# The Ties that Bias
## Specifying and Operationalizing Components of Dyadic Dependence in International Conflict*

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**Abstract**

Students of international conflict are increasingly aware of the potential problem of spatial dependence. Much of international behavior is linked spatially and temporally. Yet, many dyadic analyses of interstate interactions assume independence among units. Although there exist some technical and statistical solutions for addressing spatial dependence, directly modeling the dependence generating processes is more satisfying and intellectually informative. We consider how extra-dyadic linkages to a dispute dyad could give rise to new disputes. Alliances are designed to encourage third parties to join dyadic contests, but most existing empirical analyses consider only bilateral alliance ties as factors preventing conflict onset. Likewise, contests often extend to include new disputes involving third parties that are geographically close to, or in between disputants. We develop new data on extra-dyadic alliance ties as well as the "inbetweenness" of potential third parties' geographical location relative to conflict dyads. We show empirically that both of these linkages are strongly related to the risk of dispute onset, even while accounting for other purely dyadic factors. Our approach can be applied more broadly to address spatial dependence, and can be extended to address other spatial variables.

# 1 Introduction

Empirical research in international relations relies on dyadic analysis as a means of capturing increasingly sophisticated notions of interaction between states. Dyads are helpful for analyzing outcomes that result as a result of interaction between actors, or combinations of their characteristics, rather than the attributes of individual actors. Yet, there are also potential pitfalls in existing dyadic research. The insight that behavior will be conditioned by expectations about, or reactions to, the behavior of other actors leads directly to the conclusion that most interesting phenomena in international relations must be minimally dyadic. At the same time, the very processes that make dyadic analysis preferable to looking at individual states, or at systemic aggregates, also violate the purely dyadic research design. Dyads do not pass one another like ships in the night, independent and largely oblivious of each other's functions. If strategic interaction continues across dyadic boundaries, then researchers need to consider addressing the potential non-independence of dyads.

Interaction between dyads can be considered as a form of spatial dependence. As is well understood, assuming that observations are independent when in fact they are serially correlated mischaracterizes the data generation process, exaggerates the actual size of the sample, thereby inducing downward bias in estimates of the standard errors (suggesting excessive confidence) and can lead to unreliable coefficient estimates. Although researchers tend to be more familiar with the problem of serial dependence in time, ignoring spatial dependence between observations yields similarly troubling consequences. Most research to date on spatial dependence in international relations focuses on applications where states are the units of analysis. Only recently have researchers considered the problem of dependence in analysis where the units are dyads. Many of the suggested solutions for addressing spatial dependence in dyadic data rely on the ad-hoc use of dummy variables, or technical solutions drawn from the literature on spatial statistics intended to ensure that empirical estimates are "consistent" (see, e.g., Mansfield & Bronson 1997, Heagerty, Ward & Gleditsch 2002, Beck, Gleditsch & Beardsley 2006).

While technical solutions to spatial dependence are possible and useful for many purposes, actually modeling the processes generating dependence can offer several avenues for advancing research further. Most scholars will agree that it is better to learn something about a phenomenon of interest rather than simply obliterating problems econometrically. To use a specific example familiar to international relations researchers, consider how concerns over unequal variance across units in panel data now have researchers routinely reporting "robust" standard error estimates. Such estimates may be more realistic indicators of the standard errors of coefficient estimates since they take into account how some units display more variability than others. However, as Leamer (1994) points out, simply "White-washing" the standard errors — i.e., using White's (1980) heteroskedasticty consistent, more robust estimates — is a total black-box procedure, revealing nothing about the sources of unequal variances or their theoretical implications. Braumoeller (2006) argues that many political science phenomena suggest differences in variation between groups rather than differences in means, implying that more can be learned by modeling variance directly. We likewise believe that more can be learned about dyadic interaction by treating forms of spatial dependence between dyads as meaningful substantive phenomena in their own right, rather than conceiving of extra-dyadic ties as a statistical problem or nuisance that we should endeavor to "correct."

We focus on two forms of spatial dependence in dyadic international conflict data that we believe are particularly substantively salient and difficult to ignore econometrically, extra-dyadic alliance ties and the "inbetweenness" or geographic proximity of extra-dyadic states relative to disputants. There is a disconnect in the conflict literature between how alliances are treated theoretically and empirically. Formal military obligations span dyadic boundaries precisely in order to draw third-parties into anticipated and actual dyadic contests (see, e.g., Leeds 2003, Smith 1995, Smith 1996). In spite of the theoretical connection between alliances and spatial dependence in examining dyadic conflict, extra-dyadic alliance ties are almost wholly absent from existing quantitative research. We offer data identifying what we describe as "third" and "fourth order" alliance ties, indicating dyads where states are linked to disputants through alliances with disputants or allies of the disputants. Proximity to disputants or the strategic position of a given territory can also condition the probability that a contest in one dyad precipitates disputes with third-parties (e.g., Siverson & Starr 1991, Gleditsch 2002, Ward & Gleditsch 2002). We create data on the location of dyads involving third party states relative to conflict dyads. Our measure is based on the degree of "inbetweenness" of another dyad, as given by the geographic position of a third party $C$ relative to dyadic disputants $A$ and $B$. Using these data, we estimate the extent to which alliance ties and dispute inbetweenness serve as conduits for spatial variation in dyadic conflict, introducing additional risk of a dispute in a dyad, over and above purely dyadic characteristics.[1]

The next section discusses the general problem of dyadic dependence, and reviews technical solutions to spatial dependence. We emphasize the implications of special attention to implications for international conflict, and advocate a strategy of explicitly modeling possible linkages between dyadic observations. We two examples of the substantive approach that we advocate, where we specify extra-dyadic links through alliances and proximity. Finally, we estimate the impact of dispute inbetweenness and higher order alliance ties on the likelihood of dyadic conflict onset, and then offer some conclusions on the implications of extra-dyadic ties for international relations research.

## 2 Dyadic dependence explained

As the smallest unit capable of capturing interstate interaction, dyads stand at the nexus between foreign policy and world politics. Arguably, dyads are also the building blocks for broader theories of systemic behavior. Contemporary theories of international relations frequently rely on dyadic attributes such as regime type, interdependence, relative power, distance and other variables to explain crises and war. Some have gone as far as to claim that any theory of international relations must be based on, or evolve from, dyadic explanations (see, e.g., Bueno de Mesquita 1989).[2]

Yet, the very appeal of the dyad for strategic theory implies a problem in conducting empirical analysis based on comparing dyads or dyad years. Whereas conventional forms of statistical analysis assume that observations are independent once the appropriate "right-hand-side" covariates are taken into account (or equivalently, that the remaining errors for individual units are independent of one another), dyadic observations will have a complicated dependence structure, because the same state enters into several different dyads with other states in the system. More precisely, for a system of $N$ states, we will have a total of $N(N-1)$ directed dyads.[3] Given this complicated dependence structure, it is highly questionable whether many of these dyads are adequately characterized as independent of one another. At the extreme, the flows of actions in the directed dyad

$A \rightarrow B$ are bound to be closely related to the reverse flows in the directed dyad $B \rightarrow A$.

To give a more specific example, consider the structure of dyadic trade flows between countries. Beck, Gleditsch & Beardsley (2006) show empirically that the size of a trade flow from one state $A$ to another state $B$ tends to be positively associated with the size of other trade flows involving either $A$ or $B$, and generally very similar to the "reverse" flow from $B$ to $A$. In a random network (first studied by Rapoport 1957, Erdős & Rényi 1960), the likelihood of a similar link between $A$ and $B$ does not depend on whether there is a link from $B$ to $A$ or the extent to which $B$ and $A$ are connected. Garlaschelli & Loffredo (2004), however, show that real world networks are either highly reciprocal, so that a link from $A$ to $B$ tends to be associated with a link from $B$ to $A$, as is the case with global trade, or highly directed, so that links run only in one direction, as with journal citations, where articles tend to cite earlier publications but only rarely cite subsequent work, or material that is published later in time.

The analysis of the trade example in Beck, Gleditsch & Beardsley (2006) shows that dependence extends beyond the problem of accounting for reverse dyads. We believe that this is likely to be the case also for many other types of international interactions, including conflict. For example, a bilateral war between $A$ and $B$ can give rise to additional dyadic disputes if some third party $C$ retaliates against $A$'s aggression to defend $B$. Likewise, $C$ may attack $A$ anticipating an attack on $B$. In this case, outcomes in the dyad $AC$ cannot be said to be independent of outcomes in the dyad $AB$; war between $A$ and $B$ conditions the likelihood of war between $A$ and $C$, and vice versa.[4]

A number of scholars have studied intervention in ongoing conflict (Raknerud & Hegre 1997, Richardson 1960, Werner & Lemke 1997). However, the problem of dependence is more severe than intervention in something considered the "same" dispute in a given data set. Although existing research has told us a great deal about states' decisions to support some party in a contest, it is ultimately somewhat arbitrary what should be considered "the same" or "different" conflicts. Observers have noted that many conflictual episodes in the Militarized Interstate Dispute (MID) data are coded as a single event (possibly multilateral) in terms of the dispute number (e.g., World War II, the Mexican American War), while other contentious issues give rise to a large number of events considered separate bilateral disputes with distinct MID numbers (e.g., the Iranian threat to impose a blockade of the Strait of Hormuz in 1984). The criteria for determining whether an event or incident is part of one dispute or a different dispute are quite complex in the MID data. In essence, the key criteria used to determine whether individual incidents are seen as being part of one dispute hinges on whether incidents involve the "same" incompatibility and are connected in time, as well as whether there is evidence of coordination between parties. Moreover, the criteria for aggregating incidents into larger disputes also depend on whether a previous incident is followed by a formal settlement and whether a dispute eventually generates casualties above the level considered a war. [5] Hence, the decisions reached by the MID project do not necessarily correspond to what other scholars may consider linked or separate disputes. More generally, restricting linkages between dyads to those that result in participation in something considered the "same" dispute by the MID criteria (or other criteria) are unlikely to not fully address dyadic dependence, as the activity of a state in one conflictual relationship may affect the behavior of adversaries in other apparently unrelated conflicts or expectations about behavior.

We propose as a simpler alternative to consider whether a conflict or MID between two states

$A$ and $B$ increases or changes the likelihood of disputes among other dyads somehow connected to the dyad $AB$. Thus, we can state the dyadic dependence problem generally as the question of whether, for any dyadic flow, we find that the expected values of a particular dyadic flow differ depending on the values of other somehow "connected" dyads.

Although it is easy to imagine that many dyads would be dependent on one another, demonstrating the magnitude of dependence and how it may affect specific results and inferences with respect to dyadic conflict onset is difficult to evaluate without first having a pre-specified baseline and a set of linkages. We will return to this issue later. However, we have several studies that demonstrate evidence for dyadic dependence and its potentially troubling effects in conflict studies. Heagerty, Ward & Gleditsch (2002) show that the "naïve" standard errors assuming independence are a great deal smaller than standard error estimates based on smaller sub-samples where observations can be presumed to be essentially independent on one another. Heagerty, Ward & Gleditsch (2002) also show in a simulation of dependent dyadic data that window sub-sampled standard error estimates provide more realistic estimates of the true variance than the naïve standard errors assuming independence and other more ad hoc approaches. Furthermore, Beck, Gleditsch & Beardsley (2006) show in the context of trade that the level of trade in one dyad $AB$ is influenced by the extent of trade in other related dyads, even when we control for other factors in a standard gravity model of dyadic trade. The estimated impact of political factors can change notably depending on whether dyadic dependence is taken into account. Beck et al. (2006), for example, find significant differences in the estimates for the political variables. The coefficient estimate for democracy in their European sample increases by about 25% once they address the spatially lagged error structure, while the estimated impact of MIDs in the spatially lagged error model is reduced by over 30% from its size in the results from the regression model assuming independent observations. If dependence among dyads is important for trade flows, the same is likely to be true for conflict behavior.

We will clarify below the theoretical rationale for how alliances and geographic position give rise to dyadic dependence in interstate conflict data. First, however, we turn to conventional methods and technical approaches to assessing and addressing dyadic dependence.

# 3 Addressing dyadic dependence

The most common approach to dyadic dependence adopted by the literature is to ignore its existence. Indeed, it is striking how much attention has been given to other, related problems such as time dependence and heterogeneity in dyadic research, and how little attention has been given to dependence between observations. The lack of attention to dyadic dependence probably stems to a large extent from the training received by most political scientists, and the fact that standard econometric textbooks rarely mention the problem of cross-sectional or spatial dependence (see, e.g., Anselin 1988), even though spatial dependence among observations can give rise to the same consequences as serially correlated errors — i.e., incorrect standard errors and inconsistent coefficient estimates.

The literature on geographical or spatial dependence has clarified the consequences of cross-sectional dependence and suggested a number of ways in which such dependence can be modelled (for overviews, see Anselin 1988, Cressie 1991, Ward & Gleditsch 2008). Applications of these insights to models of state behavior have indeed contributed to our understanding about international politics (examples include Gleditsch 2002, Gleditsch & Ward 2001, Murdoch, Sandler & Sargent 1997, Sandler & Murdoch 2004). However, virtually all applications to date that have dealt with spatial dependence in a theoretically informed fashion have examined dependence between observations pertaining to states, not dyads. While relatively easy to think of spill-inns or external influences from neighbors or connected states when using individual states as the unit of analysis, assessing spatial dependence in the context of dyadic observations — i.e., interactions, without an obvious physical "location" — is much more challenging.[6] We discuss our approach to dyadic spatial dependence in the next section, after reviewing more technical solutions.

As in the case of temporal dependence, spatial dependence among dyadic observations can be treated as either "nuisance" or "substance." Following the former line, Heagerty, Ward & Gleditsch (2002) recommend using a window sub-sampling empirical variance (WESV) estimator that allows calculating consistent standard errors in the presence of spatial dependence. The advantage of the WESV approach is that it does not require correct model specification, i.e., the analyst does not need to specify what and how dyads may be dependent on one another, in order to generate valid standard error estimates. The essence of the WSEV approach is to estimate robust standard errors by defining windows or clusters that make it possible to capture within-cluster correlations and assume that all between-cluster correlations will be close to 0 (see, e.g., Lumley & Heagerty 1999, Heagerty & Lumley 2000, Heagerty, Ward & Gleditsch 2002).[7] However, this advantage at the same time implies a major disadvantage in terms of our learning about substance, as correcting standard errors by itself from the perils of spatial dependence in dyadic data does not tell us anything about the processes that are responsible for generating dyadic dependence.

A number of studies adopt ad hoc approaches to address potential problems of dependence. Mansfield & Bronson (1997), for example, use separate dummy variables for each member of a dyad. However, they offer no substantive interpretation of the $N$ different country-specific terms. Further, there is no reason to assume that the sum of two intercept differences for each of the the two dyad members will adequately reflect dyadic dependence. Fixed effects are also problematic for binary data such as conflict, and may create more problems than they putatively solve (for an extended discussion, see Beck & Katz 2001, King 2001, Oneal & Russett 2001). Using dyad specific fixed effects in the analysis of conflict, as suggested by Green, Kim & Loon (2001), for example, forces us to discard all dyads that do not experience variation in the response (in this case, conflict) and to deemphasize any possible role for time-invariant attributes. The assumption that we cannot learn anything from units or individuals that do not exhibit variation in a response is extremely restrictive.

Hoff & Ward (2004) develop a random effects model where dyadic dependence in data on international interactions is decomposed into sender and receiver effects (i.e., the effects of having particular common units in dyads). Higher order dependence, measured as the inner product of vectors representing the placement of each unit in a latent space, reflects unobserved characteristics (see also Hoff, Raftery & Handcock 2002, Ward & Hoff 2007). Although such random effects models can be very helpful for indicating dyadic dependence and helping to partition the variance in the response, it is often far from straightforward how one may interpret substantively the resulting placement of the individual countries on the underlying latent dimensions. Moreover, such random effects models for dyadic data are rarely specified with the intention of testing explicit or specific hypotheses.

In sum, while some technical solutions to dyadic spatial dependence exist and clearly may be helpful for many purposes, often such approaches obliterate rather than explicate theoretically interesting relationships, and may in many cases create their own, often intractable, problems.

# 4 Addressing dyadic dependence from a network perspective

Another more interesting alternative is to pre-specify relationships between observations by a graph or connectivity matrix $\mathbf{W}$, and then examine if the outcome for a given observation $y_i$ (in this case, a dyad) varies depending on the value of other observations $y_j$ considered "connected" or dependent on $y_i$. Spatial statistical approaches in this sense allow for modelling explicitly the processes that give rise to dependence between observations.[8] One can think of spatial dependence as a right-hand-side covariate $\mathbf{W}y$, where the estimated dependence parameter can be interpreted as the effect that observed outcomes in connected observations have on the expected value of an individual observation $y_i$.[9] This is the conceptual approach followed here, although we depart from much of the existing research in our specification of dyadic dependence.

While it is straightforward to specify plausible linkages between states based on particular attributes such as distance, alliances, or shared cultural ties, the meaning of connectivity at the dyadic level is considerably more difficult. Use of the dyad as the unit of analysis produces a large number of possible interactions, of which perhaps only a few are likely to be particularly important. Dyadic data are "explosive", in the sense that the number of possible interactions $N(N-1)$

increase extremely rapidly with the number of observations $N$. For example, for a world of 180 states, we have 32,220 distinct dyads. Although it is possible to specify that everything is dependent on everything else, assuming that all of the $N(N-1)-1$ other dyads are equally important to what happens in a dyad $AB$ in general is likely to be almost as inaccurate as assuming complete independence. To say that everything is dependent on everything else essentially means that if we have a dispute anywhere in the system, the probability of war increases for all dyads and must increase by exactly the same amount. Although it is possible to allow for aggregate differences of this type in empirical models, this approach brings us close to the form of undifferentiated or systemic aggregate analysis that dyadic analyses challenged in the first place. Perhaps everything on some level is related to everything else, but some things are likely to be more related than others.

Beck, Gleditsch & Beardsley (2006) specify dyads as dependent on one another if they include a common member, i.e., either $A$ or $B$. Even this refinement connects a considerable number of dyads, and leads to very dense graphs or adjacency matrixes. For example, for $AB$ in a single year there will be $4(N-2)+1$ other dyads involving either $A$ or $B$. For $N = 180$, this means that each dyad will be connected to 713 other common member dyads. An adjacency matrix with 713 entries for each row corresponding to one of the 32,220 distinct directed dyads would then have almost 23 million non-zero entries. Although the common member approach may work well for a continuous variable like trade, it is likely to work less well using a binary variable such as conflict, where not all dyads involving a single state in conflict are likely to see a higher risk of conflict.

Insights from international relations theory should help give us a handle on what approaches may be promising and what approaches are less likely to be helpful when specifying networks and connectivity. If we are interested only in predicting the likelihood of conflict in a dyad conditional on conflict among other dyads, we can reduce the number of possible dyadic linkages to a much smaller number of potential dependent ties by only looking at other dyads that involve members that have experienced conflict. In our approach, the risk of conflict in a first dyad $AB$ is dependent on the presence of conflict in a second dyad $CD$, if there is some type of tie between the members of dyad 1 $(A, B)$ and the members of dyad 2 $(C, D)$. In the next two sections, we consider the two kinds of linkages most commonly referred to in the literature as influencing conflict, namely military alliances and a dyadic form of geographical distance and position.

# 5 Alliance dispute connectivity

When two states experience a dyadic dispute, do we see an increase in the likelihood of disputes among other dyads tied to the disputants by alliances? Alliances are military obligations to participate (or not participate) in disputes or wars. There is a clear conceptual expectation of spatial dependence; alliances should spread violent conflicts. Alliances as predictors of the spread of disputes have of course already received a great deal of attention. However, analyses have generally considered alliances as sources of diffusion of conflict among states rather than at the dyadic level (see, e.g. Siverson & Starr 1991).[10] Just as knowing that the United Kingdom is involved in a war is not particularly informative unless we specify the opponent (e.g., Argentina or Ireland), our analyses should give us some leverage in distinguishing which of the many dyads involving a particular state are more likely to be involved in conflict following a dispute in a particular dyad.

Empirical studies have focused almost exclusively on the presence of bilateral alliances *within* *a dyad* as a predictor of disputes (in the sense of making disputes less likely), while ignoring the role of alliance ties to disputes *outside the dyad*. The initial motivation here appears to have been the possibility that support for other dyadic characteristics believed to be negatively associated with disputes, such as joint democracy, could be associated with other ties between states, such as membership in joint miliary alliances (e.g., NATO), and hence lead to spurious findings (see, .e.g, Farber & Gowa 1995). Other research considers more complicated measures of alliance portfolios as measures of preference similarity between states $A$ and $B$.(see, e.g., **?**). However, whether military alliances promote peace among its members (or not) is at best a peripheral implication of theories of alliance formation, and the empirical evidence for such effects is mixed.[11] Moreover, formal alliances are problematic as measures of common positions, since formalization of commitments often reflects a mix of common and divergent preferences (. Gartzke & Gleditsch 2004, Morrow 1991) We take the core of theories of alliance behavior to entail how promises of military assistance can bolster security against external aggression, which in turn suggest that disputes involving a state with an alliance are more likely to draw in that country's allies. Alliance theory is specifically making arguments about extra-dyadic contagion effects (extra-dyadic spatial dependence). Rather that testing or "controlling" for the likely effects of alliance on the distribution of conflict, most existing dyadic research in international relations has in this sense essentially ignored the kinds of alliance relationships hypothesized in the literature. Although there exists some work on how alliances may promote intervention in support of allies or lead to dispute expansion at the dyadic level, these studies have considered only cases in which disputes are assigned the same MID dispute code (see Gartzke & Gleditsch 2004, Leeds 2005), and have not considered the potential effects of indirect or higher order alliance ties. We surmise that disputes are more likely in dyads connected to active disputants or their allies. Our conjecture will be supported if we find evidence that higher order alliance ties influence disputes, even after we take into account conventional bilateral or purely dyadic covariates of conflict.

We create new data that identify two forms of alliance connectivity beyond a disputing dyad. The first are what we call "third order" dyads connected by alliances to the disputants. This category encompasses all dyads pairing $A$ and the allies of $B$ as well as dyads pairing $B$ and all allies of $A$. The second set of relationships involve "fourth order" alliances, where neither state is one of the direct disputants, but states are linked through alliances to the disputing parties. This category encompasses all dyads pairing allies of $A$ with states that are allies of $B$ (but not $A$ or $B$).

An example from commonly used data sources may help clarify the specific coding and the distinction we make between third order and fourth order dyads. Dispute number 4 in the MID data indicates a conflict between the United Kingdom and Albania from 15/5/1946 to 13/11/1946.[12] At the time, the United Kingdom was involved in formal bilateral alliances with Portugal (alliance #47), Iraq (#100), Egypt (#123), the Soviet Union (# 143), and Jordan (# 152). Albania, by contrast, had only one alliance partner, Yugoslavia (#154). As a result, we get six third party alliance dyads linked to the dispute between the UK and Albania, one pairing the UK with the only Albanian ally (i.e., United Kingdom-Yugoslavia), and five dyads pairing Albania with the UK's allies (i.e., Albania-Egypt, Albania-Iraq, Albania-Jordan, Albania-Portugal, and Albania-Soviet Union). There are also five fourth order dyads that arise from the pairing of Albania's one ally and the five UK allies (i.e., Egypt-Yugoslavia, Iraq-Yugoslavia, Jordan-Yugoslavia, Portugal-Yugoslavia, and

Soviet Union-Yugoslavia). Although the Middle-Eastern allies may be less likely to become involved in conflict as a result of this particular dispute, we do indeed see a MID between the UK and Yugoslavia in the same year. And in the case of the two socialist states Yugoslavia and the Soviet Union, we see a MID in 1949 following the formal break in relations. We do not argue that third and forth order alliance linkages are deterministically related to conflict. However, our conjecture that higher order alliance ties are an important influence on conflict decisions, and an important source of dyadic dependence, will be supported if we find a systematically higher likelihood of observing disputes in dyads with third or forth order alliances to states experiencing a dispute.

Before we proceed to examine the relationship between higher order alliance ties and dyadic disputes we need to clarify our use of militarized dispute data. Large scale wars are infrequent in both relative and absolute terms. Many have argued that it is possible to learn more by studying a broader set of incidents that are deemed to have a potential to escalate to war (see, e.g., Bremer & Cusack 1995). Although the Militarized Interstate Dispute data (Jones, Bremer & Singer 1996) are commonly used to identify such events in dyadic studies of conflict, the underlying MID data are themselves not dyadic, but rather list individual participants on side A and side B of a dispute. This can lead to severe problems constructing dyadic observations, as a simple pairing of multiple states on opposing sides in a dispute creates misleading conflict dyads between adversaries that nevertheless did not actually engage one another in any direct confrontation.[13] Some research on conflict onset advocates dropping all subsequent participants to something identified as the "same" dispute. However, this approach reduces World War II to a bilateral dispute between Germany and Poland. Although forcing all disputes to be uniquely dyadic may be appropriate for some research purposes, this excludes many forms of conflict of interest from analyses, and is clearly inappropriate for studying the extent to which extra dyadic ties may give rise to additional dispute dyads. In our study, we rely on a revised, dyadic, version of the MID data, developed by (Maoz 2005), which explicitly considers dyadic militarized activity.[14]

A comparison of dyadic dispute onsets with higher order alliance connectivity ties provides strong preliminary support for our conjecture. The odds of a dispute onset are about 3.67 times greater for dyads that are connected to an ongoing dispute through either third or forth party alliance ties than for dyads without such ties. As one would expect given the logic of alliance ties and alliance tightness, the effect of third party ties is somewhat larger, increasing the odds of a dispute by 8.84 times. However, fourth party ties not directly involving alliances to disputants also substantially increase the odds of a dispute, an increase of 3.16 times non-alliance behavior.

Of course, skeptics may not find this compelling evidence of dyadic dependence, since observed higher dispute probabilities could reflect other bilateral attributes such as proximity not considered here. We also know that some states are more likely to participate in both alliances and in military conflict. Moreover, if alliance ties are geographically clustered, for example, we could find a higher share of both disputes and alliances among geographically proximate states. We will consider the issue of control variables later and show that our results remain consistent when accounting for the standard catholic set of control variables used in conventional dyadic studies. First, however, we turn to a second component that may generate spatial dependence, namely geographic distance.

## 6 Distance and dispute inbetweenness

Existing international relations research has devoted considerable attention to the role of distance as a determinant of dyadic interaction (e.g., Boulding 1963, Gleditsch 2002). Everything else being equal, the likelihood that two states will interact with one another can be considered a declining function of the distance separating the two. This is a fairly well established regularity in empirical data, and is sometimes seen as an empirical law often referred to Zipf's (1949) principle of least effort. However, distance should also matter for the degree of dependence on other dyads.

In keeping with our argument we focus on geographical distance in the context of a dispute between two parties $A$ and $B$. We know from existing research that $A$ or $B$ are more likely to fight *each other* if the two states are geographically closer. However, among the many geographically close dyads, some are likely to be much more relevant than others in the context of an ongoing dispute between $A$ and $B$. In particular, third states $C$ that find themselves "in between" may become dragged into conflict with either $A$ or $B$ by virtue of their geographical position. Figure 1 illustrates the concept of inbetweenness for a conflict between $A$ and $B$ with regards to dyads involving two other states $C$ and $D$, i.e., $AC, AD, BC$, and $BD$. A conflict between $AB$ may signal trouble for $C$, as both $A$ and $B$ may attempt to make sure that $C$ behaves in particular ways or remains compliant with their demands, or that the territory of $C$ is not made available to or taken by the other party. By contrast, $D$ is less likely to become relevant in the event of conflict with $A$ or $B$ as it is less directly "in between" in interactions between $A$ and $B$. Hence, we predict that dyads $AC$ and $BC$ are more likely to experience conflict in the event of a conflict in $AB$ than is $AD$ and $BD$. Note how inbetweenness *is not* the same as distance between the two members of a dyad. In Figure 1, the distance between $B$ and $D$ is much less than the distance between $B$ and $C$, yet conflict is more likely in $BC$ given conflict in $AB$ and the inbetweenness of $C$ relative to $AB$.

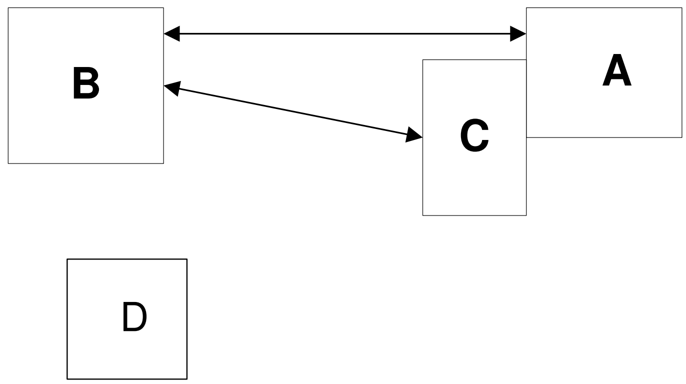


Figure 1: Inbetweenness

It is possible to show many examples of such inbetweeness in the history of warfare. Germany in 1940, for example, did not have territorial claims against the Netherlands per se, and the Netherlands remained neutral when Britain and France declared war on Germany in 1939. However, Germany nonetheless chose to invade the Netherlands on 10 May 1940 given its strategic importance. Likewise, Poland, being sandwiched between Germany/Prussia and Russia/Soviet Union, has throughout its history found itself under fire due to its strategic geographical position. Although such relationships are well-known in the case of major wars, we are likely to see similar consequences of dyadic behavior in less serious disputes, either as a result of the issues in the dispute itself or as a result of externalities of the conflict. A state may raise diplomatic protest to an aggressor for what it sees as unwarranted demands on another state, or protest over fallouts of conflicts such as stray bombings or refugee flows induced by conflict or perceived risk of conflict. Again, for our purposes, it is not critical to determine whether conflict "really" happens between $A$ and $C$ as a function of relations $AB$ exclusively or whether tension may also involve other intrinsic differences between these two countries (for example territorial claims). Dyadic dependence will persist as long as conflict $AB$ increases the risk of conflict in $AC$ or $BC$. Our approach allows us to assess the sensitivity or risk of additional dyadic disputes in $AC/BC$ following $AB$ and the degree to which $C$ is geographically in between the disputants. International relations research has given a great deal of attention to strategic aspects of geographical position such as the notion of buffer states and shatter-belt location (see, e.g., Mackinder 1904, Mahan 1890, Spykman 1944, Fazal 2004). However, most empirical studies have explored either the frequency of conflict by region (Lemke 2002, Bennett & Stam 2003) or examined the likelihood of conflict in particular states, given specific characteristics of their geographical position (e.g., Hensel & Diehl 1994, Tir 2003). As such, fundamental concepts of political geography have yet to be incorporated into dyadic studies of conflict.

We measure the inbetweenness of dyads involving a third party $C$ based on a state's geographical position relative to a dispute dyad $AB$. We use the coordinates of the capital cities as the reference points for each of the three states. Despite the limitations of looking at distances between capital cities only — which could be far from the boundaries of large or irregularly shaped countries (see, e.g., Gleditsch & Ward 2001) — data on the coordinates of capital cities are readily available and require no algorithm to identify the closest point on a perimeter or the shortest path among possible points. More specifically, we look at the inbetweenness of third states $C$ relative to $AB$ by looking at the relationship between the three dyadic distances in a triad $ABC$ — i.e., $Distance(AC)$, $Distance(BC)$, and $Distance(AB)$. If a state $C$ is on, or close to, the shortest path from the capital of $A$ to the capital of $B$ in a dispute dyad, then the ratio of $Distance(AB)$ relative to $[Distance(AC) + Distance(BC)]$ should be close to 1.[15] States that constitute big "detours" from the shortest path $Distance(AB)$ have values closer to 0. We expect that dyads $AC$ or $BC$ that have a large inbetweenness ratio to other dyads involved in disputes should be more likely to experience conflict, even when taking into account standard bilateral or purely dyadic predictors of conflict from other research. Again, to prevent problems arising from multilateral disputes, we use the Maoz dyad version of the MID data. Since several disputes could take place in a given year, we consider the maximum inbetweenness score for each dyad. The inbetweeness score is set to 0 in the event of no disputes in the system. We do not code a dyadic inbetweeness ratio for the principal disputants $AB$. For many purposes it might make sense to exclude these observations, but it would clearly be inappropriate to exclude observations involving disputes here. We instead assign such observations a value of 0.

A simple bivariate assessment of disputes by a dyad's inbetweenness ratio reveals that a higher inbetweenness score dramatically increases the risk of a contest. A shift from 0 to 1 raises the odds of a dispute by a factor of more than 30. As we show below, the effect of extra-dyadic ties is not merely an artifact of failing to control for bilateral characteristics that are associated with conflict.

## 7 Empirical analysis

We now demonstrate the importance of our two measures of extra-dyadic ties more systematically in dyadic dispute data by evaluating the relative impact of extra-dyadic ties in a standard model of dyadic conflict, based on Oneal & Russett (1999). This is an appropriate study to replicate and use as a baseline for our purposes, since Oneal and Russett respond to criticism over the use of a restricted set of dyads deemed "politically relevant" in their previous studies, and instead consider the full population of dyads, with annual observations for the period 1950-1992. Using politically relevant dyads could be seen as pre-selecting the sample and would be inappropriate for assessing dyadic interdependence.[16]

Following Oneal and Russett, we include other right hand side covariates that may influence the risk of a dispute are a measure of the joint democracy level of the two states in a dyad, the lower and higher of the two dependence scores (i.e., trade over GDP), whether the two states are contiguous, the distance between their capitals, whether the parties have a formal alliance, the capability ratio of the larger to the smaller state, whether a dyad includes a major power, as well as non-parametric controls for temporal dependence based on the number of consecutive years of peace following the approach outlined in Beck, Katz & Tucker (1998). We refer readers to Oneal & Russett (1999) for information on data and variable construction as well as the theoretical rationale for the model. The dependent variable is conflict onset, in which subsequent years of a dispute event are dropped.

All the right hand side variables in the Oneal and Russett study are lagged by one calendar year to avoid possible endogeneity (i.e., to ensure that values of right hand side variables are not produced by prior conflict onset). Although lagging independent variables is common, the practice raises some problematic issues for our indicators of extra-dyadic ties. By not lagging we risk distorting the temporal order by including onset in linked dyads that occur prior to dispute onsets that we conceive of as activating the link. However, we also risk missing simultaneous or dyadic disputes that occur later in the sane year following an onset. We suspect that most readers will view endogeneity and reverse causation as the greater source of potential concern here, and report estimates using lagged values for the higher order extra dyadic links through alliances and inbetweeness scores. These should be regarded as more conservative estimates; using contemporaneous, or non-temporally lagged, values for the extra-dyadic ties suggests similar results. Finally, using the temporal lag of extra-dyadic links so that these are predetermined also avoids some of the more problematic issues of estimation in the presence of simultaneity, which are particularly difficult for binary dependent variables where the likelihood function becomes mathematically intractable, and can be convenient if theoretically justifiable (see Beck, Gleditsch & Beardsley 2006, Besag 1974, Ward & Gleditsch 2002).

We start by first estimating the standard Oneal and Russett model, and the results are shown in Table 1. This will serve as a baseline model for assessing the contribution of our extra-dyadic variables and whether these provide information pertinent to conflict onset. Since these estimated coefficients are identical to those reported by Oneal and Russett, we omit further discussion of their implications here. The second column of Table 1 reports the standard, or "naïve", standard errors, assuming that all the dyadic observations are independent of one another. In the third column, we report standard errors based on window sub-sampled variance estimates, with a correction for the intercept (WSEV one-step, hereafter WSEV.1), using a window size of 6.[17] Our substantive results mirror those of Heagerty, Ward & Gleditsch (2002), who estimate a similar model for dyadic dispute data; we find that WSEV.1 estimates are considerably larger than the naïve standard errors. The fourth column gives the ratio of the WSEV.1 SE to the naïve SE. The WSEV.1 SEs are on average are about 2.09 times larger. The much smaller standard errors assuming independence between observations again strongly suggests that there are important linkages between the observations that influence the risk of war for a particular dyad, and that the risk of war is not exclusively captured by attributes of particular dyads, but also involves relationships with other dyads. However, correcting the standard errors to make these more realistic of the true extent of uncertainty by itself does not tell us much about where this dependency originates or what kind of linkages can influence the risk of war.

Table 1: Oneal and Russett model of dispute onset

| **Variable** | $\widehat{\beta}$ | **Naïve SE** | **WSEV.1 SE** | **Ratio** |
|---|---|---|---|---|
| Joint democracy | -0.003 | <0.001 | 0.001 | 1.871 |
| Lower of dependence ratios | -51.855 | 14.817 | 30.286 | 2.039 |
| Higher of dependence ratios | 1.520 | 1.377 | 2.276 | 1.649 |
| Contiguous | 2.460 | 0.094 | 0.142 | 1.512 |
| Intercapital distance, logged | -0.592 | 0.036 | 0.062 | 1.732 |
| Major power in dyad | 1.912 | 0.091 | 0.336 | 3.667 |
| A & B allied | -0.532 | 0.082 | 0.205 | 2.492 |
| Capability ratio, logged | -0.231 | 0.027 | 0.056 | 2.058 |
| | | | | |
| N | 271,262 | | | |
| Log-likelihood | -4,478.8132 | | | |
| LR $\chi^2_{(12)}$ | 5,112.40 | | | |
| $BIC'$ | -4,962.27 | | | |

Note: Coefficients for intercept and the peace years terms are omitted from the table

In Model 2 in Table 2, we add to the baseline model our new measures of third and fourth order alliance ties as well as our measures of dispute inbetweenness. Since we are estimating a model that suggests that whether we see onsets in any one observation is unlikely to be independent of the response in other dyads, it makes little substantive sense to use SE estimates that assume independence (e.g., Buckley & Westerland 2004). We thus report only the WSEV.1 standard error estimates. Column three of Table 2 reports the ratio of the estimated coefficients to their WSEV

WSEV.1 standard error estimates.

Table 2: Model with extra-dyadic ties

| **Variable** | $\widehat{\beta}$ | **WSEV.1 SE** | $\widehat{\beta}$**/WSEV.1 SE** | $\Delta\beta$ **(%)** |
|---|---|---|---|---|
| Joint democracy | -0.003 | 0.001 | -4.143 | -22.118 |
| Lower of dependence ratios | -48.53 | 26.917 | -1.803 | -6.412 |
| Higher of dependence ratios | 0.691 | 2.473 | 0.279 | -54.553 |
| Contiguity | 2.244 | 0.122 | 18.445 | -8.774 |
| Intercapital distance, logged | -0.571 | 0.050 | -11.375 | -3.672 |
| Major power in dyad | 1.195 | 0.252 | 4.746 | -37.512 |
| A & B allied | -0.697 | 0.233 | -2.994 | 30.988 |
| Capability ratio, logged | -0.208 | 0.057 | -3.679 | -9.702 |
| Third order alliance tie | 0.809 | 0.178 | 4.535 | NA |
| Forth order alliance tie | 0.426 | 0.179 | 2.385 | NA |
| MID inbetweenness ratio | 1.061 | 0.177 | 5.988 | NA |
| N | 271,262 | | | |
| Log-likelihood | -4,293.683 | | | |
| LR $\chi^2_{(15)}$ | 5,482.664 | | | |
| $BIC'$ | -5,295.001 | | | |
| $\Delta BIC'$ | 332.728 | | | |

Note: Coefficients for intercept and the peace years terms are omitted from the table

As can be seen from the coefficient estimates in the first column of Table 2, we find positive coefficient estimates for all our measures of extra dyadic ties to a disputing dyad, indicating that such ties strongly influence the risk of conflict onset in a dyad, over and beyond purely dyadic characteristics of the two member states. The coefficients demonstrate that having third or fourth order linkages through alliances to other dyads involved in a dispute can strongly increase the chances that a particular dyad experiences a militarized dispute onset. Moreover, the magnitude of the coefficients suggests that the increase in risk is substantial. Indeed, the risk of war from a third order alliance link is greater than the decrease associated with a bilateral alliance between $A$ and $B$. The estimated impact of a state having both third and fourth order alliance ties to a dyad in a dispute (over half of the dyads with third order alliance ties also have fourth order ties) actually exceeds the estimated effect of the dyad including a major power. This provides strong support for our claim that dyadic dependence through alliance ties is important in understanding the risk of violent conflict. Previous research has focused on the alleged pacifying effect of bilateral alliances. However, the role of alliances on diminishing the prospects for conflict among members are at best a secondary motive for formation of most alliance formations, relative to their ability to deter aggression and ensure support in the context of a conflict. Our results reveal that alliances are important not so much for creating peace among friends as pitting friends against enemies, including enemies of friends. As alliance theory has always suggested, third and fourth order alliance ties identify dyads where militarized conflict is likely to flow across dyadic boundaries, and it is possible to capture these insights in dyadic specifications.

Just as alliances serve to connect dyads and help us identify where we are more likely to see the diffusion of disputes, the likelihood of additional conflicts is also influenced by the geographical position of a dyad. Whereas previous work has considered only the distance between members of a dyads, our results also suggest that the geographical position of a dyad relative to an ongoing dispute can have a substantial effect on the likelihood of disputes. More specifically, dyads involving third parties that are more "inbetween" relative to the members of an ongoing dispute dyad are much more likely to experience conflict onset than dyads that are in a more peripheral position.

Column four indicates the percentage change of the estimated coefficients in Model 2 relative to the coefficients in Model 1, i.e., $[(\beta_{m2} - \beta_{m1}) / \beta_{m1}] \times 100$. Although the implied predictions in a logit model will depend on the baseline and thus the estimated intercept, the change in the effect on the log-odds of an event can be seen as an approximate measure of how sensitive our inferences are to including higher order alliance ties. Beyond the substantive importance of extra-dyadic linkages in their own right, our results reveal how many of the estimated coefficients change notably when we expand a purely dyadic model to include extra dyadic ties. In this case, for example, we find that the coefficient estimate for major powers is attenuated by almost 40% when we add extra-dyadic ties whereas the negative coefficient estimate for bilateral alliance ties increases by about 30%. One way to interpret the resulting change in the estimated impact of major power status when we include extra-dyadic ties is that considering links to other dyads can allow is to understand the mechanisms that underly the support for the perhaps most a-theoretical control variable in conflict studies. Recall that major powers typically are defined as states that are particularly likely to resort to violence, but such definitions tell us nothing about why they are more likely to experience conflict. We know that major powers have more involvement in military alliances and hence enter into more dyads linked by alliances. Our results suggest that these alliances in turn entangle major powers in a greater number of conflicts. As we show, higher order alliance ties lead the states involved to be more likely to contract a contagious conflict. Similarly, states with high capabilities are better able to exercise war-fighting strategies involving strategic territory. Major powers appear to be more prone to pursue the logic of inbetweeness disputes. Taking into account these extra-dyadic ties decreases the estimated coefficient of major power status by itself to about 60% of the original size of the estimate returned by Model 1.

The estimated standard errors can also change depending the specification of the mean model. In Table 2, the standard error estimate for the lower dependence ratio for example is lower in the model with the extra dyadic ties, so that the ratio of the coefficient to its standard error is higher in the model with extra dyadic ties (-1.8) than in the purely dyadic model (-1.71). Even though we do not have examples of coefficients that shift conventional significance criteria here, our inferences and relationships could change notably depending on whether we control for extra-dyadic ties, especially if the estimates for purely dyadic variables correlate closely with omitted dyadic dependencies that also influence conflict.

Standard significance tests and measures of model evaluation such as the difference in the $LR - \chi^2$ suggest that adding third and fourth order alliance ties as well as our inbetweeness score make a significant contribution to the model. However, dyadic models of conflict onset with annual observations have a very large $N$, with a very large number of apparent degrees of freedom. Some argue that standard significant tests are inappropriate in very large samples, since even minor differences are likely to be statistically significant from 0, even if the substantive differences implied by the estimated coefficients are trivial (e.g., McCloskey & Ziliak 1996). The Bayes factor, or the ratio of the posterior odds for one model against another, provides one way to evaluate whether extra-dyadic ties contribute notably to our knowledge about the outbreak of disputes. Let $M_1$ denote the baseline dispute model derived from Oneal and Russett with purely dyadic attributes and let $M_2$ denote the model with extra-dyadic ties. Raftery (1995, 134) proposes approximating the Bayes factor for some model $M_k$ through a Bayesian Information Criterion (BIC′), given as:

$$BIC'_k = -\chi^2_{k0} + p_k ln\,(n)$$

where $\chi^2_{k0}$ is the likelihood ratio test statistic for $M_k$ against the null model $M_0, p_k$ is the number of degrees of freedom, and $n$ the number of observations. Unlike standard significance tests, BIC′ "penalizes" models that consume more degrees of freedom and large samples. A negative $BIC_k^{'}$ provides evidence for model $M_k$ over the null. We know already that $M_2$, or the expanded model with extra-dyadic ties in Table 2 with extra-dyadic ties, must fit at least as well as the baseline model $M_1$, since the exclusively dyadic model $M_1$ is a subset of $M_2$. However, to determine whether we should prefer $M_2$ over the more parsimonious $M_1$, we must assess whether the fit is "sufficiently" improved to warrant the loss of four additional degrees of freedom. The Bayes factor approximation for one model $M_A$ over another model $M_B$ is simply the difference between $BIC_{M_A}^{'}$ and $BIC_{M_B}^{'}$. In this case, we have $BIC_{M_1}^{'} = -4,962.27$ (see Table 1) for the baseline model $M_1$ and $BIC_{M_2}^{'} = -5,295.001$ for the model with higher order alliance ties and dispute inbetweeness. Since both $BIC'$s are negative, they do notably better than the null model. However, as $BIC_{M_2}^{'}$ is smaller yet than $BIC_{M_1}^{'}$, model $M_2$ with transnational factors has stronger support from the data than the purely dyadic model $M_1$. The Bayes factor approximation given by the difference between $BIC_{M_1}^{'}$ and $BIC_{M_2}^{'}$ is $332.728$, far exceeding the threshold of 10 that Raftery (1995, 139) characterizes as "very strong" evidence in favor of one model over another. Hence, we conclude that the model with extra-dyadic ties provides additional information on the distribution of conflict, and that the increase in fit is not trivial relative to the additional degrees of freedom consumed.

Another way to evaluate the differences in overall model performance is to look at the model's ability to correctly assign higher probabilities of conflict to those dyads that actually experience conflict without generating too many cases of high probabilities of conflict among dyads where we do not see disputes. Since a single year is a relatively short time interval, it is perhaps not reasonable to demand that, to be useful, a model must be able to classify a dispute as more likely than peace in a single year (i.e., $Pr(y_{i,t} \geq 0.5)$ given covariates $x_{i,t}$).[18] A probability less than $0.5$ can still imply a high probability of an event over a longer interval. For example, if the probability of an event in one year is fixed at $0.3$, the likelihood that the event does not occur over a two year interval will be less than $0.5$ as $(1 - 0.3)^2 = 0.49$. As such, researchers often find it helpful to also consider a lower prediction threshold $C$, and see how well a model can classify conflict outcomes and non-conflict outcomes based on the predicted $Pr(dispute_{i,t} \geq C)$. The State Failure Task Force Report, for example, considers a prediction threshold of 0.25 in their forecasts of state failure (e.g., Esty, Goldstone, Gurr, Harf, Levy, Dabelko, Surko & Unger 1998, King & Zeng 2001). By this criterion, the model with extra-dyadic ties correctly identifies 248 out of a total of 1078 dispute onsets, while the purely dyadic Oneal and Russett baseline model only calls 228 disputes correctly. More generally, the appropriate threshold $C$ depends on the relative risk of missing a conflict that occurs relative to incorrectly predicting conflicts where they do not occur. However, since any one single classification threshold could be seen as arbitrary, it is often useful to evaluate the performance of models. Moreover, we care not just about the share of conflicts called correctly, but also the number of false positives. A Receiver-Operating-Characteristic (ROC) plot allows researchers to compare the predictions of a model over a range of possible prediction thresholds, $C$. The vertical axis of a ROC plot indicates the share of 1s correctly identified while the horizontal axis provides the share of incorrect 1s predicted by the model. Each point on the ROC curve thus indicates the share of correct and incorrect 1s for a particular prediction threshold criteria $C$.[19]

Figure 2 compares the predictions from the baseline model (red line) to the full model with the extra-dyadic ties (black line). The higher the ROC curve is above the 45 degree line, the better the model fit. The ROC line for the full Model 2 with extra-dyadic ties is always above the ROC line for the baseline Model 1, and hence does notably better, irrespective of prediction threshold.

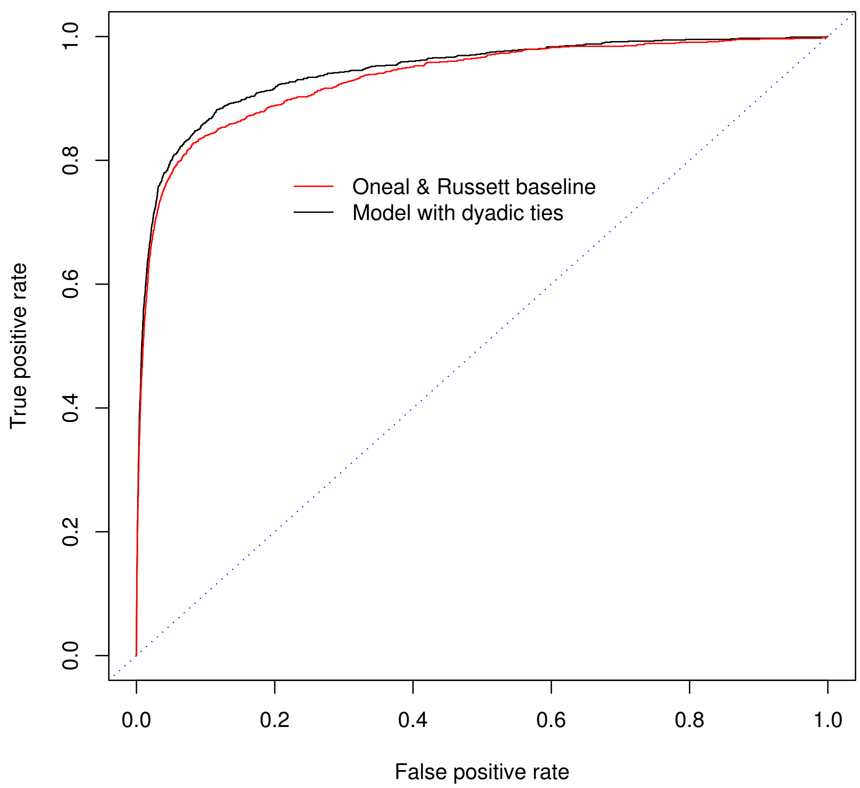


Figure 2: Receiver-Operating-Characteristic (ROC) plot, comparing the predictions of the full Model 2 with the baseline Oneal and Russett Model 1

Clearly, introducing extra-dyadic ties allows us to do a better job in accounting for which dyads seem more likely to experience disputes. However, it is also instructive to consider what sort of dyads would be flagged as having a high likelihood of conflict. Consider, for example, the case of Iraq around the first Gulf War. Following the invasion of Kuwait, Iraq becomes involved in a large number of disputes with neighboring countries such as Bahrain, Saudi Arabia, Qatar, and Turkey. The baseline model with only bilateral ties looks only at exclusively bilateral attributes (e.g., whether states are contiguous). The predictions of likely conflict in dyads with Iraq and other states are not affected by conflict in other dyads involving Iraq. The full model incorporating extra dyadic ties assigns higher probabilities to these cases, suggesting likely candidates for conflict in the wake of the initial Iraq-Kuwait dispute (or following conflict between the USA and Kuwait), since these dyads have high inbetweenness scores given the ongoing dispute. The statistical evidence we have presented here suggests that such extra-dyadic factors are important more generally and indeed often appear to be associated with a significant increase in dispute onset. Our findings give strong support to the argument that many of the reasons why we see dispute onset result from variables or processes that take place outside the affected dyad. By thinking carefully about how dyads are linked in ways that disseminate conflict, we can develop specific hypotheses about various sources underlying the observed dependence between dyads. We believe the approach here can be informative for other types of extra-dyadic ties and outcomes other than militarized disputes.

# 8 Conclusions

Whereas much of the early development of the field looked to individual states or the international system as a whole in seeking to explain world politics, attempts to capture bilateral interaction through dyads have increasingly become the dominant unit of analysis in international relations. The turn to the dyad as the modal unit of analysis has clearly been extremely productive in many ways for international relations research, helping to foster a new generation of cumulative research that has generated many important findings. As we argue, however, the concerns over strategic interaction that led researchers to consider dyads in the first place strongly suggest that looking exclusively at bilateral dyads may be insufficient to understand the full implications of strategic interaction. Individual dyads are in practice unlikely to be independent of one another, and the outcomes in one dyad are often strongly linked by ties to other dyads. We have shown how extra-dyadic alliance ties and dispute inbetweenness condition the risk of war and prospects for peace within dyads. This dyadic dependence cannot be reduced to attributes of individual dyads, but it is possible to identify the sources of dependence directly and include these in dyadic analysis.

Of course, many other sources of extra-dyadic ties and dependence other than alliance links are possible. We believe that the approach here provides a stepping stone for looking at other sources of extra-dyadic interdependence in interstate conflict data, as well as linkages between conflict within states and conflict between states. Dyadic data allow us to specify and test hypotheses about a large and diverse range of dyadic linkages. For example, one may think of other types of ties between states such as ethnic ties and majority/minority dynamics that could help understand the relationship between domestic and interstate conflict. We know that contiguous dyads where one of the members experience a civil war are more likely to experience interstate disputes (see Gleditsch, Salehyan & Schultz 2008). Furthermore, an inspection of cases where the two forms of conflict coincide suggest that the civil conflict either involves or generates contentious issues and externalities that lead to tension between states. Outbreaks of civil conflict are more likely when ethnic groups cross state boundaries (e.g. Gleditsch 2007), and there is considerable evidence suggesting that interstate conflict is more likely when ethnic minority groups are majorities in other states (see Gartzke & Gleditsch 2006, Davis & Moore 1997). Hence, we can think of ethnic ties as links that may be activated in the context of an ongoing conflict, and examine whether a domestic conflict involving one group in one state makes conflict more likely in dyads combining this state with other countries where the group is present, and perhaps politically privileged.

More generally, looking to extra-dyadic ties brings us closer to common concepts of how international interactions are formed and evolve. Observers of world politics think in terms of clusters of issues and actors. The 2006 confrontation between Israel and Hezbollah, for example, led Israel to take violent action against Hezbollah strongholds in Southern Lebanon. This in turn spurred many observers to fear potential conflict and tension in other dyads, such as states sympathetic to Hezbollah, notably Syria and Iran. Researchers and observes alike think of conflict in terms of "hot spots" of contentious issues and multiple linked actors. Incorporating such linkages in dyadic models can bring dyadic empirical research closer to our notion of a world of dense linkages between actors, and help us develop a sounder basis for understanding why and when dyads see crises and engage in conflict.

# Notes

[1]Our list of extra-dyadic influences on war and peace is certainly not intended to be exhaustive or compete; other contributing factors await further research. However, we believe that ours is a useful initial effort, and that any list of the key sources of spatial dependence in international conflict is likely to include proximity and alliances.

[2]Treating dyads as the primary units of interest in the international system is not uncontroversial. System theories such as neo-realism (e.g., Waltz 1979), for example, see the international system is the most appropriate unit of analysis, while hegemonic stability theory (e.g., Gilpin 1981) and long cycle theory (e.g., Goldstein 1988) emphasize the importance of particular external sources of change in system structure. For a review of criticism of systemic approaches, see Bueno de Mesquita (2003).

[3]If we do not distinguish the direction of behavior in a relationship between two states $A$ and $B$ (i.e., $A \rightarrow B$ versus $B \rightarrow A$), there are $\left[N(N-1)\right]/2$ "undirected" dyads (i.e., $A \leftrightarrow B$) in a system of $N$ states.

[4]Defense doctrines often talk about preemptive and preventive attacks, where the former are countermeasures to immanent attacks, while the latter are measures against perceived long-term threats (see Reiter 2006). Although preemptive wars may not be very frequent (Reiter 1995), preventive attacks are quite common and at the present an explicit US policy (Wirtz & Russell 2003).

[5]We refer to (Jones, Bremer & Singer 1996, 174-7) for details on the stated rules of how the MID project aggregates incidents into disputes. Obviously, applying the stated rules and actually making decisions about these issues requires considerable subjective judgement, and none of the sources for these decisions are documented for data prior to 1993. Whether the MID criteria are appropriate or have construct validity must be judged relative to a research question. (Fordham & Sarver 2001) provides a helpful discussion of how the MID criteria can be problematic for many research questions and can give rise to systemic errors. Even if one accepts that the MID criteria as valid, possible and non-random errors in the application of these criteria may give rise to other, potentially complex biases.

[6]Furthermore, dyadic studies in international relations often look at binary outcomes, as opposed to continuous variables such as degrees of interaction (for example trade flows). This gives rise to more complex estimation issues, and the standard estimators for models of spatial dependence for continuous variables are not directly applicable (for an overview, see Ward & Gleditsch 2002).

[7]WSEV can be seen as a generalization of the well-known idea of clusters in panel studies, where Sandwich type variance estimators allow for serial correlation within individual observations over time but assume independence across individuals (see Huber 1981, White 1980), to space-time dependent data. Building on the idea of estimation by subsampling (see Politis, Romano & Wolf 1999), the WSEV approach seeks to define windows that they are far enough "apart" to be nearly independent, and then approximate an estimate of the variance of sample statistics by evaluating and averaging the variance of estimates computed over the windows or sub-samples,

which will remain valid if the model specification is not fully correct or accurately reflect the dependence between observations. Our replication code provides code for implementing WSEV for $R$.

[8]Some spatial statistical models treat spatial dependence as a spatially clustered error pattern, but this is more in line with the nuisance approach to spatial dependence, even if the expected patterns of dependence are specified in advance. See (Beck, Gleditsch & Beardsley 2006, Ward & Gleditsch 2008).

[9]The spatial statistical literature in Economics sometimes refers to $\mathbf{W}y$ as the "spatial lag" of $y$. This terminology is somewhat unfortunate since different matrices $\mathbf{W}$ give raise to different "spatial lags" and $\mathbf{W}$ need not rely on spatial distance. The connectivity matrix $\mathbf{W}$ is often normalized so that each row will sum to 1, which implies that $\mathbf{W}y$ can be interpreted as the average of $y$ among connected observations. Although this may be appropriate for many applications, in many international relations applications it may be helpful to consider binary connectivity matrixes (i.e., sum of $y$ in connected observations), or other features such as the Boolean product or maximum.

[10]Vasquez (2004) includes dummy variables for extra-dyadic alliance ties, but does not code the identity of the ally.

[11]Bueno de Mesquita (1981) even argues that miliary alliances should increase the prospects for wars among this member, and claims to offer empirical evidence for such a tendency, although this finding remains disputed (see Ray 1990). Bearce, Flanagan & Floros (2006) argue that alliances only notably reduce the risk of conflict among members when these approach power parity.

[12]Dates are provided in the standard day/month/year format, rather than the US month/day/year convention.

[13]For example, dyads involving allied powers and Finland have sometimes been held to constitute an exception to the so-called democratic peace, as these states appear on opposite sides in the COW conflict data. However, the Western powers who declared war on Finland (who allied with the Axis due the conflict with the Soviet Union rather than opposition to the Western Allies) such as the UK did not actually attack Finland, and many such as the US pointedly did not declare war on Finland (see Ray 1995).

[14]One might argue that MIDs are an overly encompassing category of conflict behavior, including many events that do not result in violence, the involvement of governments, or even clear evidence of interaction between states (see Gleditsch 2004, Hewitt & Goertz 2005). Although these arguments may have considerable merit, we use all MIDs here to ensure comparability with other research. Moreover, using a more inclusive conflict measure should if anything bias against finding support for higher order dyadic dependencies.

[15]The triangle inequality ensures that the measure is positive and bounded by 1 for point data such as capital cities. For non-metric distance measures such as minimum distances the triangle inequality will not necessarily hold as it is possible that the ratio could be a great deal more than 1. However, the measure would still have a similar interpretation, and this approach will work as long as at least one of the distances in the denominator is strictly positive.

[16]The Oneal and Russett dataset is smaller than the full universe of dyad years over the period

due to missing values. Although one could derive estimates for missing values, whether to do this or how to best do this remains contentious, and we do not pursue this here.

[17]The WSEV estimator tends toward a negative bias for the intercept due to truncation from the window size and substitution. The one-step estimator provides a correction for the downward bias, based on re-estimating without the particular subsample. See Heagerty, Ward & Gleditsch (2002) and Heagerty & Lumley (2000) for further details.

[18]At the extreme, we should obviously be skeptical of anyone who would claim to predict an attack taking place on 11 September rather than 10 September. Still, it is meaningful to ask whether theories can make predictions about the risk of attack against a specific target like the World Trade Center a longer time interval. Theories of terrorist behavior do indeed suggest likely targets based on the aims of active terrorist groups, their prior attack history and choice of tactics (including, twice, the WTC), as well the increased difficulty of striking against targets in the Middle East and the USA following recent efforts to secure US military bases in the Middle East (see Schrodt 2002).

[19]See King & Zeng (2001) and Sing, Sander, Beerenwinkel & Lengauer (2005) for additional details on ROC plots.

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