 - d = \$70$ ). If interdependent, *A* proposes that *B* accept \$20 plus the benefit (\$10). The same range of states *B* that accepted \$30 previously (since  $\$30 \geq \$50 - c$  if  $c \geq \$20$ ) now accepts \$20 (since  $\$20 + \$10$  [the benefit]  $\geq \$50 - c$  if  $c \geq \$20$ ). State *A* again makes an offer that a given opponent just prefers to fighting, weighted by the odds that *B* is the given opponent. Interdependence is simply subsumed in bargaining. Since they fail to reduce uncertainty, opportunity costs generally do not alter the prospects of engaging in costly contests.<sup>48</sup>

Economic interdependence *can* motivate peace in two ways. First, conflict may occasionally be so expensive relative to the expected value of fighting that states

48. The result is general to symmetric bargains (see proposition 4 in the appendix).

prefer any offer rather than enduring a contest. Suppose  $B$ 's war costs range from \$50 to \$90.  $B$ 's expected value for war thus ranges from \$0 to  $-\$40$ . Because  $B$  stands to lose more from fighting than its value for the stakes,  $B$  prefers to concede. We refer to this as a boundary solution because it is possible only by assuming that stakes in the contest are bounded. Bounded stakes are reasonable, especially when issues are of tertiary importance or when costs are extreme (as in nuclear war). Interdependent dyads may avoid costly contests if economic linkages decrease the expected value of competition to the point where one party prefers conceding to competing. Yet economic benefits seldom equate in consequence to nuclear war. Issues over which states may consider major contests are unlikely to meet boundary conditions for interdependence. Instead, boundary solutions are relevant when liberal states experience relatively minor conflict. Finally, competition can continue even given boundary conditions. Liberal dyads deterred from war can still compete by manipulating the risk of contests.<sup>49</sup>

Second, instead of deterring conflict, interdependence can convey credible signals, obviating the need for costly military contests. Actors' behaviors potentially inform observers about the value of strategic variables, dissipating private information. Interdependent states that endure opportunity costs in pursuit of political objectives differentiate themselves from other, less resolved, competitors. To the degree that nonviolent conflict allows observers to identify opponents, costly signaling also allows efficient *ex ante* bargaining. States seek to obtain settlements while competing for preferable terms. War is less often necessary when states possess nonviolent methods that credibly inform.

Suppose that in the earlier model state  $B$  can choose to preempt interdependence ( $h$ ) with a sanction ( $s$ ).  $B$  first chooses whether to eliminate interdependence.  $A$  then makes a demand, which  $B$  accepts or rejects. The solution to this signaling game is technical and is detailed in the appendix. The intuition, however, is simple. States  $B$  that are unresolved (high war costs) retain the benefits of interdependence. Unresolved states prefer interdependence and a demanding settlement to fighting. Resolved states (low-war-cost states) prefer to fight rather than to accept a poor settlement. Since states willing to fight expect to forfeit the benefit, these states are more willing to signal, destroying interdependence at the outset. Costly signals credibly inform  $A$  about opponent resolve.  $A$  in turn makes a more generous offer to resolved opponents so that they prefer the settlement to fighting.<sup>50</sup>

49. Schelling notes that any contest can be converted into a lottery over additional outcomes by playing brinkmanship games, so that even contests that are unacceptably costly (for example, general nuclear war) are imaginable as risky probabilistic consequences of competition. Schelling 1960 and 1966.

50. The result is general (see proposition 4 in the appendix). Banks offers a proof implying that the results are generalizable to the entire class of bargaining games in which offers are endogenous and unrestricted. Banks 1990.

## How Interdependence Functions in the Context of Politics

The task remaining is to link conflict behavior (or its absence) to economic activity. Economic ties between states may be portrayed as lying along a continuum from pure autarky (closed economies) to perfectly integrated (one economy). It makes no sense to discuss the role of interstate economics under autarky. Instead, for economies that are not closed, we must delineate the channels through which states are interrelated. We distinguish between market interactions and policy interactions.

Economic exchanges between market agents occur in a particular market. If market agents happen to belong to different national political entities, then their economic exchanges relate states in that market. For the processes of markets to influence conflict behavior, two conditions must hold. First, states must be able to intercede to obstruct economic benefits. This may seem a trivial point, but many economic exchanges—such as trade between an opponent and third parties—may not be readily obstructed, or may only be interfered with under extreme conditions (violations of the law of the sea, and so on). Second, benefits must generally be jointly contingent. States can technically signal through almost any costly act, but doing so makes little sense given incentives to compete. A man may seek to demonstrate his resolve by severing a limb, but subsequent efforts to bargain will be hindered by the fact that his opponent retains all his initial appendages.<sup>51</sup> The man is better off proving his resolve by severing the opponent's limb. To the degree that one is able, an actor should attempt to demonstrate resolve in a manner that does not damage the actor's own bargaining position.

While trade may or may not be affected by political shocks, we argue that capital markets are particularly vulnerable to intervention. Assume an equilibrium in capital markets at time  $t$ . Next imagine that a political shock occurs that increases risk (investments yield a lower return or principal is in greater danger). Re-equilibrating such a system requires capital outflows and/or larger returns. If political shocks impose more costs on users of capital, then to the degree that states rely on capital markets for prosperity, they also rely on political stability. Political shocks that endanger capital also threaten economic prosperity. The more interdependent states become, the greater the effect on capital markets of small changes in political risk. We have shown that opportunity costs cannot alter the probability of costly contests. Instead, a willingness to endure costs in pursuit of political goals demonstrates resolve and informs opponents. Capital interdependence promotes peace by allowing states to engage in costly signaling and reducing the need to resort to violence to obtain settlements.

51. A reviewer notes that the example is reminiscent of the Black Knight scene in Monty Python's *The Holy Grail*. The Black Knight guards a small bridge. "None shall pass!" he exclaims as King Arthur and the Knights of the Round Table approach. The problem is that previous contests have left the Black Knight short several limbs. While no one doubts the Black Knight's resolve, his costly signals have also effectively undermined his bargaining position. Hence the humor.

Events surrounding the Agadir crisis may serve to illustrate the argument. The gold standard prior to World War I was based on the commitment by three major powers (Britain, France, and Germany) to maintain their currency convertibility into gold. The three states attached top priority to defense of the gold standard to ensure benefits from a stable international monetary system, a commitment that was credible among investors.<sup>52</sup> In June 1911 France sent troops to the Moroccan capital, Fez, ostensibly to protect European residents. Germany saw the move as an effort to further French claims in Morocco and sought compensation. Negotiations broke down in July and war seemed imminent. At this point France and Britain began withdrawing funds from German banks, leading to a financial crisis in September that threatened the solvency of the German currency and risked suspension of the gold standard. In November the Germans decided to concede, signing a treaty recognizing Morocco as a French protectorate.<sup>53</sup> Britain and France were able to demonstrate their resolve short of military violence through a costly signal that threatened a common economic asset.

At the macroeconomic policy level, states construct fiscal and monetary policies to manage aggregate demand and supply. For nonautarchic economies, states' monetary and fiscal policies produce externalities that are transmitted to foreign economies through trade and exchange rates. To manage such externalities, states coordinate bilateral and international monetary arrangements. When states' markets are integrated, monetary policy autonomy in one state depends on the type of exchange rate regime. If state *A* pegs its currency to state *B*, *A* must then pursue the policy of state *B*. Yet the two states have asymmetric influence. As anchor currency, *B* enjoys policy autonomy, but abuse of policy independence leads to external imbalances that threaten the credibility of a fixed-rate regime. *B* has a stake over the long run in maintaining the currency peg.<sup>54</sup> Manipulation of the relationship is thus risky and can demonstrate resolve to the degree that coordination is valuable.<sup>55</sup>

By increasing the economic interdependence of members, monetary policy coordination creates a mechanism that allows credible signals of political resolve through economic acts. For example, the post-World War II Bretton Woods system was essentially a zone in which members pegged currencies to the dollar, expecting convertibility of the dollar into gold. On 26 July 1956 Egyptian president Gamal Abdel Nasser nationalized the Suez Canal. On 31 October British and French forces attacked Egypt after negotiations to resolve the crisis failed. Despite vocal opposition from the United States, Britain and France decided to continue efforts to seize the canal and overthrow the Nasser regime. On 5 November the U.S. government started to sell pounds. British reserves fell by 15 percent within a month. U.S.

52. Eichengreen 1996.

53. Kirshner 1995.

54. Simmons offers examples of governments torn between international commitment to the gold standard and domestic needs for more policy autonomy during the interwar years. Simmons 1994.

55. Gilpin argues that the Bretton Woods system failed due to irresponsible U.S. economic policies. Gilpin 1987.

Treasury secretary George Humphrey informed Britain that unless it obeyed the UN resolution and withdrew from Suez, the United States would continue to sell pounds and block British access to International Monetary Fund (IMF) reserves. On 6 November Britain ordered a cease-fire, in effect forcing the French to end military operations as well.<sup>56</sup> It may be questioned whether the United States would have intervened militarily to block British and French efforts in Egypt; fortunately, such an effort was not necessary. The Bretton Woods system made it possible for the United States to demonstrate resolve short of military force, jeopardizing valuable economic linkages but averting the need for costlier actions.

In summary, traditional studies of economics and international conflict only pay attention to a particular type of market, the goods market, and one channel of economic linkages, international trade. The influence of economics is underestimated and the causal mechanisms overly simplified. We argue that linkages between economics and peace are more complex than previously postulated. Interdependence through capital and trade acts as a costly signal, reducing uncertainty about relative resolve and lessening the need for militarized disputes. Instead of being deterred by opportunity costs, interdependent states can use opportunity costs as costly signals demonstrating resolve.

## Research Design

A large body of literature shows that economic interdependence is related to interstate conflict even after controlling for a variety of factors. We build on this body of work; specifically, we adopt most aspects of the research design represented by Oneal and Russett and Russett, Oneal, and Davis.<sup>57</sup> By using largely the same methods, data, and research design, we offer a clear look at the implications of our analysis. Our sample and unit of analysis is thus politically relevant dyad years, 1951 to 1985.<sup>58</sup>

In adopting many aspects of the research design in Oneal and Russett, and Russett, Oneal, and Davis, we also inherit limitations. The data are limited to contiguous and major powers in a period largely coterminous with the Cold War, a period of rising trade and financial interdependence and increased monetary policy coordination. Although we believe our theory is general, readers are nonetheless cautioned to keep these data limitations in mind when interpreting our results. Future research may collect data for earlier periods or test our argument in broader empirical contexts.<sup>59</sup>

56. Kirshner 1995.

57. See Oneal and Russett 1997; and Russett, Oneal, and Davis 1998.

58. Oneal and Russett describe the temporal domain as 1950–85, but the data contain no observations for 1950. Oneal and Russett 1997.

59. Integrated capital markets are arguably a feature relatively unique to recent decades. Data collection in the pre–World War II era are unlikely to alter the results reported here because so many dyads would report flows and stocks near zero.

## The Dependent Variable

The dependent variable is the onset of a militarized interstate dispute (MID), coded 1 for any dyad year in which a threat, display, use of force or war begins, and zero otherwise (including the subsequent years of a multiyear dispute).<sup>60</sup> We use data by Zeev Maoz (DYMID1.0), which offers an authoritative dyadic coding and corrects a number of coding errors in previous versions of the MID data.<sup>61</sup>

Construction for our dependent variable is novel in other ways. Russett, Oneal, and Davis look at MID involvement (the presence or absence of a MID in a given dyad year).<sup>62</sup> Since statistical models assume cases are independent, we prefer assessing MID onset rather than involvement. As a result, our sample contains 622 dyad years of MID onset, whereas Russett, Oneal, and Davis report 947 dyad years of MID involvement, a difference of 325 dyad years. Results using the Russett, Oneal, and Davis dependent variable are included for comparison but are discussed only briefly.<sup>63</sup>

Signaling suggests that interdependent states avoid escalating crises to militarized threats or violence. Ideally, analysis would involve assessing the presence or absence of signals followed by the presence or absence of escalated behavior. Unfortunately, existing data do not allow for direct assessment of escalation. MIDs are coded based on the most intense dispute behavior for each actor in a crisis. Assessing escalation with MIDs is thus highly problematic. Instead, we anticipate that much of the behavior indicative of signaling occurs below the threshold of MIDs. Signaling is assessed indirectly by associating the presence or absence of the ability to signal with changes in the dispute propensity of dyads in the form of the probabilistic presence or absence of MIDs.

### *Measuring Monetary Interdependence*

A state may peg its currency to a precious metal or a foreign currency, engage in a cooperative arrangement with a group of other countries to maintain its exchange rate within a certain “band,” or float the currency to allow the market to determine its equilibrium exchange rate. Whatever exchange-rate regime a state chooses, the regime links national economies so that local economic shocks and policies have foreign externalities. The choice of exchange-rate regime implies different degrees

60. For discussions of the MID data, see Gochman and Maoz 1984; and Jones, Bremer, and Singer 1996.

61. Maoz 1999.

62. See Russett, Oneal, and Davis 1998; and Oneal and Russett 1997.

63. Russett, Oneal, and Davis appear to code disputes using initial and terminal years of the dispute as a whole, rather than from individual participants. Russett, Oneal, and Davis 1998. Coding errors result from the entry and exit of actors in multiparty disputes of greater than one-year duration. For example, Thailand and the Soviet Union are considered a dispute dyad from 1964 to 1975 (dispute 611, Vietnam War), even though the two states' participation in the contest never overlaps (Soviet participation begins on 25 February 1964 and ends on 18 April 1965; Thailand, 21 September 1967 to 28 January 1973). Russett, Oneal, and Davis report 160 “disputes” between actors not coded as disputes in the MID data (they also code 165 subsequent-year disputes). Russett, Oneal, and Davis 1998.

of monetary interdependence. A peg demands greater interstate commitment and an associated loss of autonomy. Pegging makes it easier to exchange currencies and for the country to maintain price stability. Yet a state that pegs its currency to a foreign currency relies heavily on the economic management of the foreign economy. Therefore, states maintaining fixed exchange rates face a double-edged sword. The regime may facilitate exchange and provide incentives to avoid conflict, but asymmetry may also increase uncertainty about policy acts and ultimately fail to deter disputes. Similarly, states embarked on a cooperative exchange-rate arrangement, such as the European Monetary System (EMS) have greater commitment to each other compared with an independently floating system.

We see three relevant aspects of currency areas and monetary pegs for signaling. First, such arrangements can demonstrate resolve. States that possess beneficial regimes can reveal information about the relative value of competitive political objectives by threats or acts that jeopardize the status quo. Second, integrating one economy with others restricts a state's ability to shelter itself from negative economic consequences of political shocks. A state must not only stand to lose wealth in signaling but also be unable to avert this loss. Finally, it is important to note that other factors that historically lead to monetary integration confound the signaling effect of regimes. Old colonial or imperialist ties, proximity, dependency, and other factors may cause developing states to participate in regimes but resent participation. The underlying factors may be correlated with strong motives for conflict so that signaling appears to fail when in fact it mitigates disputes. Monetary policy coordination is theoretically consistent with, and supportive of, the signaling argument. Further, we see this role as expanding in the future as states like Argentina peg their currencies for purely economic purposes.

We construct two variables to measure the impact of monetary interdependence on interstate conflict. The first variable, PEGGING, measures the existence, coded 1, or absence, coded zero, of pegging between the anchor currency and another currency. Since the 1960s, eleven currencies have served as anchor currencies. Our sample involves the four largest anchor currencies (the American dollar, the British pound, the French franc, and the South African rand). PEGGING's expected sign depends on which effect is stronger, signaling (pegging is negatively correlated with disputes), or the selection effects associated with pegging, which are positively correlated to interstate disputes.

JOINT CURRENCY AREA measures whether states in a dyad peg their currencies to the same anchor currency, coded 1, or not, coded zero. The measure involves members of the four currency areas and one cooperative arrangement system (the EMS) during the sample period. This variable captures both currency area linkage and the effect of the cooperative arrangements.<sup>64</sup> JOINT CURRENCY AREA is expected to reduce the onset of interstate conflict (a negative sign).

64. Ideally, currency area membership and cooperative arrangements could be tested separately. We cannot estimate the effect of the EMS alone. There is no variance in dispute behavior because no MIDIS occur among EMS members. JOINT CURRENCY AREA, when purged of EMS dyads, is still significant.



Data for these two variables are obtained from the IMF's *Annual Reports on Exchange Arrangements and Exchange Controls* and the *International Financial Statistics Yearbooks*. Data for the exchange-rate regime variables start from 1966. Inclusion of PEGGING and JOINT CURRENCY AREA leaves 10,399 usable cases (out of the original 20,990).

### *Measuring the Impact of Capital Investment*

Capital seeks higher risk-adjusted returns. Risk is contingent on government restrictions, the degree of domestic capital market integration into world markets, and the overall exposure of the economy to direct investments. This has three implications for international conflict. First, states in conflict may place more stringent government restrictions on foreign exchange, payments settlement, capital repatriation, or even nationalization. Since conflict threatens investments among disputing states, it makes such investments less desirable and capital becomes relatively scarce. Second, political shocks produce negative externalities affecting investments. Military conflict increases uncertainty and risk to *any* capital investment, all else being equal, and reduces risk-adjusted rates of return. The more globally integrated a state's capital market, the more likely that capital will flee. Third, states that are heavily exposed to capital flows are more vulnerable to disruptions. Policy actions that increase risk for capital are costlier for political leaders and thus demonstrate stronger resolve.

States that are heavily dependent on international capital markets for national economic well being are much more vulnerable to the will of these markets. States can disengage their economies from the global system. They can also seek to restrict the movement of capital across their borders. However, attempts to limit the influence of international markets on domestic economies also limit growth. States cannot restrict the free movement of capital without raising the cost of production.

We construct two measures to capture dyadic levels of governmental openness and exposure to capital.  $CAOPEN_L$  measures eight types of government restrictions on foreign exchange, current, and capital account transactions. Restrictions include limits on payments for capital transactions, limits on payments for current transactions, prescription of currency, import surcharges, advance import deposits, surrender requirements for export proceeds, bilateral payments arrangements with IMF members, and bilateral payments arrangements with nonmembers.<sup>65</sup> We compute the difference between eight (the maximum number of restrictions) and the sum of restrictions for each country in a dyad. We then follow the weak link assumption used by Russett, Oneal, and Davis. The lower of the two monadic values in a dyad measures the openness of a dyad to capital investments. We expect the variable to have a negative effect on disputes.

65. These data are collected from summary tables of the IMF's *Annual Reports on Exchange Arrangements and Exchange Controls* since 1966.

CAP FLOWS<sub>L</sub> indicates a state's exposure to foreign direct investments (FDI), measured as the ratio of gross FDI over gross domestic product (GDP) in purchasing power parity (PPP).<sup>66</sup> Direct investments include equity capital, reinvestment of earnings, and other long- and short-term capital. The measure is lagged one period to control for endogeneity (disputes may repress current and future investments). We use the lower of the two monadic values in a dyad to measure the exposure of a dyad to capital investments. CAP FLOWS<sub>L</sub> is expected to negatively affect the onset of disputes. Data are from the World Bank's World Development Indicators database.<sup>67</sup> The variable contains many missing cases. Including the variable drops the sample size to about 2,200 dyad years, so results should be interpreted with some caution.

### *Control Variables*

We include control variables from Russett, Oneal, and Davis. We also add temporal spline variables for duration dependence and later include a control for endogenous preferences among states.

DEPEND measures trade interdependence in a dyad. It equals the lower of the two monadic trade dependence scores (bilateral trade/GDP) in the dyad for a given year, lagged one year to avoid reciprocal effects of conflict on trade.<sup>68</sup> DEPEND should decrease the risk of disputes.

Two variables are included to measure regime type. Monadic democracy is first calculated as the difference between reported values for democracy (DEMOC) and autocracy (AUTOC) in Polity III (values range from 10 [democratic] to -10 [autocratic] for each variable).<sup>69</sup> Democracy low (DEM<sub>L</sub>) is then calculated using the lower of the two monadic democracy values, whereas democracy high (DEM<sub>H</sub>) equals the higher value in a dyad year. DEM<sub>L</sub> thus measures the threshold of dyadic democracy (weak-link assumption), whereas DEM<sub>H</sub> measures asymmetry in regime type. Research on the democratic peace leads us to expect DEM<sub>L</sub> to be negative while DEM<sub>H</sub> is positive.

States that are growing economically may be disinclined to engage in militarized conflicts. Alternately, economic growth may encourage expansionist tendencies. The rates of change in GDP per capita for states in the dyad are first obtained using moving averages over a three-year period (one- or two-year periods when missing values are present). Based on the weak-link assumption, low economic growth (GROWTH<sub>L</sub>) equals the lower of the two growth rates in a dyad.

CONTIGUITY is a dummy variable for geographic contiguity coded 1 when both states in a dyad are contiguous (or within 150 miles by sea), and zero otherwise.

66. Ideally, we would also include portfolio investments, but the data are extremely limited.

67. World Bank 1998.

68. Trade data are from IMF 1993. GDP data (purchasing power parity) are from Summers and Heston 1991.

69. Jagers and Gurr 1995.

Either because of opportunity, willingness, or both, bordering states have a higher risk of experiencing disputes than distant states.

*ALLIES* is also a dummy, coded 1 when both states of a dyad share a military alliance or if each is separately allied with the United States. Allies may be disinclined to fight each other.

*CAPRAT* controls for the balance of power in a dyad by measuring the ratio of composite national capabilities scores (*CINC*). *CINC* scores, from the Correlates of War (*COW*) project, measure a state's share of world capabilities in three dimensions: demographic (total and urban population), economic (energy consumption and iron/steel production), and military (expenditures and total personnel).<sup>70</sup> Disputes may be less (or more) likely in dyads with an imbalance of power.

We also follow Nathaniel Beck, Jonathan N. Katz, and Richard Tucker and construct temporal splines (*\_SPLINE<sub>1</sub>*, *\_SPLINE<sub>2</sub>*, and *\_SPLINE<sub>3</sub>*) to control for duration dependence.<sup>71</sup> Because they are simply statistical corrective measures, we exclude splines that are not significant. The statistical findings remain substantially the same.

Several analysts suggest either that states' interests confound the effect of interdependence or that interdependence itself leads states to form similar interests.<sup>72</sup> (In Table 4, we add *AFFINITY*, a variable based on an index of the similarity of states' voting behavior in the UN General Assembly. We add the variable to assess and control for the effect of preference similarity.<sup>73</sup>)

Finally, our analysis omits two variables used by Russett, Oneal, and Davis. First, we found that once temporal dependence is controlled for, joint membership in intergovernmental organizations (IGOs) becomes *positive* and highly statistically significant, implying that IGO membership *increases* interstate conflict.<sup>74</sup> We doubt that IGO membership induces states to fight one another. Rather, we suspect that IGOs differ as to purpose, with some IGOs serving as proxies for rivalries and others performing the constraining role imagined by Kant and others. We suspect a flaw in

70. Singer, Bremer, and Stuckey 1972.

71. See Beck, Katz, and Tucker 1998. Other work in the research program incorporates this technique. See Oneal and Russett 1999a,b. We also examined a fixed-effects model. Green, Kim, and Yoon offer a rationale for controlling dyad-specific effects in binary cross-sectional time-series analysis by estimating intercepts for each dyad. Results of fixed-effects models are discouraging for quantitative IR research. Green, Kim, and Yoon 2001, 441. We see the technique as problematic. Coefficients lack theoretical justification, tend to absorb or encumber much of the limited variance in statistical models of conflict, and yield nonintuitive results (for example, contiguity becomes insignificant as a predictor of dispute behavior).

72. Morrow argues that measures of interdependence may really be capturing interest similarity. Morrow 1999. Papayoanou and Solingen each suggest (though in different ways) that interdependence can lead states to form similar interests. See Papayoanou 1999; and Solingen 1998.

73. Oneal and Russett 1999b and others have applied this technique to assess political closeness. See Oneal and Russett 1999b; and Gartzke 1998 and 2000.

74. The authors of the study acknowledge the problem. Personal communication with John Oneal. Including the IGO variable weakens results for most of the capital and monetary variables (though most are still significant), due to collinearity.

variable construction rather than in theory. Thus, given the anomalous finding and the lack of need for the variable in this study, we remove the indicator.<sup>75</sup>

We also omit Russett, Oneal, and Davis' variable for trend in trade dependence. Oneal and Russett themselves often omit the variable, which is rarely statistically significant. Including the trend variable does not alter our results, though it makes the model less parsimonious.

### *Plan for Model Estimation and Presentation*

We begin with a baseline specification from Russett, Oneal, and Davis, excluding the variables for joint-IGO membership and trend in trade dependence but adding temporal splines.

$$\begin{aligned} \text{MID}_{ij,t} = & \beta_0 + \beta_1 * \text{DEM}_{L,ij} + \beta_2 * \text{DEM}_{H,ij} + \beta_3 * \text{DEP}_{L,ij,t-1} + \beta_4 * \text{GROWTH}_{L,ij} \quad (1) \\ & + \beta_5 * \text{ALLIES}_{ij} + \beta_6 * \text{CONTIG}_{ij} + \beta_7 * \text{CAPRAT}_{ij} + \beta_8 * \text{\_SPLINE}_{1ij} \\ & + \beta_9 * \text{\_SPLINE}_{2ij} + \beta_{10} * \text{SPLINE}_{3ij} \end{aligned}$$

We extend the basic model by first adding the monetary variables and then the capital variables.<sup>76</sup> One might argue that our research design errs in light of previous studies that appear to support the opportunity cost model. How do we show that peace is caused by signaling? The problem is really with previous studies that assume (but fail to demonstrate) that a negative relationship results from opportunity costs. Rigorous theory shows that a negative relationship is the *wrong* hypothesis for the opportunity cost model, that opportunity costs predict no relationship. We also show that the negative relationship is the correct hypothesis for the signaling model. Thus although our empirical results appear to substantiate previous claims, our theory directly contradicts previous purported causes.

Our statistical findings are presented in four tables. Table 1 presents the results from five specifications. Model 1 reports the baseline (listed earlier); model 2 introduces PEGGING and JOINT CURRENCY AREA; model 3 introduces CAOPEN<sub>L</sub> and CAP FLOWS<sub>L</sub>; model 4 includes PEGGING, JOINT CURRENCY AREA, and CAOPEN<sub>L</sub>; and model 5 reports the full model including all variables. Table 2 provides a substantive interpretation of some of the results from Table 1. Table 3 presents model results using Russett, Oneal, and Davis' dependent variable MID involvement. Table 4 then reestimates the models in Table 1 while controlling for preference similarity by adding AFFINITY.

Ideally, we would only present the results of the “true” causal model (or at least the one that we believe captures the true causal process). However, the variables of

75. We explore the anomalous result—and seek to formulate a better indicator of IGO membership—in other research.

76. Analysis is conducted using probit in Stata 6.0, with robust standard errors and adjusting for clustering on dyads.

**TABLE 1.** *Probit estimates of the effects of economic interdependence on MID onset, 1951–85 (using MID data from Maoz)*

<i>Independent variables</i>	<i>Model 1</i>	<i>Model 2</i>	<i>Model 3</i>	<i>Model 4</i>	<i>Model 5</i>
DEMOCRACY <sub>L</sub>	-0.0244*** (0.0065)	-0.0001 (0.0064)	0.0072 (0.0122)	0.0058 (0.0063)	0.0092 (0.0123)
DEMOCRACY <sub>H</sub>	0.0195*** (0.006)	0.0168*** (0.0062)	0.0202* (0.0112)	0.0128** (0.0064)	0.0138 (0.0114)
DEPENDENCE <sub>L,t-1</sub>	-6.2620 (5.6863)	-4.6895 (3.8974)	-32.1126** (15.895)	-0.0442 (3.900)	-30.536** (15.825)
ECONOMIC GROWTH <sub>L</sub>	-0.0178*** (0.0059)	-0.0308*** (0.0078)	-0.0207 (0.0196)	-0.0309*** (0.0074)	-0.0184 (0.0193)
ALLIES	-0.1539* (0.0065)	-1.7665 (0.0064)	-1.0442 (0.0122)	-1.4858 (0.0063)	-1.0665 (0.0123)
CONTIGUITY	0.6491*** (0.0996)	0.7659*** (0.1050)	0.7001*** (0.1751)	0.7283*** (0.1125)	0.7552*** (0.1796)
CAPABILITY RATIO	-0.0010*** (0.0003)	-0.0011*** (0.0004)	-0.0004 (0.0003)	-0.0007* (0.0003)	-0.0008* (0.00049)
JOINT CURRENCY AREA	—	-0.1618** (0.0758)	—	-0.1503* (0.0781)	-0.2368 (0.3979)
PEGGING	—	0.2990** (0.1495)	—	0.2346 (0.1520)	0.5285** (0.2215)
CAOPEN <sub>L,t-1</sub>	—	—	-0.0962* (0.0509)	-0.0777*** (0.0241)	-0.0866* (0.0523)
CAP FLOWS <sub>L,t-1</sub>	—	—	-0.3988** (0.1973)	—	-0.4473** (0.2001)
SPLINE <sub>1</sub>	0.0029*** (0.0003)	0.0029*** (0.0005)	0.0021*** (0.0004)	0.0029*** (0.0005)	0.0021*** (0.0004)
SPLINE <sub>2</sub>	-0.0022*** (0.0003)	-0.0021*** (0.0005)	-0.0011*** (0.0002)	-0.0021*** (0.0005)	-0.0010*** (0.0002)
SPLINE <sub>3</sub>	0.0007*** (0.0002)	0.0007** (0.0002)	—	0.0006** (0.0002)	—
Constant	-1.8176*** (0.1047)	-1.7665*** (0.1141)	-1.0442*** (0.2436)	-1.4858*** (0.1395)	-1.0665*** (0.2610)
<i>N</i>	10,399	20,990	2,202	9,303	2,133
Wald test	280.25	270.24	126.31	295.49	143.49
<i>p</i> -value	0.0000	0.0000	0.0000	0.0000	0.0000
Log likelihood	-934.795	-2,273.58	-202.087	-869.763	-198.943
Pseudo <i>R</i> <sup>2</sup>	0.2237	0.1884	0.3103	0.2322	0.3161

Source: Maoz 1999 (DYMID1.0 data).

Note: Numbers in parentheses are robust standard errors, adjusted for clustering over dyads.

\*\*\**p* < .01, two-tailed test.

\*\**p* < .05, two-tailed test.

\**p* < .10, two-tailed test.

interest limit the sample size. For example, model 5 in Table 1, including all variables, contains only 2,133 observations. By comparison, model 1 has 20,990 observations. Multiple specifications show whether variables of interest are robust across samples. Insignificant results may still be due to inadequacies in the data.

**TABLE 2.** *The relative risk of MID onset in five different scenarios (based on coefficient estimates in model 5 of Table 1)*

<i>Scenarios</i>	<i>Model 5</i>	<i>Relative risk of MID compared to baseline</i>
1. Baseline scenario: democracy low, democracy high, trade dependence low, economic growth low, capability ratio, CAP FLOWS <sub><i>t,t-1</i></sub> , and CAOPEN <sub><i>t,t-1</i></sub> at sample mean values; allies, JOINT CURRENCY AREA, and PEGGING equal 0; and contiguity equals 1	0.0105	100%
2. JOINT CURRENCY AREA equals 1; other variables at baseline values	0.0054	51% (-0.0051)
3. CAP FLOWS <sub><i>t,t-1</i></sub> and CAOPEN <sub><i>t,t-1</i></sub> increase by one standard deviation; other variables at baseline values	0.0028	27% (-0.0077)
4. JOINT CURRENCY AREA equals 1; CAP FLOWS <sub><i>t,t-1</i></sub> and CAOPEN <sub><i>t,t-1</i></sub> and trade dependence low increase by one standard deviation; other variables at baseline values	0.0013	12% (-0.0092)

*Note:* Numbers in parentheses are changes in probability.

However, an incremental approach shows whether some variables are sensitive to other variables. In the next section, we discuss our findings and explore theoretical implications of the results.

## Results

Table 1 provides broad support for our argument. Results for democracy are surprising and perhaps noteworthy. Adding economic variables generally makes DEM<sub>*t*</sub>, the low democracy score, statistically insignificant.<sup>77</sup>

### *Monetary Interdependence*

In Model 2 PEGGING is positive and significant at the 5 percent level. Asymmetry between the pegging state and the pegged appears to correlate with dyads in which

77. We use the following method to assess the effect of missing values. First, we set missing values for four key economic variables to high values within each dyad and estimate the models. We then set missing values to low values in dyads and reestimate the models. The two sets of results identify upper and lower bounds of possible results. Results for the key economic variables remain largely the same (We omit reporting results since they are equivalent to those in Table 1).

**TABLE 3.** Probit estimates of the effects of economic interdependence on MID involvement, 1951–85 (using data from Russett, Oneal, and Davis)

<i>Independent variables</i>	<i>Model 1</i>	<i>Model 2</i>	<i>Model 3</i>	<i>Model 4</i>	<i>Model 5</i>
DEMOCRACY SCORE <sub>L</sub>	-0.0309*** (0.0072)	-0.0027 (0.0072)	0.0157 (0.0125)	0.0035 (0.0072)	0.0199 (0.0128)
DEMOCRACY <sub>H</sub>	0.0143** (0.0066)	0.0130* (0.0074)	0.0219* (0.0121)	0.0066 (0.0079)	0.0151 (0.0128)
DEPENDENCE SCORE <sub>L,t-1</sub>	-7.7653 (6.7218)	-5.1846 (4.3416)	-42.870** (17.588)	-1.7752 (4.2965)	-41.857** (17.412)
THREE-YEAR ECONOMIC GROWTH <sub>L</sub>	-0.0168** (0.0069)	-0.0287*** (0.0080)	-0.0182 (0.0197)	-0.0297*** (0.0081)	-0.0157 (0.0198)
ALLIES	-0.2121** (0.0897)	-1.7665 (0.0980)	-1.0442 (0.01926)	-1.4858 (0.0971)	-1.0665 (0.1916)
CONTIGUITY	0.4582*** (0.1039)	0.5086*** (0.1252)	0.5769*** (0.1918)	0.4670*** (0.1320)	0.6329*** (0.1993)
CAPABILITY RATIO	-0.0012*** (0.0004)	-0.0013*** (0.0005)	-0.0005 (0.0004)	-0.0008** (0.0004)	-0.0010* (0.0006)
JOINT CURRENCY AREA	—	-0.1419* (0.0831)	—	-0.1144 (0.0878)	0.2242 (0.3487)
PEGGING	—	0.2446 (0.1750)	—	0.1333 (0.1712)	0.7317 (0.2220)
CAOPEN <sub>L,t-1</sub>	—	—	-0.0930* (0.0550)	-0.0579** (0.0273)	-0.0914 (0.0572)
CAP FLOWS <sub>L,t-1</sub>	—	—	-0.4551** (0.2260)	—	-0.4894** (0.2355)
SPLINE <sub>1</sub>	0.0049*** (0.0004)	0.0048*** (0.0005)	0.0028*** (0.0004)	0.0048*** (0.0006)	0.0029*** (0.0004)
SPLINE <sub>2</sub>	-0.0040*** (0.0004)	-0.0037*** (0.0005)	-0.0014*** (0.0002)	-0.0038*** (0.0005)	-0.0014*** (0.0002)
SPLINE <sub>3</sub>	0.0015*** (0.0002)	0.0014*** (0.0002)	—	0.0014*** (0.0002)	—
Constant	-1.3502*** (0.1088)	-1.2308*** (0.1369)	-0.6073*** (0.2352)	-0.9737*** (0.1548)	-0.6058** (0.2520)
<i>N</i>	20,990	10,399	2,202	9,303	2,133
Wald test	392.09	405.5	152.27	407.17	158.15
<i>p</i> -value	0.0000	0.0000	0.0000	0.0000	0.0000
Log likelihood	-2,950.2028	-1,155.0101	-225.96639	-1,054.624	-220.62855
Pseudo <i>R</i> <sup>2</sup>	0.2356	0.2710	0.3886	0.2803	0.3983

Source: Russett, Oneal, and Davis 1998.

Note: Numbers in parentheses are robust standard errors.

\*\*\**p* < .01; two-tailed test.

\*\**p* < .05; two-tailed test.

\**p* < .10; two-tailed test.

**TABLE 4.** *Probit estimates of the effects of economic interdependence and preference similarity on MID onset, 1951–85 (using data from Maoz)*

<i>Independent variables</i>	<i>Model 1</i>	<i>Model 2</i>	<i>Model 3</i>	<i>Model 4</i>	<i>Model 5</i>
DEMOCRACY SCORE <sub>L</sub>	-0.0098 (0.006)	0.0034 (0.0068)	0.0058 (0.0123)	0.0082 (0.0069)	0.0079 (0.0124)
DEMOCRACY <sub>H</sub>	0.0141* (0.0058)	0.0147** (0.0069)	0.0214* (0.0112)	0.0127* (0.0068)	0.0151 (0.0114)
DEPENDENCE <sub>L,t-1</sub>	-6.0440 (5.0769)	-3.8462 (3.9350)	-35.156** (16.474)	-0.0611 (0.1674)	-36.023** (16.481)
ECONOMIC GROWTH <sub>L</sub>	-0.0199*** (0.0068)	-0.0319*** (0.0081)	-0.0340* (0.0189)	-0.3807 (3.9433)	-0.0312* (0.0188)
ALLIES	-0.0281 (0.0968)	0.1164 (0.0964)	-0.1005 (0.01945)	-0.0320*** (0.0076)	-0.1336 (0.1874)
CONTIGUITY	0.7604*** (0.1089)	0.8014*** (0.1163)	0.6865*** (0.1770)	0.804 (0.0937)	0.7672*** (0.1932)
CAPABILITY RATIO	-0.0006** (0.0002)	-0.0009** (0.0003)	-0.0004 (0.0004)	0.7591*** (0.1201)	-0.0009* (0.0005)
PREFERENCE SIMILARITY <sub>t-1</sub>	-0.3314*** (0.1066)	-0.1003 (0.1560)	0.2240 (0.2889)	-0.0007** (0.0003)	0.2732 (0.2833)
JOINT CURRENCY AREA	—	-0.1796** (0.0821)	—	-0.1679** (0.0851)	0.2209 (0.4028)
PEGGING	—	0.2498 (0.1551)	—	0.2398 (0.1618)	0.6411** (0.2684)
CAOPEN <sub>L,t-1</sub>	—	—	-0.0820* (0.0503)	-0.0784*** (0.0239)	-0.0711 (0.0509)
CAP FLOWS <sub>L,t-1</sub>	—	—	-0.4422** (0.2035)	—	-0.4859** (0.2062)
SPLINE <sub>1</sub>	0.0027*** (0.0004)	0.0029*** (0.0005)	0.0023*** (0.0004)	0.0029*** (0.0005)	0.0023*** (0.0004)
SPLINE <sub>2</sub>	-0.0020*** (0.0004)	-0.0021*** (0.0005)	-0.0012*** (0.0002)	-0.0021*** (0.0005)	-0.0012*** (0.0002)
SPLINE <sub>3</sub>	0.0007*** (0.0002)	0.0007** (0.0002)	—	0.0007** (0.0002)	—
Constant	-1.8080*** (0.0877)	-1.7651*** (0.1125)	-1.0991*** (0.2306)	-1.4842*** (0.1314)	-1.1377** (0.2483)
<i>N</i>	17,389	9,687	2,111	9,030	2,054
Wald test	233.11	255.99	129.13	284.00	134.09
<i>p</i> -value	0.0000	0.0000	0.0000	0.0000	0.0000
Log likelihood	-1,766.376	-872.50087	-181.82611	-819.40204	-179.0754
Pseudo <i>R</i> <sup>2</sup>	0.1932	0.2241	0.3334	0.2377	0.3395

Source: Maoz 1999.

Note: Numbers in parentheses are robust standard errors, adjusted for clustering in dyads.

\*\*\**p* < .01; two-tailed test.

\*\**p* < .05; two-tailed test.

\**p* < .10; two-tailed test.



there is greater friction, swamping any signaling effect.<sup>78</sup> JOINT CURRENCY AREA is significant (and negative) at the 5 percent level. Membership in a common currency area or in the EMS reduces disputes. Note that in model 2, both  $DEM_L$  and  $DEP_L$  have the expected negative sign but neither is significant.

PEGGING is positive but statistically insignificant once we control for joint financial openness ( $CAOPEN_L$ ) in model 4. However, the variable becomes positive and statistically significant again in model 5 (the full model with a limited sample,  $N = 2,133$ ). JOINT CURRENCY AREA also has the expected negative sign in both models 4 and 5 but is significant only in model 4.

### *Impact of Capital Investments*

Model 3 includes the baseline plus  $CAOPEN_L$  and  $CAP FLOWS_L$ .  $CAOPEN_L$ , measuring financial openness in a dyad over current and capital account transactions, is statistically significant and has the expected negative sign. Governmental openness to interstate financial activity is negatively related to conflict behavior.  $CAP FLOWS_L$ , measuring joint state exposure to direct investments, is also statistically significant and in the expected negative direction. Even though they are correlated ( $r = 0.53$ ), the significance of both variables suggests that they tap into different dimensions of the same economic process and that both dimensions help to dampen the onset of militarized disputes.

In model 4,  $CAOPEN_L$  is also negative and statistically significant at the 1 percent level, based on a much larger sample compared to model 2 and controlling for the monetary variables. In model 5 (the full model), both  $CAOPEN_L$  and  $CAP FLOWS_L$  remain statistically significant in the expected directions. The robustness of these results favors the validity of our theoretical arguments.

### *Model Comparison and Substantive Implications*

Comparing log likelihoods and pseudo  $R^2$ , it is clear that model 5 has the best overall fit, with the caveat that the five models are based on different samples. Including trade dependence, openness to capital flows, and monetary coordination seems to best reflect underlying processes.

Note that Russett, Oneal, and Davis' measure of trade dependence ( $DEP_L$ ) is statistically significant only in models 3 and 5, based on a limited sample of over 2,000 observations. Much of the influence of trade appears to be absorbed by capital and currency area variables, along with the splines. Correlation is 0.25 between  $CAP FLOWS_L$  and  $DEP_L$ , 0.28 between  $CAOPEN_L$  and  $DEP_L$ , and 0.11 between  $DEP_L$  and JOINT CURRENCY AREA. The results highlight the importance of examining cross-national economic linkages other than trade. It is misleading to draw inferences about the impact of economic exchanges on interstate conflict just from trade interdependence.

The results also suggest that it is premature to conclude that *all* economic linkages contribute to peace. PEGGING shows that asymmetric interstate monetary relations

correlate positively with conflict, a result consistent with other studies. Asymmetrically interdependent dyads (where one state is vulnerable) are somewhat more likely to experience a militarized dispute. The result may be a consequence of selection effects that associate historical pegs with asymmetric dependent linkages. We speculate that contemporary efforts at pegging may be more benign (a topic of future research).

Table 2 reports the probability of MID onset in four scenarios based on parameter estimates in model 5. The first row in Table 2 reports baseline probabilities of a MID in absolute and relative terms. Holding  $DEM_L$ ,  $DEM_H$ ,  $DEP_L$ ,  $GROWTH_L$ ,  $CAPRAT$ , the splines,  $CAP FLOWS_L$ , and  $CAOPEN_L$  at their sample mean values, setting  $ALLIES$ ,  $PEGGING$ , and  $JOINT CURRENCY AREA$  to zero, and setting  $CONTIG$  to 1, the likelihood of a MID is 0.0105 (the relative-risk column reports 100 percent, since this scenario is the baseline). In row 2, when  $JOINT CURRENCY AREA$  equals 1 (currency area linkage), the probability of a MID declines to 0.0054, or only 51 percent of baseline conditions. Row 3 shows that increasing exposure to direct investments ( $CAP FLOWS_L$ ) and openness to capital ( $CAOPEN_L$ ) by 1 standard deviation reduces the probability of dispute onset to 0.0028, or only 27 percent of baseline conditions.

Finally, we argue that these economic processes all represent elements of interdependence and that they tend to be mutually reinforcing. Changes in trade interdependence are likely to involve similar shifts in investment ( $CAP FLOWS_L$ ) and government liberalization of capital flows restrictions ( $CAOPEN_L$ ). States sharing currency area membership tend to trade and invest among themselves. Thus assessing one aspect of interdependence while holding others constant likely underestimates the actual contribution of economics to peace. Row 4, Table 2 reports the effect of an increase of one standard deviation in  $DEP_L$ ,  $CAOPEN_L$ , and  $CAP FLOWS_L$ , together with currency area membership ( $JOINT CURRENCY AREA = 1$ ). The probability of MID onset decreases from 0.0105 in the baseline to 0.0013, so that these dyads are only about 12 percent as likely to experience dispute onset.

### *Control Variables*

Table 1 reveals surprising results for some of the control variables. Adding monetary and capital variables in models 2–5 makes joint democracy ( $DEM_L$ ) insignificant. These variables,  $CAP FLOWS_L$  in particular, shrink the sample size dramatically, so the results may be due to changes in the sample. Variance in regime type may be reduced by nonrandom missing values for the capital variables. Democracy may also lose significance because of covariance with capital variables. Yet monetary and capital variables are significant even while democracy is not, indicating that variation in regime type is subsumed by greater variation in these economic variables. While adding observations may increase variance in regime type, it will certainly increase variance in capital and monetary variables.<sup>79</sup>

79. We expect to continue exploring this topic in subsequent research.

Of the other control variables, economic growth has a robust pacifying effect on militarized disputes in models 1, 2, and 4. Geographic contiguity has the expected positive effect on the chance of a military dispute in all models. The spline variables controlling duration dependence are also all significant.<sup>80</sup> Power preponderance (an imbalance of power in a dyad) reduces the odds of a dispute, but not significantly in models 3 and 5. Except in model 1, alliance ties are not significant.

### *Results Based on Dispute Involvement*

Table 3 reports results using Russett, Oneal, and Davis' dependent variable (MID involvement plus discrepant cases). Results for variables of interest depart in some cases from those in Table 1, but results also show the consistency of our findings. Model 2 in Table 3 shows that *JOINT CURRENCY AREA* is statistically significant at the 10 percent level and has the expected negative sign, whereas *PEGGING* is insignificant. In model 3, *CAOPEN<sub>L</sub>* and *CAP FLOWS<sub>L</sub>* are both significant in the expected negative direction. In model 4, *CAOPEN<sub>L</sub>* is statistically significant and negative, but *JOINT CURRENCY AREA* and *PEGGING* are not significant. In model 5, *CAP FLOWS<sub>L</sub>* remains significant in the expected direction, and *CAP OPEN<sub>L</sub>* is close to being significant at the 10 percent level. *PEGGING* is significant and positive. *JOINT CURRENCY AREA*, however, is not significant. In none of the last four models in Table 3 is democracy significant. Trade dependence (*DEP<sub>L</sub>*) is significant in models 3 and 5.

### *Results After Controlling for Preference Similarity*

Morrow argues that trade correlates with conflict in part because trade patterns reflect political closeness.<sup>81</sup> If so, then the effect of economic variables may actually be attributable to a measure of interest similarity. Some analysts go further, arguing that interdependence actually creates interest similarity.<sup>82</sup> Omitting a measure of the closeness of political interests might produce spurious findings. To examine the sensitivity of our results, we replicate models in Table 1 but include a measure of interstate preference similarity, *AFFINITY*. The statistical results appear in Table 4.

In model 2 of Table 4 *JOINT CURRENCY AREA* is significant at the 5 percent level (negative sign), and *PEGGING* is insignificant. In model 3 *CAOPEN<sub>L</sub>* is marginally significant at the 10 percent level, *CAP FLOWS<sub>L</sub>* is significant at the 5 percent level, and both variables have the expected negative sign. In model 4 *CAOPEN<sub>L</sub>* and *JOINT CURRENCY AREA* are negative and significant, and *PEGGING* is positive and insignificant. Finally, model 5 shows that *CAOPEN<sub>L</sub>*, *CAP FLOWS<sub>L</sub>*, and *JOINT CURRENCY AREA* are negative, with only *CAP FLOWS<sub>L</sub>* being statistically significant (though *CAOPEN<sub>L</sub>* is significant at the 10 percent level for a one-tailed test). *PEGGING* is positive and

80. Models 3 and 5 omit a spline variable that is not significant. Including the third spline does not change the results.

81. Morrow 1999.

82. See Papayoanou 1999; and Solingen 1998.

statistically significant. Note that the measure of similar interests is significant only in models 1 and 4. This may result from sample differences and from the correlation of *AFFINITY* with *DEP<sub>L</sub>*, *CAOPEN<sub>L</sub>*, *CAP FLOWS<sub>L</sub>*, and *JOINT CURRENCY AREA*. States with economic ties tend to have similar political preferences, or vice versa. Still, even after controlling for preference similarity, monetary and capital ties reduce disputes. States' interests may converge with interdependence, but their contribution to peace does not appear to eclipse the direct effects of our broader set of economic variables. The results are consistent with our argument that economic ties increase the range and efficiency of signaling between states, thus reducing the need for military violence.

## Conclusion

We have reviewed arguments for the effect of economic interdependence on peace. We show that existing accounts do not adequately explain why liberal economies are less likely to fight, but that a signaling argument is consistent with the observation of a liberal peace. We also expand interdependence to include financial and monetary integration, offering a set of variables that measure these processes. Our results corroborate our hypotheses. This study is limited by data and by a theoretical framework that necessarily simplifies reality. Still, despite weaknesses, the combination of theory and analysis offers a compelling and not-inconsiderable refinement of the relationship between economics and peace.

Trade and direct investment increase cross-border economic contact and raise a state's stake in maintaining linkages. Monetary coordination and interdependence demand that states strike deals. Through such interactions, states create a broad set of mutually beneficial economic linkages. While these linkages may deter very modest clashes, their main impact is as a substitute method for resolving conflict. Political shocks that threaten to damage or destroy economic linkages generate information, reducing uncertainty when leaders bargain. Threats from interdependent states carry more weight than threats from autarchic states precisely because markets inform observers as to the veracity of political "cheap talk." Multiple channels of economic interactions help states to credibly communicate, increasing the "vocabulary" available to states in attempting to assess relative resolve.

A signaling interpretation of interdependence offers some promise both analytically and in terms of international events. If costly signaling through economic interdependence reduces states' recourse to military violence, then increasing economic interdependence (globalization) implies the prospect of a more pacific global system. The magnitude of the pacific effect of interdependence is difficult to assess, however, since other factors, such as increasing polarization, may add to the motives for conflict. At the same time, the signaling argument implies that much of

the variance in the propensity for conflict is unknowable.<sup>83</sup> Before we can have greater confidence in our results, we need to examine a larger data sample, including all dyads and longer time spans. Precise measures may be obtained by limiting the sample to U.S. dyads. Finally, the effects of democracy on conflict appear to require additional assessment. However, our findings provide evidence (and a rationale) suggesting that liberal economics may be at least as salient to peace as liberal politics.

## Appendix

Here we provide formal proofs of key propositions in the text in the form of simple bargaining games. In each game, two states ( $A$  and  $B$ ) compete over the disposition of spoils in a unit space (representing issues, territory, and so on), where  $A$ 's ideal point is arbitrarily coded zero and  $B$ 's ideal point is coded 1. Utilities for outcomes decline linearly (generalizable to any monotonic function) in the distance from players' ideal points (disposition of spoils is zero-sum). Games in propositions 1–3 offer parsimonious conditions sufficient to motivate the propositions. In these games,  $A$ 's utility for its ideal point (zero) is coded 1.  $B$ 's utility for outcomes varies with "type" and is selected randomly from a uniform distribution of unit interval ( $t \sim \text{Un}[0,1]$ ). Types weight outcomes so that types  $B$  near 1 are "resolved," and types  $B$  near zero care relatively little about the stakes. Jeffrey S. Banks offers a proof showing that proofs like those in propositions 1–3 are generalizable for the entire class of bargaining games with endogenous offers and one-sided asymmetric information.<sup>84</sup> Proposition 4 shows that propositions 1–3 are robust to two-sided asymmetric information ( $A$  has type space  $t_A \sim \text{Un}[0,1]$ ).

The sequence of play for games in propositions 1–3 is for  $A$  to propose a take-it-or-leave-it offer ( $d$ ) to  $B$  ( $A$  receives  $1 - d$ ). Player  $B$  then either accepts the demand or rejects it, leading to a costly contest with a lottery over the stakes. We assume that the *ex ante* probability that either player wins a contest equals the ratio of military capabilities in the dyad ( $a$  for player  $B$ , and  $1 - a$  for player  $A$ ).  $B$ 's decision to fight is dichotomous ( $f$ , where  $f = 1$  is "fight," and zero is "accept,"  $A$ 's beliefs about types ( $b$ ) may be probabilistic). Fighting imposes a positive cost on both players (the non-zero-sum component of the game). Proofs for proposition 4 involve an additional stage of bargaining and two-sided asymmetric information. Models with asymmetric information involve Perfect Bayesian equilibria. Results are generalizable to other distributions.

PROPOSITION 1: UNCERTAINTY IS NECESSARY FOR COSTLY CONTESTS (WARS, AND SO ON). *The proposition requires demonstrating that costly contests occur only with strategic uncertainty (asymmetric information). States  $A$  and  $B$  never fight if  $A$  knows  $B$ 's type. If  $A$  is uncertain about  $B$ 's type, then war can occur. We first model the full information game and then introduce asymmetric information (for  $B$ ).*

83. Gartzke shows that an informational theory of war implies that researchers cannot anticipate contests from crises unless researchers are better informed about participants' private information than are the participants themselves. Gartzke 1999.

84. Banks 1990.

*Variables*

- $a = B$ 's odds of victory (ratio of military capabilities in the dyad,  $[0 \leq a \leq 1]$ )
- $b_A = A$ 's beliefs about  $B$ 's type ( $t$ )
- $c =$  Each state's cost for fighting,  $c [0 < c \leq 1/2]$
- $d = A$ 's proposal ( $0 \leq d \leq 1$ ).  $A$  receives utility  $1 - d$ , ( $U_A(d = 0) = 1$ )
- $f = B$ 's decision to fight (and  $A$ 's estimate)  $[0 \leq f \leq 1]$
- $t = B$ 's type ( $0 \leq t \leq 1$ ) drawn at random from type space  $T \sim \text{Un}[0,1]$

*State B's Problem*

$$\max U_B \text{ w.r.t. } f, \text{ s.t. } f \in [0,1].$$

$$U_B = [(1 - f) \cdot (t \cdot d)] + [f \cdot ((t \cdot a) - c)], \quad \frac{\partial U_B}{\partial f} = t \cdot (a - d) - c$$

If

$$d < a - \frac{c}{t},$$

then  $B$ 's utility is increasing in  $f$ .  $B$  accepts  $A$ 's proposal ( $f = 0$ ) if

$$d \geq a - \frac{c}{t},$$

else  $f = 1$ .

*State A's Problem*

$$\max U_A \text{ w.r.t. } d, \text{ s.t. } 0 \leq d \leq 1.$$

$$U_A = [(1 - f) \cdot (1 - d)] + [f \cdot ((1 - a) - c)], \quad \frac{\partial U_A}{\partial d} = (f - 1).$$

$A$ 's utility is decreasing in the offer ( $d$ ), up to the point where  $B$  is willing to fight ( $f$ ).  $A$ 's optimal demand is one  $B$  is just willing to accept. If  $A$  knows  $B$ 's type, then  $A$  makes this demand. If  $A$  does not know  $B$ 's type, then  $A$  will sometimes make a demand that  $B$  prefers to reject, leading to war.

*Full Information Solution (A knows B's type)*

$A$ 's calculation of  $d$ : Since  $U_A$  is decreasing in  $d$ ,  $A$  prefers

$$d = a - \frac{c}{t}$$

to any

$$d > a - \frac{c}{t},$$

and

$$(1 - d) = 1 - a + \frac{c}{t} \text{ (A's payoff for not fighting)}$$

is preferred to  $1 - a - c$  (A's payoff for fighting) for all types  $B$  ( $t > 0$ ). Since  $A$  knows  $B$ 's type (and thus  $B$ 's reservation price), and since  $d$  is endogenous, capabilities, resolve, costs, and other factors are subsumed in  $A$ 's offer and do not motivate a contest.

*Equilibrium.* In all cases,  $A$  proposes

$$d^* = a - \frac{c}{t},$$

and  $B$  accepts ( $f = 0$ ).

*Asymmetric Information Solution (A does not know B's type).*

$A$ 's calculation of  $d$ : Given  $B$ 's private information about its type,  $A$  calculates its best response to each type of  $B$  weighted by the odds of encountering any given type.  $A$ 's optimal proposal ( $d^*$ ) is a function of the definite integral of  $B$ 's reservation price over the domain of  $B$ 's type space ( $T$ ),

$$\int_0^1 \frac{\partial U_B}{\partial f} \cdot f(t) dt = \int_0^1 [t(a - d) - c] \cdot f(t) dt = \frac{1}{2} (a - 2c - d).$$

Setting the integral equal to zero and solving for  $d$  yields  $d = a - 2c$ . This implies that  $f = 1$  if

$$(a - 2c) < \left( a - \frac{c}{t} \right) \quad [ \quad t > \frac{1}{2},$$

else if

$$t \leq \frac{1}{2}, \quad f = 0.$$

Changing only the informational conditions leads to a motive for costly contests.

*Equilibrium.*  $A$  proposes  $d^* = a - 2c$ .  $B$  accepts ( $f = 0$ ) if

$$t \leq \frac{1}{2}$$

and rejects (war) otherwise.  $A$ 's beliefs equal  $(b_A|t, t \in T \sim \text{Un}[0,1])$ , but there is no opportunity to update before the offer. Q.E.D.

PROPOSITION 2: OPPORTUNITY COST ARGUMENTS FOR INTERDEPENDENCE HAVE LITTLE OR NO EFFECT ON THE PROBABILITY OF COSTLY CONTESTS. *The second proposition requires showing that the addition of a mutual benefit for actors (where the benefit is conditional on cooperation) does not alter the probability of costly contests. We add a mutual benefit ( $h$ ). We show that interdependence through opportunity costs is subsumed in bargaining and has no effect on conflict behavior.*

*Variables.* The variables are the same as in the previous model, with the addition of opportunity costs.

$h$  = Each actor's benefit from economic exchange, [ $h \geq 0$ ]

*State B's Problem*

$\max U_B$  w.r.t.  $f$ , s.t.  $f \in [0,1]$ .

$$U_B = [(1 - f) \cdot (t \cdot d + h)] + [f \cdot ((t \cdot a) - c)], \quad \frac{\partial U_B}{\partial f} = t \cdot (a - d) - c - h.$$

If

$$d < a - \frac{c + h}{t},$$

then  $B$ 's utility is increasing in  $f$ .  $B$  accepts ( $f = 0$ ) if

$$d \geq a - \frac{c + h}{t},$$

else  $f = 1$ .

*State A's Problem*

$\max U_A$  w.r.t.  $d$ , s.t.  $0 \leq d \leq 1$ .

$$U_A = [(1 - f) \cdot (1 - d + h)] + [f \cdot ((1 - a) - c)], \quad \frac{\partial U_A}{\partial d} = (f - 1).$$

$A$ 's utility again decreases in  $d$  until  $B$  prefers fighting ( $f = 1$ ) to  $A$ 's demand.  $A$ 's optimal demand is again one  $B$  will just accept. The addition of a mutual benefit threatened by a contest ( $h$ ) shifts  $B$ 's reservation price. If benefits can be anticipated,  $A$  simply subsumes  $B$ 's opportunity costs into a more extractive demand. Unanticipated benefits (states probably



know if they are interdependent) are a potential motive—not a palliative—for costly contests since they contribute to asymmetric information.

*Solution.*

A's calculation of  $d$ : The solution is similar to the asymmetric information game in proposition 1. A calculates its best response to each type  $B$  weighted by the odds of encountering any given type.

$$\int_0^1 \frac{\partial U_B}{\partial f} \cdot f(t) dt = \int_0^1 [t(a - d) - c - h] \cdot f(t) dt = \frac{1}{2} (a - 2c - d - 2h).$$

Solving for  $d$  yields  $d = a - 2c - 2h$ . A expects  $f = 1$  if

$$(a - 2c - 2h) < \left( a - \frac{c + h}{t} \right) \quad [ \quad t > \frac{1}{2},$$

else if

$$t \leq \frac{1}{2}, \quad f = 0.$$

Opportunity costs fail to motivate a decline in costly contests. Given endogenous bargains, altering payoffs without changing informational conditions in the game cannot change the odds of a fight. Player A simply subsumes changes in  $B$ 's reservation price in a more exacting demand. Uncertainty about interdependence can lead  $A$  to make a demand that  $B$  rejects, but this cannot account for peace.

*Equilibrium.* A proposes  $d^* = a - 2c - 2h$ .  $B$  accepts ( $f = 0$ ) if

$$t \leq \frac{1}{2}$$

and rejects otherwise. A's beliefs equal

$$(b_A | t, t \in T \sim \text{Un}[0, 1]).$$

Again, updating occurs after the offer.

Q.E.D.

PROPOSITION 3: COSTLY SIGNALING CAN EXPLAIN THE APPARENT EFFECT OF INTERDEPENDENCE ON THE PROPENSITY FOR COSTLY CONTESTS. *Proposition 3 involves a more complex framework and solution. We need to show that a mutual benefit can allow actors to signal, leading to peace. We again begin with asymmetric information and a mutual benefit (h). Instead of directly inhibiting contests, however, opportunity costs offer a cheaper method of demonstrating resolve. In the signaling game, B has the option to preemptively eliminate*

*interdependence* ( $h$ ).  $B$  might signal using a portion of  $h$  ( $v \leq h$ ), but results are monotonic, and this complicates presentation. Also, to simplify the game (and with no loss of generality) we assume  $B$  weakly prefers signaling if indifferent.

*Variables.* The variables are the same as in the previous model, though  $B$  now has a second decision variable.

$$s = B\text{'s signaling decision (whether to delete the mutual benefit, } h) [0 \leq s \leq 1]$$

*State B's Problem*

$$\max U_B \text{ w.r.t. } s, f, \text{ s.t. } s, f \in [0,1].$$

$$U_B = (1 - s)[t \cdot d_0 + h] + s \cdot \{[(1 - f)(t \cdot d_1)] + [f(t \cdot a) - c]\},$$

$$\frac{\partial U_B^{s=1}}{\partial f} = t \cdot (a - d_1) - c, \quad \frac{\partial U_B}{\partial s} = t \cdot (d_1(1 - f) - d_0 + a \cdot f) - h - c \cdot f.$$

Define  $\tau \in T$ , s.t.

$$\frac{\partial U_B}{\partial s} = 0 \quad \text{if } t = \tau.$$

$B$  signals ( $s = 1$ ) if

$$d_0 < af + d_1(1 - f) - \frac{h + c \cdot f}{t},$$

and if

$$d_1 < a - \frac{c}{t},$$

then  $B$  also fights ( $f = 1$ ).

*State A's Problem*

$$\max U_A \text{ w.r.t. } d_i, \text{ s.t. } 0 \leq d_i \leq 1,$$

where  $i \in [0,1]$ .

$$U_A = (1 - s)[1 - d_0 + h] + s \cdot \{[(1 - f)(1 - d_1)] + [f(1 - a) - c]\},$$

$$\frac{\partial U_A}{\partial d_0} = (s - 1), \quad \frac{\partial U_B}{\partial d_1} = s(f - 1).$$

A's best response remains an offer each B will just accept discounted by the odds of any given type, but A must also gauge how offers affect B's choice of subgame. The less generous the baseline ( $d_0$ ), the more often B ends the benefit ( $h$ ). The greater the signaling demand ( $d_1$ ), the more often B prefers fighting. A's optimal demands make A indifferent between subgames. Since B can play A's game, the calculation is the basis for common conjecture. If B expects to reject the offer, B always signals.

*Solution.*

A's calculation of  $d_1$ : A first calculates a best response to each type B willing to signal ( $d_1$ ,  $\tau$  to 1). Both players then use  $d_1$ ,  $\tau$ , A's estimate of  $f$ , and A's utility to solve for a baseline demand ( $d_0$ ).

$$\int_{\tau}^1 \frac{\partial U_B^{s=1}}{\partial f} \cdot f(t) dt = \int_{\tau}^1 [t(a - d_1) - c] \cdot f(t) dt = \frac{1}{2} [(\tau - 1)(a - 2c - d_1 + \tau(a - d_1))].$$

Solving for  $d_1$  yields

$$d_1 = a - \frac{2c}{1 + \tau}.$$

Substituting  $d_1$  into

$$\frac{\partial U_B}{\partial s}$$

and solving for  $\tau$  produces

$$\tau = \frac{-a + h + d_0 + c(2 - f) + \sqrt{(-a + h + d_0 + c(2 - f))^2 + 4(a - d_0)(b + f \cdot c)}}{2(a - d_0)}.$$

Using Bayes's theorem, the conditional probability of a fight  $P(f=1|s=1)$  is

$$\begin{aligned} & \frac{P(f = 1) \cdot P(s = 1|f = 1)}{P(f = 1) \cdot P(s = 1|f = 1) + P(f = 0) \cdot P(s = 1|f = 0)} \\ &= \frac{\left(1 - \frac{1}{2}(1 + \tau)\right) 1}{\left(1 - \frac{1}{2}(1 + \tau)\right) 1 + \frac{1}{2}(1 + \tau) \left(\frac{\frac{1}{2}(1 + \tau) - \tau}{\frac{1}{2}(1 + \tau)}\right)} = \frac{1}{2} \end{aligned}$$

Substituting for  $\tau, d_1, s,$  and  $f$  in  $A$ 's utility function and solving the optimization problem, we obtain

$$d_0 = \frac{4h^2 + c^2 + 4ah - 2ac + 4hc - 2\sqrt{2} \cdot c^{3/2} \cdot \sqrt{2h + c}}{2(2h - c)}.$$

Substituting  $d_0$  and solving for  $d_1$ , we now obtain both of  $A$ 's demands in terms of game parameters:

$$d_1 = \frac{2c(4h^2 + c^2 + 4hc - 2\sqrt{2} \cdot c^{3/2} \cdot \sqrt{2h + c})}{2c^2 - \sqrt{2} \cdot c^{3/2} \cdot \sqrt{2h + c} + 2(c - 2h) \cdot \sqrt{\frac{c(4h^3 + c^3 + 2h^2c - 2h\sqrt{2} \cdot c^{3/2} \cdot \sqrt{2h + c}}{(c - 2h)^2)}}}.$$

$B$  compares payoffs in each subgame to decide whether to signal ( $s$ ). Substituting and solving for ( $\tau$ ):

$$\frac{\left( 2(c - 2h)(h + cf) \left( 2\sqrt{2} \cdot c^{3/2} \cdot \sqrt{2h + c} - 2c^2 + (4h - 2) \left( \sqrt{\frac{c(4h^3 + c^3 + 2h^2c - 2h\sqrt{2} \cdot c^{3/2} \cdot \sqrt{2h + c}}{(c - 2h)^2)}} \right) \right) \right)}{\left( (4h^2 + c^3 + 4hc - \sqrt{2} \cdot c^{3/2} \cdot \sqrt{2h + c})(c(c(2 - 4f) + 8h(f - 1) + \sqrt{2} \cdot c^{3/2} \cdot \sqrt{2h + c})) \right. \\ \left. + (4h - 2c) \cdot \left( \sqrt{\frac{c(4h^3 + c^3 + 2h^2c - 2h\sqrt{2} \cdot c^{3/2} \cdot \sqrt{2h + c}}{(c - 2h)^2}} \right) \right)}$$

$A$ 's demands nullify relative power ( $a$ ).  $A$  expects  $f = 1$  if

$$d_1 t < at - c \quad [ \quad 2ct > c(1 + \tau) \quad [ \quad t > \frac{c(1 + \tau)}{2c} = \frac{1}{2}(1 + \tau),$$

else  $f = 0$ . Since

$$\frac{1}{2}(1 + \tau) > \frac{1}{2}, \quad \sim \tau > 0,$$

the probability of fighting in both the opportunity cost and signaling games is the same only if  $h = 0$ .

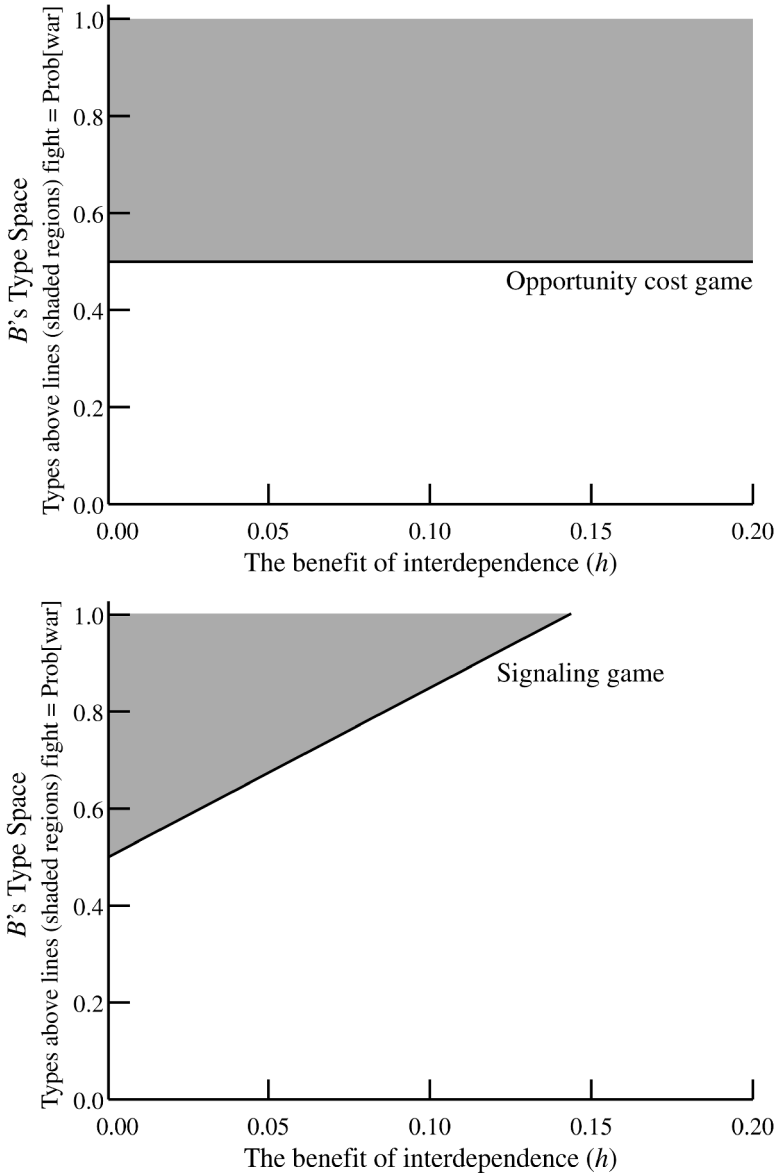
*Equilibrium.*  $A$  offers  $d_i^*, i \in [0,1]$ .  $B$  accepts  $d_0$  ( $s = 0, f = 0$ ) if  $t \leq \tau$ .  $d_1$  ( $s = 1, f = 0$ ) if

$$\frac{1}{2}(1 + \tau) \geq t > \tau,$$

and fights ( $s = 1, f = 1$ ) otherwise.

$A$ 's beliefs equal

$$(b_A^{s=1} | t, t \in T \sim \text{Un}[\tau, 1], b_A^{s=0} | t, t \in T \sim \text{Un}[0, \tau]).$$



**FIGURE 1.** *The range of types B that fight (probability of war)*

The graphs in Figure 1 show the relationship between interdependence ( $h$ , horizontal axis) and types  $B$  ( $t$ , vertical axis,  $c = 1/4$ ). The horizontal line at 0.5 is for opportunity costs. Types  $B$  larger than 0.5 fight at all levels of interdependence. The line sloping upward

represents signaling. The greater the mutual benefit sacrificed as a signal, the fewer types  $B$  that fight. The finding is general to situations where  $B$  sacrifices only part of the benefit of interdependence. Signaling reduces dispute frequency. Q.E.D.

PROPOSITION 4: PROPOSITIONS 1–3 HOLD FOR TWO-SIDED ASYMMETRIC INFORMATION, SYMMETRIC BARGAINING, AND TEMPORAL DISCOUNTS. *Proposition 4 claims that previous propositions are robust to relaxing model assumptions. Science favors the simplest account consistent with behavior of interest. Still, it is worth confirming the generality of results from parsimonious models. We show that our conclusions do not depend on bargaining symmetry or the treatment of uncertainty or time. Other aspects of the games, such as structure, are unlikely to alter results. Banks shows that for all two-player bargaining games where one actor is privately informed, both the odds of a contest and the equilibrium settlement increase monotonically in the informed actor’s payoffs.<sup>85</sup> Given Banks’ proof and equilibrium expectations, it follows that propositions 1–3 hold for at least the class of two-player bargaining games in which offers are endogenous and unrestricted. The following games feature a two-stage sequence of play.  $B$  can now make a counteroffer.  $A$  then accepts  $B$ ’s counter or fights.*

*Proposition 1.* Proposition 1 is trivially satisfied. Since one-sided asymmetric information is sufficient to motivate costly contests (and full information is not), two-sided asymmetric information is also sufficient.

*Proposition 2.* Utilities appear with the interdependence parameter ( $h_i$ ), but the value of benefits can be zero.

*Variables.* Variables are the same, though symmetric play requires the use of subscripts.

$\delta_i$  = Player’s discount for payoffs in the second period (after  $B$ ’s counter,  $i \in [A,B]$ ).

$p$  =  $B$ ’s proposal decision (whether to propose  $d_B$  or accept  $d$ ) [ $0 \leq d_B \leq 1$ ].

*State A’s Problem*

$\max U_A$  w.r.t.  $d$ , s.t.  $0 \leq d \leq 1$ , and  $f_A$ , s.t.  $f_A \in [0, 1]$ .

$$U_A = \{[p\delta_A(1 - f_A)(t_A(1 - d_B) + h_A)] + [f_A(t_A(1 - a) - c)]\} + (1 - p)(t_A(1 - d) + h_A(1 + \delta)),$$

$$\frac{\partial U_A}{\partial d} = t_A(p - 1), \quad \frac{\partial U_A^{p=1}}{\partial f_A} = \delta_A[t_A(d_B - a) - c - h_A].$$

*State B’s Problem*

$\max U_B$  w.r.t.  $d_B$ , s.t.  $0 \leq d_B \leq 1$ , and  $p$ , s.t.  $p \in [0, 1]$ .

85. Ibid.

$$U_B = p\delta_B\{[(1 - f_A)(td_B + h_B)] + [f_A(ta - c)]\} + (1 - p)(td + h_B(1 + \delta_B)),$$

$$\frac{\partial U_B}{\partial p} = t[\delta_B(d_B(1 - f_A) + f_Aa) - d] - b(1 + \delta_B f_A) - \delta_B f_A c,$$

$$\frac{\partial U_B^{p=1}}{\partial d_B} = \delta_B[t(1 - f_A)].$$

A's offer is again one each B just accepts, but this time B can make a counteroffer. B in turn makes an offer A just accepts. The less generous A's initial offer (d), the more often B prefers to counter (d<sub>B</sub>). A then chooses between fighting (f<sub>A</sub>) and accepting B's counterproposal.

*Solution.*

B's calculation of d<sub>B*i*</sub> (p = 1): B makes a best counteroffer weighted by the odds of each type A.

$$\int_0^1 \frac{\partial U_A^{p=1}}{\partial f_A} \cdot f(t_A) dt_A = \int_0^1 \delta_A [t_A(d_B - a) - c - h_A] \cdot f(t_A) dt_A = \frac{1}{2} \delta_A (d_B - a - 2(c + h_A)).$$

Solving,

$$d_B = a + 2(c + h_A); f_A = 1 \text{ if } a + 2(c + h_A) > a + \frac{c + h_A}{t_A} \quad [ \quad t_A > \frac{1}{2},$$

else if t<sub>A</sub> ≤ 1/2, f<sub>A</sub> = 0.

B's calculation of p: B's optimal counter

$$(d_B^*) \quad [ \quad P(f_A = 1) = \frac{1}{2}.$$

Simplifying

$$\frac{\partial U_B}{\partial p}$$

and solving for

$$\tau = \frac{\delta_B(h + c) + 2h}{2(\delta_B(a + h_A + c) - d)}.$$

If  $A$  offers

$$d < \delta_B(a + h_A + c) - \frac{\delta_B(h + c) - 2h}{2t}, \quad p = 1, \text{ else } p = 0.$$

$A$ 's calculation of  $d$ :  $A$  can play  $B$ 's game, anticipating  $B$ 's offer,  $B$ 's estimate of  $f_A$  and  $\tau$  to calculate  $P(p = 1) = (1 - \tau)$ . Substituting values, then recalculating

$$\frac{\partial U_B}{\partial p}$$

and solving the integral:

$$\begin{aligned} \int_0^1 \frac{\partial U_B}{\partial p} \cdot f(t) dt &= \int_0^1 t[\delta_B(a + c + h_A) - d] - \frac{1}{2}(\delta_B(c + h) + 1) \cdot f(t) dt \\ &= \frac{1}{2}(\delta_B(a + h_A) - h(2 + \delta_B) - d) \end{aligned}$$

Solving,  $d = \delta_B(a + h_A) - h(2 + \delta_B)$ . Substituting  $d$ ,  $d_B$ ,  $\tau = 1/2$ .  $B$  accepts  $A$ 's offer if  $t \leq 1/2$ , else  $p = 1$ . If  $p = 1$ ,  $A$  accepts  $B$ 's offer if  $t_A \leq 1/2$ . This is so regardless of values assigned to  $h$  and  $h_A$ .

*Equilibrium.*  $A$  proposes  $d^* = \delta_B(a + h_A) - h(2 + \delta_B)$  and  $B$  accepts ( $p = 0$ ) if  $t \leq 1/2$ , else if  $p = 1$ ,  $B$  offers  $d_B^* = a + 2(c + h_A)$  and  $A$  accepts ( $f_A = 0$ ) if  $t_A \leq 1/2$ , else ( $f_A = 1$ ).  $A$ 's beliefs equal  $(b_A|t, t \in T \sim \text{Un}[0,1])$ .  $B$ 's beliefs are  $(b_B|t_A, t_A \in T_A \sim \text{Un}[0,1])$ .

The probability of a contest is independent of the benefit of interdependence ( $h$  or  $h_A$ ) because such benefits (and all other parameters that can be anticipated) are subsumed in players' offers.

*Proposition 3.* Some terms are presented in implicit form to save space and because the equations are quite bulky.

*Variables.* Variables are the same as in the previous model; subscripts are again used to identify player, offers, and so on.

*State A's Problem*

$$\max U_A \text{ w.r.t. } d_i, \text{ s.t. } 0 \leq d_i \leq 1,$$

where  $i \in [0,1]$ , and  $s_A, f_A$ , s.t.  $s_A, f_A \in [0,1]$ .

$$\begin{aligned} U_A &= (1 - s)[t_A(1 - d_0) + h_A(1 + \delta_A)] + s\{(1 - p)(t_A(1 - d_1) + h_A\delta_A) \\ &\quad + p[(1 - s_A)(\delta_A(t_A(1 - d_{B0}) + h_A)) + s_A(\delta_A((1 - f_A)t_A(1 - d_{B1})) \\ &\quad + f_A(t_A(1 - a) - c))]\}, \end{aligned}$$



$$\frac{\partial U_A}{\partial d_0} = t_A(s - 1), \quad \frac{\partial U_A}{\partial d_1} = t_A s(p - 1), \quad \frac{\partial U_A^{s=1, p=1, s_A=1}}{\partial f_A} = \delta_A[t_A(d_{B1} - a) - c],$$

$$\frac{\partial U_A^{s=1, p=1}}{\partial s_A} = \delta_A[t_A(d_{B0} - d_{B1}(1 - f_A) - f_A a) - f_A c - h_A].$$

Define

$$\tau_A \in T, \text{ s.t. } \frac{\partial U_A^{s=1, p=1}}{\partial s_A} = 0$$

if  $t_A = \tau_A$ . A signals ( $s_A = 1$ ) if

$$d_0 > d_{B1}(1 - f_A) + af_A + \frac{h_A + f_A c}{t_A},$$

and if

$$d_{B1} > a + \frac{c}{t_A}, \quad A \text{ fights } (f_A = 1).$$

*State B's Problem*

$$\max U_B \text{ w.r.t. } d_{Bi}, \text{ s.t. } 0 \leq d_{Bi} \leq 1,$$

where  $i \in [0,1]$ , and  $p, s, \text{ s.t. } p, s \in [0,1]$ .

$$U_B = (1 - s)[td_0 + h(1 + \delta_B)] + s\{(1 - p)(td_1 + h\delta_B) + p[(1 - s_A)(\delta_B(td_{B0} + h)) + s_A(\delta_B((1 - f_A)td_{B1} + f_A(ta - c)))]\},$$

$$\frac{\partial U_B}{\partial d_{B0}} = \delta_B p s t(1 - s_A), \quad \frac{\partial U_B}{\partial d_{B1}} = \delta_B p s s_A t(1 - f_A),$$

$$\frac{\partial U_B}{\partial s} = t[d_1((1 - p) - d_0 + \delta_B p(d_{B0}(1 - s_A) + s_A(d_{B1}(1 - f_A) + af_A))] - \delta_B p s_A(h + f_A c) - h$$

$$\frac{\partial U_B^{s=1}}{\partial p} = t[\delta_B(s_A(d_{B1}(1 - f_A) + af_A) + d_{B0}(1 - s_A)) - d_1] - \delta_B s_A(h + f_A c).$$

$$\tau \in T, \text{ s.t. } \frac{\partial U_B^{s=1}}{\partial s} = 0$$

if  $t = \tau$ . ( $s = 1$ ) if

$$d_0 < d_1(1 - p) + \delta_B p(d_{B0}(1 - s_A) + s_A(d_{B1}(1 - f_A) + af_A)) - \frac{(\delta_B p s_A(h + f_A c) + h)}{t},$$

and  $B$  also proposes ( $p = 1$ ) if

$$d_1 < \delta_B(d_{B0}(1 - s_A) + s_A(d_{B1}(1 - f_A) + af_A)) - \frac{\delta_B s_A(h + f_A c)}{t}.$$

*Solution.*

$B$ 's calculation of  $d_{B_i}$ :  $B$  calculates a best response to each type  $A$  that signals ( $d_{B1}$ ,  $\tau_A$  to 1). States then use  $d_{B1}$ ,  $\tau_A$ ,  $A$ 's estimate of  $f_A$ , and  $B$ 's utility to solve for ( $d_{B0}$ ).

$$\begin{aligned} \int_{\tau_A}^1 \frac{\partial U_A^{s=1, p=1, s_A=1}}{\partial f_A} f(t_A) dt_A &= \int_{\tau_A}^1 [\delta_A(t_A(d_{B1} - a) - c)] f(t_A) dt_A \\ &= \frac{1}{2} \delta_A(\tau_A - 1)(2c + (a - d_{B1})(1 + \tau_A)). \end{aligned}$$

Solving for  $d_{B1}$ ,

$$d_{B1} = a - \frac{2c}{1 + \tau_A}.$$

Substituting  $d_{B1}$  into

$$\frac{\partial U_A^{s=1, p=1}}{\partial s_A}$$

and solving for  $\tau_A$ :

$$\tau_A = \frac{d_{B0} - a - h_A - c(2 - f_A) - \sqrt{(a + h_A - d_{B0} + c(2 - f_A))^2 + 4(a - d_{B0})(h_A + f_A c)}}{2(a - d_{B0})}.$$

Using Bayes's theorem, the conditional probability of a fight  $P(f_A = 1, s_A = 1)$  is:

$$\begin{aligned} &\frac{P(f_A = 1) \cdot P(s_A = 1 | f_A = 1)}{P(f_A = 1) \cdot P(s_A = 1 | f_A = 1) + P(f_A = 0) \cdot P(s_A = 1 | f_A = 0)} \\ &= \frac{\left(1 - \frac{1}{2}(1 + \tau_A)\right) 1}{\left(1 - \frac{1}{2}(1 + \tau_A)\right) 1 + \frac{1}{2}(1 + \tau_A) \left(\frac{\frac{1}{2}(1 + \tau_A) - \tau_A}{\frac{1}{2}(1 + \tau_A)}\right)} = \frac{1}{2}. \end{aligned}$$

Substituting for  $\tau_A$ ,  $d_{B1}$ ,  $s_A$  and  $f_A$  in  $B$ 's optimization problem

$$\left( \int_{\tau_p}^1 \frac{\partial U_B^{s=1, p=1}}{\partial d_{B0}} \right)$$

and solving for  $d_{B0}$ :

$$d_{B0} = \frac{1}{2(1 + \tau_p)(2h - \tau_p c)} \{ [2a(1 + \tau_p)(2h - \tau_p c) - 2b(c(1 + \tau_p) + 2\sqrt{c}\sqrt{2h + c}\sqrt{1 + \tau_p} + 2h_A(1 + \tau_p))] + \sqrt{c}[(2h(1 + \tau_p) \times (-\sqrt{c}\sqrt{2h + c}\sqrt{1 + \tau_p}) + c(-\sqrt{c}(1 + \tau_p) + \sqrt{2h + c}\sqrt{1 + \tau_p}(1 + 3\tau_p)))] \}$$

$B$ 's calculation of  $p$ :  $\tau_p$  is the type  $B$  just indifferent between accepting  $A$ 's proposal ( $d_1$ ) and countering. Setting

$$\frac{\partial U_B^{s=1}}{\partial p} = 0$$

and solving for  $t$ :

$$\tau_p = \frac{\delta_B s_A (h + f_A c)}{\delta_B (s_A (d_{B1} (1 - f_A) + a f_A) + d_{B0} (1 - s_A)) - d_1}$$

If  $A$  offers

$$d_1 < \delta_B (d_{B0} (1 - s_A) + s_A (d_{B1} (1 - f_A) + a f_A)) - \frac{\delta_B s_A (h + f_A c)}{t},$$

$$p = 1, \text{ else } p = 0.$$

$A$ 's calculation of  $d_i$ :  $A$  calculates best response offers ( $d_i$ ) to each type  $B$ , given  $B$ 's signal ( $s$ ), common conjectures about  $\tau_A$  and  $\tau_p$ , and anticipating  $B$ 's offers ( $d_{B0}$  and  $d_{B1}$ ) and  $B$ 's estimate of  $P(f_A)$ . If  $B$  signals ( $s = 1$ ),  $A$  offers  $d_1$  equal to the solution to the optimization problem

$$\left( \int_{\tau}^1 \frac{\partial U_B^{s=1}}{\partial p} \right):$$

$$d_1 = \delta_B (d_{B0} (1 - s_A) + s_A (d_{B1} (1 - f_A) + a f_A)) - \frac{2(\delta_B s_A (h + f_A c))}{1 + \tau}$$

Substituting  $d_1$  in

$$\tau_p \left[ \tau_p = \frac{1 + \tau}{2} \right].$$

$B$  accepts  $d_1$  if

$$t < \frac{1 + \tau}{2}, \text{ else } (p = 1).$$

Using Bayes's theorem,  $A$ 's estimate  $P(p = 1 | s = 1)$ , is

$$\frac{P(p = 1) \cdot P(s = 1 | p = 1)}{P(p = 1) \cdot P(s = 1 | p = 1) + P(p = 0) \cdot P(s = 1 | p = 0)} = \frac{\left(1 - \frac{1}{2}(1 + \tau)\right) 1}{\left(1 - \frac{1}{2}(1 + \tau)\right) 1 + \frac{1}{2}(1 + \tau) \left(\frac{\frac{1}{2}(1 + \tau) - \tau}{\frac{1}{2}(1 + \tau)}\right)} = \frac{1}{2}.$$

Setting  $\left(\frac{\delta U_B}{\delta s}\right) = 0$  and solving for  $t$ :

$$\tau = \frac{\delta_B s_A (h + f_A c) + h}{\delta_B p (s_A (d_{B1}(1 - f_A) + af_A) + d_{B0}(1 - s_A)) + d_1(1 - p) - d_0}.$$

If  $A$  offers

$$d_0 < \delta_B p (d_{B0}(1 - s_A) + s_A (d_{B1}(1 - f_A) + af_A)) + d_1(1 - p) - \frac{\delta_B p s_A (h + f_A c) + h}{t}, \quad p = 1, \text{ else } p = 0.$$

Substituting known or estimated values of  $\tau$ ,  $\tau_A$ ,  $d_1$ ,  $d_{B0}$ ,  $d_{B1}$ ,  $s_A$ , and  $f_A$  in  $A$ 's optimization problem

$$\left( \int_0^1 \frac{\partial U_B}{\partial d_0} \right)$$

and solving,

$$d_0 = \delta_B p (d_{B0}(1 - s_A) + s_A(d_{B1}(1 - f_A) + af_A)) + d_1(1 - p) - \frac{\delta_B p s_A (h + f_A c) + h}{t},$$

where  $\tau$  is as defined earlier. (Solutions for terms in explicit form were obtained using the software package *Mathematica*. The explicit form equations are extremely cumbersome and are omitted here.)

*Equilibrium.* A offers  $d_i^*$ ,  $i \in [0,1]$ . B accepts  $d_0$  ( $s = 0$ ) if  $t \leq \tau$ , else if  $t > \tau$ , B signals ( $s = 1$ ), accepting  $d_1$  if  $\frac{1}{2}(1 + \tau) \cdot t \geq \tau$ , and proposes ( $p = 1$ ) otherwise. B offers  $d_{Bi}^*$ ,  $i \in [0,1]$ . A accepts  $d_{B0}$  ( $s_A = 0$ ) if  $t_A \leq \tau_A$ , else if  $t_A > \tau_A$ , A signals ( $s_A = 1$ ), accepting  $d_{B1}$  ( $s_A = 1, f_A = 0$ ) if  $\frac{1}{2}(1 + \tau_A) \cdot t_A \geq \tau_A$ , and fights ( $s_A = 1, f_A = 1$ ) otherwise. A's beliefs equal

$$(b_A^{s=1} | t, t \in T \sim \text{Un}[\tau, 1], b_A^{s=0} | t, t \in T \sim \text{Un}[0, \tau]).$$

B's beliefs equal

$$(b_B^{s_A=1} | t_A, t_A \in T \sim \text{Un}[\tau_A, 1], b_B^{s_A=0} | t_A, t_A \in T \sim \text{Un}[0, \tau_A]).$$

Contests occur in the symmetric signaling game if  $1 \geq t_i > \frac{1}{2}(1 + \tau_i)$ , whereas contests occur in the opportunity cost game if  $1 \geq t_i > \frac{1}{2}$  (where  $i$  is for  $t$  and  $t_A$ ). Since

$$1 - \frac{1}{2}(1 + \tau_i) = \frac{1}{2}(1 - \tau_i) \leq \frac{1}{2},$$

contests in the signaling game are always weakly less likely to occur than in the opportunity cost game. More important, since  $h_i > 0$  [  $\tau_i > 0$  and since

$$\frac{1}{2}(1 + \tau_i) < \frac{1}{2} \text{ if } \tau_A > 0,$$

it follows that interdependence reduces the frequency of costly contests, but *only* in the signaling game. These results corroborate the findings in proposition 3. The results also testify to the parsimony of the previous model. Q.E.D.

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