A three-degree horizon of peace in the military alliance network

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States form defensive military alliances to enhance their security in the face of potential or realized interstate conflict. The network of these international alliances is increasingly interconnected, now linking most of the states in a complex web of ties. These alliances can be used both as a tool for securing cooperation and to foster peace between direct partners. However, do indirect connections—such as the ally of an ally or even further out in the alliance network—result in lower probabilities of conflict? We investigate the extent to which military alliances produce peace between states that are not directly allied. We find that the peacemaking horizon of indirect alliances extends through the network up to three degrees of separation. Within this horizon of influence, a lack of decay in the effect of degrees of distance indicates that alliances do not diminish with respect to their ability to affect peace regardless of whether or not the states in question are directly allied. Beyond the three-degree horizon of influence, we observe a sharp decline in the effect of indirect alliances on bilateral peace. Further investigation reveals that the community structure of the alliance network plays a role in establishing this horizon, but the effects of indirect alliances are not spurious to the community structure.

INTRODUCTION

The tendency of political organizations to ally likely dates back to the earliest permanent human settlements and certainly predates the modern political state by at least two millennia (1). The formation of modern military alliances is multifaceted: States ally to counter common threats, to bolster one another’s security, and even to help facilitate peace between potential rivals (2,3). Military alliances are typically understood as a tool for securing defensive cooperation and fostering peace between direct allies (4–9). Despite the long history of the practice of forming alliances, the effect of the alliance network’s structure on bilateral peace is poorly understood.

The past century has seen the advent of alliances meant to exist in times of peace as well as war, and the corresponding increase in the interconnectedness of the alliance network has been dramatic. The system has gone from 8 individual alliance ties in 1900 to 1115 in 2000, including bilateral and multilateral defense pacts.

Much research has shown that allies are less likely to fight one another (6,10), but we lack any understanding of higher-order effects. That is, are states whose only connection is a common ally—those separated by two degrees—less likely to fight? What about pairs connected at three or more degrees? To answer this question, we examine the conflict propensities of indirectly allied states through the concept of path length. Within the alliance networks, direct allies have a path length of one degree, the allies of allies have a path length of two degrees, and so on (fig. S1 and tables S1 to S3). That is, if state i is allied to j, j is allied to k, and k is allied with l, then the path length between i and l is three. Figure 1 shows the concept of distance in a network—the shortest number of links required to connect one state to another—and the focal question of bilateral conflict.

Many states that have never signed a formal defensive pact have at some point experienced the pacifying effect of higher-order alliances. One example is Turkey and Iran, who did not enter into conflict at any level from 1965 to 1979, during which period they were indirectly connected in the alliance network at two degrees of separation. After losing this connection in 1980, disputes arose between the neighbors, reaching a peak in 1987 when Turkey was mediating the conflict between Iran and Iraq and became involved itself in a militarized dispute with fatalities.

In another case, Spain and its former colony Morocco had several disputes with one another in the 1970s, including an incident in 1972 when the states deployed naval forces to exchange fire after failing to reach a new fishery agreement. However, the states have maintained peaceful relations since they established an indirect alliance at three degrees of separation beginning in 1981. Using state-of-the-art statistical models for network data, we investigate the importance of path length and identify the horizon within which indirect alliances contribute to bilateral peace.

Defensive alliances are formal promises “to assist a partner actively in the event of an attack on the partner’s sovereignty or territorial integrity” (11). Hence, they signal a basic level of agreement and affinity between the allied states. Although alliance partners may not agree on every issue, an alliance is unlikely to be sustained if the partners have large differences in their preferences with respect to the security environment. That is, the basic condition that must be met for a defensive alliance to form and persist is that the allied parties must agree that major changes to the status quo are in neither of their best interests at that time. We use this as our operational understanding of an alliance.

Although some scholars have argued that alliances can actually increase the risk of conflict incidence or escalation, by drawing more actors into ongoing conflicts or by encouraging states to behave more recklessly than they otherwise would have (12–14), there are compelling reasons to discount these arguments. First, alliances are sometimes formed to address already tense security situations, making a positive association between alliances and wars potentially spurious (10). Further, recent evidence suggests that defensive pacts (the alliances with which our study is concerned) are associated with less conflict, not more (15). On balance, we therefore expect defensive alliance ties to be associated with a reduced risk of conflict. Our study starts from this premise about direct alliance ties and considers the ramifications of indirect ties with the expectation that these ties...
should reduce the risk of conflict but should have a less pronounced effect than direct alliances.

A basic argument about the transitive properties of positive affinity in social networks holds that the friend of my friend should be my friend or at least not my enemy. If an actor i has enough in common with another actor j to form a positive bond, and j has enough in common with a third actor k to form a positive bond, then this would suggest that actors i and k have a fair amount in common. They may not be friends, but enmity between the two would be surprising. We can then ask how far this logic extends. If the ally of my ally should, at minimum, not be my enemy, what about the ally of my ally of my ally? Unlike existing studies, which have examined the effects of direct alliances on the conflict propensities of states and have used measures like alliance portfolio similarity to consider the consequences of shared security preferences (16), our study is designed to capture the effects of the emergent complexity inherent in the international alliance network. This approach is different from that of studies testing classic hypotheses about the relationship between direct alliance ties and conflict between states. We both test the general expectation that indirect alliance ties have an effect on conflict propensity and probe the radius within which indirect connections can effectively foster peace.

If states i and k both agree substantially with j on the security status quo, this would suggest that i and k should also have a fair amount in common, and that they should agree with one another, at least in broad strokes. A naive expectation drawn from this argument could be that a chain of allies, however long, should lead to peaceful relations between the members of the chain. That is, allies of allies of allies would be expected to behave peaceably, as would allies of allies of allies of allies and so on. This simple transitive logic leads to our first network hypothesis about indirect alliance effects: The ability of higher-order alliances to suppress conflict is constant, regardless of the degree of the connection.

The network of international defensive alliances in the post–World War II period forms a giant cluster (or it can be said to be “percolated”). The web of alliance connections includes nearly all actors in the system, and there are few isolated clusters of alliances. This means that most of the states are connected to each other indirectly at some degree. If the first network hypothesis were on target, then it should be the case that conflict is quite rare between any states having one or more defensive alliances. However, the increasing density of the alliance network has not been accompanied by a reduction in military conflict (17).

To square the transitive argument about higher-order alliances with the empirical reality of alliance network percolation and the lack of near-complete global peace, we return to our consideration of the three states: i allied to j allied to k. If i and k agree with one another on the security status quo, then they might well decide to ally with each other. This is the sort of transitive agreement on security that we would expect to lead to triadic closure—i, j, and k all being allied—and broad multilateral alliances. Not only has this pattern of multilateral alliances been posited in the literature, but it also has robust empirical support (17, 18). This pattern of alliances has a strong effect on conflict between the states under consideration: Not only is the probability of military conflict lower between allies (6, 10, 19), but also having allies in common further lowers the probability of conflict.

If trilateral (or multilateral) agreement on the status quo tends to lead to trilateral (or multilateral) alliances and the lower probability of conflict between allies that accompanies them, then the fact that i and k are not directly allied sends a distinctly different signal than if they were. It might be the case that the ij alliance pertains to one aspect of the status quo and the jk alliance to another, meaning that the ik pair might lack the common ground to form an alliance between them. Yet, although i and k may not have sufficient common ground to form an alliance, it seems relatively unlikely that their interests and attitudes toward the security status quo would be so diametrically opposed as to lead to conflict between the two of them. Thus, we expect a second-order alliance like that between i and k to reduce the probability of military conflict between the two of them relative to a pair of states that share no alliance connections.

The same dynamic applies to third- and fourth-order alliances. If the lack of a direct alliance between states that share a common ally carries information, then we can expect that every time the order of the alliance is increased, the two states under consideration have progressively less and less in common in terms of their attitudes toward the security status quo. One can think of this like a game of telephone, with each additional degree of separation introducing some decrease in the amount of agreement between the originating state and the terminating state. This dynamic takes on the form of a decay: the extent to which originating state i and some other state in the chain of alliance connections p agree on the security status quo decays, possibly nonlinearly, because the distance between those two states in the alliance network increases. As the degree of agreement on the status quo decreases with each step, the probability of conflict between the two states sees a corresponding increase. It is important to note that this increase is not relative to the conflict propensity of two unconnected states but relative to two states that are directly allied. The theorized decay in the peacemaking ability of alliances at higher degrees results in our second network hypothesis that the probability of conflict is
lower for dyads closer to each other in the alliance network than for dyads connected through higher degrees of separation.

However, these processes do not function independently of regional dynamics. Specifically, past research has shown that alliance dynamics interact strongly with geographic contiguity (20). Contemplating this persistent interaction, it is difficult to imagine two contiguous states at any location in an alliance chain having the same probability of conflict as a similarly located noncontiguous pair, and there are very few states, however close their geographic distance, that have the power to project serious conflict over another state. Thus, it is reasonable to account for power projection capabilities by including a dichotomous measure of state contiguity. We hypothesize that the effect of degrees of separation in the alliance network is strongly interactive with geographic contiguity; the effect is expected to be stronger for contiguous states.

Last, our analysis also considers the effects of the communities that states form within the alliance network. Communities here refer to sets of countries that are joined together in tightly interconnected groups, between which the connections are sparse (21). This sort of community structure, which has been studied extensively in social and biological networks, is also observed in the alliance network. It is also worth noting that a state can simultaneously participate in several multinational alliances, but this view of network communities places each state into exactly one community, as identified by a specific partition algorithm. Members of a community share a greater common interest in the security status quo than outside states do. The community also provides forums through which members can strive for peaceful dispute settlements. States belonging to different communities may have opposing interests and are more likely to resort to force in the face of international disputes. Thus, we expect that the community structure of the alliance network contributes to the peacemaking effect of indirect alliances.

RESULTS

Context of the study
We identify the network horizon within which indirect alliances—those at degrees of separation greater than one—contribute to bilateral peace and probe the drivers of the observed pattern. We seek to distinguish between two main possibilities for the effects of indirect alliances. Our premise is that states form defensive alliances because they see their security interests as fundamentally aligned with those of their partners.

We would expect that states’ interests align closely with those of their allies but less closely with those of more distant connections. If this is the case, then the first possibility is that the effect of alliances will gradually decline as the degree of separation increases before eventually disappearing. Such a pattern has been found in empirical studies of social networks (22–24). Alternatively, it may be that the peacemaking influence of indirect alliances is driven by the structure of the overall alliance network and the communities that form within it. If this is the case, then the boundaries of communities of states more tightly connected to each other than to the rest of the network will define the horizon of peacemaking in the alliance network. Such a process would produce an effect on conflict for low-order indirect alliances before rapidly losing influence between more distantly connected states. This second possibility implies that the observed effect of indirect alliance ties on conflict likelihood could be spurious, driven by community effects that drive down the probability of conflict for closely connected states. Following our main results, we perform a mediation analysis to weigh these two possibilities.

Our application has an important difference from previous studies on the role of network connection: International conflict requires the states involved to be able to engage one another militarily. There are barriers to war that are difficult for most states to surmount. Chief among these barriers is physical distance. Some degree of proximity is usually necessary for states to develop conflicts of interest severe enough to escalate to violence. Only an extreme minority of states are capable of projecting power over considerable distances, making proximity a requirement for the act of war in most cases; Bolivia and Angola could not fight a war with each other even if they wanted to. Moreover, physical contiguity is usually necessary for war, because few states are capable of projecting force over one or more of their neighbors. This is all to say that the goals and expectations outlined above apply to pairs of states sufficiently proximate to engage in war rather than the less interesting set of states for which conflict is structurally unlikely.

We use the temporal exponential random graph model (TERGM) (25–28) for longitudinal network data to trace the impact of indirect alliances on bilateral conflict from 1965 to 2000 (see Materials and Methods for model details). A serious military conflict is coded as any incident that involved the direct and deliberate use of violence by the armed forces of one state against another, and cases were drawn from version 3.0 of the Militarized Interstate Dispute (MID) data set gathered by the Correlates of War (COW) project (29). We restrict our analysis to MIDs of levels 4 and 5, because those are the hostility levels in which actors in at least one country make the deliberate choice to deploy military violence against another.

To build the conflict network for each time step, we linked a pair of states if they engage in a new serious military dispute in that year. The alliance network was constructed from the Alliance Treaty Obligations and Provisions (ATOP) data set (11). We connect a pair of states in the alliance network if they have at least one active defense pact in that given year. We then create indicators for the path distance between all pairs of states in the network. These indicators serve as our key predictors. We include these indicators in our network model together with well-documented controls found to influence conflict behavior: joint democracy (30), geographic contiguity (29), combined national capability ratio (31), and trade dependence (32). Details on the methods, data, and measures are presented in Materials and Methods. Figure 2 shows the interplay between the alliance and conflict networks.

Besides accounting for alliances and control covariates as described above, we also include endogenous factors that reflect the structural features of the outcome network. These endogenous factors must be specified in the data-generating process to avoid omitted variable bias and misspecification. The existence of a k-star in the conflict network implies that the central state is in conflict with k other states (33). We use the alternating k-star statistic proposed by Snijders et al. (34), in which the weights have alternating signs in a geometrically decreasing fashion. Triangles describe a situation where states i and j are in conflict, although they both are at war with another state k simultaneously. This configuration is unlikely to occur in the international conflict network, according to the logic that “the enemy of my enemy is my friend.” If state i is fighting state j, and state j is fighting state k, then it is unlikely states i and k will fight each other (27). We include the geometrically weighted edgewise shared partner (GWESP) statistic for closed conflictual triads in our model (34).
Apart from $k$-stars and triangles, we examine a more complex endogenous effect of the outcome network: the four-cycle, which is the configuration that occurs when dyads $ij, jk, kl,$ and $li$ are connected but dyads $ik$ and $jl$ are not. In our outcome network, this would produce a subgraph structure, where states $i$ and $j$, $j$ and $k$, $k$ and $l$, and $l$ and $i$ are fighting each other, but states $i$ and $k$, and $j$ and $l$ are not in conflict. The four-cycle accounts for a pattern of relations, where the existing ties in the conflict network might affect the chances of a new conflict (35).

The three-degree peacemaking horizon

Our statistical analysis reveals that both direct and indirect alliances of up to three degrees have a strong suppressive effect on conflict. This relationship is borne out in the raw data (Fig. 3 and fig. S2): Across all years in the period of observation, pairs of states that were unallied (directly or indirectly) experienced higher rates of conflict than pairs with direct or indirect alliances. This holds true for both physically contiguous and noncontiguous states, though we naturally see a higher conflict rate among contiguous states because contiguous pairs are most likely to develop serious conflicts of interest and have the ability to fight.

Fig. 2. The interplay between the international alliance and conflict networks. (Top) Networks in 1965, 1980, and 2000. States are plotted as nodes in the network, and the node color indicates the number of alliances of a given state, with darker nodes having more allies. Red ties represent conflicts in all plots, whereas alliance ties are in different colors across time. Names of communities are given by the multinational alliance to which most of the members in the community belong. On the world map of 1980, with the alliance network in light orange, we illustrate sample states in higher-order alliances. Spain and Italy, joined together by the United States, are at two degrees of separation. Central African Republic and Sudan, allies at three degrees of separation, are connected by France and Djibouti. CSTO, Collective Security Treaty Organization; ECOWAS, Economic Community of West African States; ECCAS, Economic Community of Central African States; ANAD, Agreement of Non-Aggression and Defense Assistance.

Fig. 3. Conflict onset by degree of separation for geographically contiguous states in the alliance network. Pairs of states that are not connected at any degree are denoted as infinite ("Inf"), and conflict onsets are observed between contiguous states at up to five degrees of separation. (Left) Rate of conflict onset from the raw data, with the pink horizontal line indicating the average rate for contiguous dyads. The first three degrees of separation see below-average conflict onset rates. (Right) Dyads at degrees of separation ranging from one to four are sampled, and their respective conflict probabilities conditional on the rest of the network are computed. The plot shows the probability of conflict when an alliance is present or absent between a contiguous pair of states with 95% confidence intervals. The probability of conflict drops substantially between contiguous states indirectly allied up to three degrees.
Among all alliance pairs, geographically contiguous pairs have a much higher rate of conflict than noncontiguous pairs. This is as expected because those pairs are the most at risk, and alliances are sometimes used to maintain peace between rivals. Most interesting, however, is the fact that the conflict rate drops markedly among alliances within three degrees: states allied with one, two, or even three degrees of separation enjoy lower conflict rates than other pairs. Hence, allies within three degrees of separation, whether contiguous or not, form the most peaceable strata of state pairs in the international system.

Our results show that indirect alliances promote peace up to three degrees of separation among geographically contiguous states in the alliance network but have no effect at higher degrees of separation. That is, allies, the allies of allies, and the allies of allies of allies enjoy lower rates of military conflict than would be expected otherwise. In the TERGMs fit to the data, we see a substantial interaction effect between one-degree (that is, direct) alliances and geographic contiguity, where the coefficient is $-1.49$ ($-1.92$ to $-0.99$; Model 1, Table 1), and the coefficient for the main effect of one-degree alliances is 0.96, which suggests that contiguous states at one degree of separation in the alliance network tend to be less likely to experience interstate conflict. Similarly, the coefficient for the main effect of two-degree alliances is 0.17, whereas its interaction with contiguity is a statistically reliable $-0.84$ ($-1.45$ to $-0.27$), and the main effect for three-degree alliances is 0.44, whereas its interaction is a statistically reliable $-1.28$ ($-2.10$ to $-0.54$). A more detailed model interpretation is presented in fig. S3.

Examining the predicted probabilities of conflict produced by this model further clarifies the results (Fig. 3): For contiguous states, the probability of conflict decreases by a substantial margin for alliances of one to three degrees, but this effect is lost beyond three degrees; for noncontiguous states, there is no discernible effect. The predicted probabilities of conflict are affected not only by the alliance network but also by control factors such as democracy, trade, and capability ratio. Together, these results indicate that an alliance (direct or indirect) reduces the risk of conflict between states separated by up to three degrees, but no farther (see fig. S4 for model goodness of fit and table S4 for summary statistics).

The suppressive effect of indirect alliances does not lose potency as the degrees of separation are increased, up to the horizon of three degrees. Although it would seem natural that the peacemaking effect of these connections should wane as the degrees of separation between two indirect allies increase, we observe a consistent effect across three degrees, followed by a sharp drop-off in the pacifying effect at four degrees of separation and higher. Thus, although our results bear some resemblance to previous studies that have identified “three degrees of influence” in social networks of individuals (22–24), these earlier explanations cannot account for the lack of decay within the horizon of influence and the sharp drop-off we observe outside that horizon. These results are robust even when we knock out some control variables or endogenous factors (table S5) or replace the MID conflict data by Maoz’s dispute data (table S6) (37). The three-degree horizon of influence can also be recovered in the more classic logistic model (Model a2, table S7).

In addition, to theoretically complement our study, we also control for heterogeneity in the dispute data and use only state-to-state disputes onsets as the dependent variable (38). As the MID codebook indicates, some disputes at hostility level 4 do not involve government-to-government conflict; cases such as the seizure of a fishing vessel belonging to a citizen of another state, which are much less likely to involve decisions from, or authorization by, key executives, are included in the data set.

These disputes, which Gibler and Little (38) refer to as “protest-dependent MIDs,” are caused by different processes and are unlikely to escalate to major warfare. These cases targeting private citizens may introduce additional measurement bias and are not in accordance with...
the classic definition of militarized conflict, so it is useful to differentiate these cases from disputes that represent militarized actions authorized by state governments. Therefore, we examine only state-directed disputes as our dependent variable in an additional test. This analysis recovers the three-degree peacemaking horizon of defensive alliances (table S7) and strengthens our main findings reported previously.

The predicted probability of conflict between contiguous states that are connected by an indirect alliance also drops remarkably when higher-order effects are included in the model (fig. S5). Consider, for example, the relations between Russia and Turkey, long characterized by tension and mistrust. They share an indirect alliance at two degrees, and we see a sharp decline in the predicted probability of conflict when we account for higher-order effects. Poland and Russia, third-order allies, also decrease their likelihood of conflict when we consider connections at higher orders. This effect is not significant at the fourth order.

Why is the effect of indirect alliances limited to three degrees of separation, and why does the suppressive effect not decay? One might look to the instability of longer path lengths in a network (for example, cutting a tie has compounding effects on the persistence of longer paths) for an explanation of the prior. The volatility of paths through the network increases greatly after three degrees (fig. S6), but this instability alone does not provide an explanation for the persistent strength and lack of decay of indirect alliances’ suppression of conflict within the first three degrees.

Community structure of the alliance network
To better understand the three-degree peacemaking horizon of alliances and the lack of effect decay within that horizon, we examined the community structures of the alliance networks (Fig. 4). As discussed earlier, we seek to determine whether alliance ties have an independent conflict-suppressing effect within three degrees of separation or whether the observed effect is spurious, driven by the community structure of the alliance network. We first discuss the procedure for identifying communities in the network and then perform a mediation analysis to determine whether the effect of alliance ties on conflict is strictly attributable to the intervening variable of community structure.

We identified communities of states in the alliance network based on the extent to which the states in the communities are better connected to each other than to those outside the community. We define two community variables: “Within community” captures whether a pair of states belongs to the same community, and “neighboring communities” indicates whether the pair of states is in separate, but closely linked, communities. Specifically, a pair of communities is regarded as neighboring if they are themselves weakly connected by one or more alliances. We expect joint membership in an alliance community to push members toward peaceful relationships by providing members with mechanisms for dispute settlement and mediation (39). Furthermore, states in these close communities of allies likely have broad agreement on the security status quo. This scenario also applies if the focal states are affiliated with different alliance communities, but these communities are more connected to each other than to other communities. Therefore, we also expect alliances in the neighboring communities to have a tendency to maintain peaceful relations. We expect that the within community and neighboring communities together correspond with the boundary, beyond which the effectiveness of alliances drops drastically.

We present the results derived from applying the Walktrap algorithm to partition the alliance network into communities (40). Networks with a high modularity score have dense connections between vertices within communities but sparse connections between vertices in different communities. Modularity values may range in $[-0.5, 1]$. In our application to the alliance network, observed modularity values range from approximately 0.55 to 0.65, which indicates obvious community clustering (fig. S7). Concern over possibly not finding the true maximum modularity partition and the possibility of near optimal partitions make it prudent to also consider the quality of partitions offered by different community detection methods (41). As a check on the robustness of our Walktrap measure, we apply several different community detection algorithms for each system year. Among the candidate algorithms, Walktrap usually defines a community structure with a median modularity score (40, 42–46). Because Walktrap does not have the most strict or loose criteria among other popular methods, it is a fairly conservative choice. This was our motivation for using its results in the main text.

Figure S8 presents an intuitive picture of the community structure we find in the alliance network, where states are colored to indicate their community membership. Because the community assignments are based on the alliance network only, we occasionally see a few close, politically relevant, states that are assigned different communities. An interesting example is Canada, which has been a key member of the North Atlantic Treaty Organization (NATO) while maintaining close relationships with the American countries. In fig. S8, Canada is sometimes assigned to the NATO community and sometimes to the American community. The community assignment of states that have close ties with states in more than one community (United States and Canada) is somewhat algorithm-dependent and may vary across years in these special cases. For this reason, we have assigned states that have ties with most of the states in more than one community to both communities, as described above. Other special states, such as Japan,
Australia, Philippines, and Pakistan, have only one defensive alliance connection in the network (with the United States), and modularity assignment for these states is sometimes variable. Because our analysis incorporates both within community dyads and neighboring community dyads, these special cases do not affect our results because they can mostly be categorized in either variable with their close friends (for example, in 1965, the United States and Canada dyad appears in the neighboring communities, whereas in 2000 they are assigned to one community). Apart from these states, most of the states are well classified into exactly one regionally based community. Figure 4 shows that more than 90% of alliances within three degrees of separation fall into either category of the community variables, whereas less than 8% of alliances at four or higher degrees of separation are contained in these community variables. Statistical analysis shows that the within community indicator has a significantly negative effect on conflict [main effect, 0.70; interaction with contiguity, \(-1.16\) \(\leftarrow -1.54\) to \(-0.73\); Model 2, Table 1], whereas neighboring communities also significantly reduce conflict onsets [main effect, 0.63; interaction with contiguity, \(-1.43\) \(\leftarrow -2.02\) to \(-0.87\)]. Thus, it appears that the sharp decline in alliance effectiveness at four degrees of separation could occur because states at this distance no longer share membership in common communities that represent shared interests.

However, further exploration reveals that the finding that three or fewer degrees of separation are associated with reduced levels of violent conflict is not epiphenomenal to the community structure. That is, both indirect alliance ties and community structure play independent roles in reducing the probability of conflict. In Table S7, a mediation analysis finds that the community structure only partially mediates the relationship between alliances of up to three degrees and conflict (47). The relationship between states linked through alliances of up to three degrees and conflict (Model a2 in Table S7, path c in fig. S9) is significant \((P < 0.05, \text{step 1 of Baron and Kenny’s method})\). Moreover, the relationships between alliances of up to three degrees and community structure (Models a4 and a5, \(P < 0.05, \text{step 2 of Baron and Kenny’s method}\)) and between community structure and conflict (Model a3, \(P < 0.05, \text{step 3 of Baron and Kenny’s method}\)) are both significant. After controlling for community structure, both community structure and the alliance variables remain significant in predicting conflict (Model a1, \(P < 0.05, \text{step 4 of Baron and Kenny’s method}\)), indicating that the community structure of the alliance network partially mediates the relationship between alliances within three degrees of separation and conflict. Therefore, although the community structure exhibits a strong relationship with alliance degrees, the three-degree peacemaking horizon appears to be an independent feature of the alliance network, rather than an artifact of community structure. Our model results are robust to the choice of graph partitioning algorithm. Models based on community variables generated by different algorithms suggest very similar results that do not affect our substantive inferences (for example, a partial mediation between community structure and the three-degree horizon) in any way. Because presenting those results here would amount to reprinting the feature tables of our analysis with minor variations in the coefficient values, we do not present tables of these results. These tables are available upon request.

### DISCUSSION

Our findings suggest radical new directions for the study of international politics by demonstrating that state behaviors can spread indirectly through international networks. We have shown that international politics can no longer be viewed as sets of bilateral relations but that bilateral relations are embedded within international networks that influence even states that are not formally or directly connected. This approach and its findings step far outside of the established practice in international relations scholarship. We have merely scratched the surface of what indirect ties can teach us about the functioning of the international system. We have also shown that communities and neighboring communities can exert strong effects on the behavior of their members. Considering international networks in terms of their community structures is also a promising area for future research (48, 49).

Our results reveal four novel and important features of the international political system. First, we have identified the network horizon within which military alliances contribute to bilateral peace. Indirect alliances make peace more likely between states separated by as much as three degrees. Second, we showed that the peacemaking ability of indirect alliances does not lose its potency within this horizon of influence. The effect of (in)direct alliances on conflict is consistently strong for states separated by up to three degrees, after which indirect alliances quickly lose their impact. Our analysis suggests that this finding is partially driven by the influence of community structures—states cluster into various subnetwork communities that shape state behavior beyond the influence of formal alliances—but the horizon of three degrees of separation also has an independent effect. Last, we found that the impact of these alliances is strongest for contiguous states. Because neighboring states are particularly likely to fight, any institution that can reduce the risk of violence for contiguous states is normatively important for those seeking to engineer a safer international system. Together, these findings suggest that policy-makers assessing threats might have less reason to be concerned about states to whom they are connected, even indirectly, by up to three degrees, whereas states outside this “low-risk zone” could pose a greater threat. Therefore, our study provides policy-makers with an additional tool to assist with the allocation of security resources. Our findings suggest that leaders would be wise to focus their attention on those states separated by more than three degrees in the network of international military alliances, because these states present the greatest risk of serious conflict.

### MATERIALS AND METHODS

#### Conflict data

Our outcome is a complete international network in which ties indicate serious interstate conflict onsets (MID levels 4 and 5) from 1965 to 2000. The original data came from version 3.0 of the MIDs data set of the COW Project (29). A dyad in the network for a given year was coded 1 (0 otherwise) if at least one conflict started during this time period. MIDs were defined as cases of conflict in which the threat, display, or use of force (including war) by one member state is explicitly directed toward the government, official representatives, official forces, property, or territory of another state (50).

In the MIDs data set, hostility levels for each dispute are identified by (i) no militarized action, (ii) threat to use force, (iii) display of force, (iv) use of force, or (v) war. We included conflict onsets of levels 4 and 5 only, because these are the cases involving the deliberate use of military force by state actors. This sometimes leads to full-scale war (defined as MIDs involving more than 1000 battle deaths) and sometimes does not.

#### Defensive alliances

To compute the indicators that captured the degree of separation between two states in the defensive alliance network, we used the
This data set included all the bilateral and multilateral defensive agreements between 1815 and 2003. To match the available date ranges for other input variables, we used the data from 1965 to 2000. We constructed the defensive alliance network for each year, in which a dyad was coded 1 if a bilateral or multilateral defense pact existed between the states, and 0 otherwise. Because most defensive commitments were reciprocal, we regarded the network as undirected. Although the network was not completely undirected, less than 1% of the defensive commitments in the ATOP data set were directed.

The degrees of separation of alliances for a given dyad were the length of the shortest path between them along the graph, which could be directly calculated from the defensive alliance network. The matrices for dyads at one degree of separation were composed of a binary coding during the time period in which we were interested: 1 if the states of the dyad were connected in the defensive alliance network and 0 otherwise. The dyads in the two-degree matrices were coded as 1 if the degree of separation between the pair was two, and 0 otherwise. Similar definitions hold for other higher-degree variables.

To operationalize the community structure, we first used the Walktrap algorithm to assign each state a specific community, including isolates (unallied states). We then retained those communities that had at least four members and discarded the rest. In so doing, we obtained the major communities in the alliance network, where each state belonged to exactly one community. However, some states had important ties to multiple communities; for example, the United States and Canada in 2000 had close relations with both the NATO and Organization of American States groups of states. It was not reasonable to classify these states into one community and omit them from the other. Therefore, we accounted for this overlapping of states by adding a state as a member to another community if it was allied to most of the members (more than 50% of states) there. Communities were heavily regionally based, and in most cases, only very few major powers, such as the United States, had memberships in more than one community. Thus, the above step of classifying state memberships in multiple communities has good performance in characterizing the alliance networks. After identifying all the well-defined communities in each system year, we defined two community variables: within community and neighboring communities. If a pair of states belonged to the same community, then it was coded 1 in within community (0 otherwise). If two communities had one or more direct alliances linking them, then they were regarded as neighboring communities. Therefore, we defined the neighboring communities variable to contain all pairs of states that belonged to two different but neighboring communities, and these pairs were coded 1 (0 otherwise). Because there were states that were classified as belonging to more than one community, some pairs were categorized as both within community and neighboring community pairs.

### Control variables

In addition to the key covariates and endogenous factors, we also included a set of commonly used control variables that the existing literature has shown to influence conflict. Because conflicts are more likely between states that are geographically close to each other, we included a measure of direct contiguity. Direct contiguity accounts for the existence of a shared land border or a separation of no more than 150 miles of water between the focal pair of states; the dyad was coded 1 if the states are contiguous by this standard and 0 otherwise (29). Because contiguity strongly affects the dynamics of both alliances and conflict, one could expect contiguity and alliances to be relatively dependent. Conflicts are most likely to take place between proximate states; thus, we expected that our alliance measures would have the strongest effect in contiguous dyads. Therefore, we used interaction effects between our alliance measures and contiguity to capture the dynamics between alliances and conflict.

To examine how regime type affected the likelihood of conflict, we included a measure of democracy in a dyad (30). As is standard in the conflict literature, a state was regarded as a democracy if its Polity score was 7 or higher, and a nondemocracy otherwise. A dyad in the democracy matrix was coded 1 if both states were democracies, and 0 otherwise. According to the democratic peace literature, the probability of conflict should be lower between two democratic states (51).

In addition, we included the dyad’s capability ratio, which is defined as the log of state $i$’s capability score divided by state $j$’s when $i$ has larger capability. We obtained our data from version 4.0 of the COW project’s National Material Capabilities data set (52) through the EUGene data preparation and formatting tool (53). Because a weaker state is less likely to provoke a war against a significantly more powerful state, a large capability ratio should have a deterrent effect on conflict.

Another important exogenous factor was trade dependence. The trade dependence of state $i$ on state $j$ was the volume of trade flows from $i$ to $j$, standardized by the gross domestic product (GDP) per capita of $i$. We constructed this factor from version 4.3 beta of Gleditsch’s (32) dyadic trade flow data set and version 6.0 beta of his GDP per capita data. Because 2.5% of the values in the trade flow variable were missing, we used single imputation to fill in these missing values based on observations on other dyad-year variables (54). We also imputed several missing GDP values based on the trends of surrounding data for the same state (55). If a state’s trade depends heavily on another state, it is unlikely that it would provoke a war and risk losing the benefits from this trade flow. Therefore, large values of trade dependence should inhibit conflict.

### Models

Our outcome was the network of serious MIDs that involved the deliberate use of violence, including war, by one state against a target in another state. These data were inherently relational. Because the conflict behavior of one pair of states may affect the conflict behavior of other pairs of states, the data must be considered as a complex network rather than a series of independent and identically distributed dyadic observations. Models assuming independent observations, such as the logistic regression model, will be biased when applied to such data (27). We used a TERGM (26, 28), a longitudinal extension of the exponential random graph model (ERGM) first proposed by Wasserman and Pattison (25), to model the interdependence inherent in our data. ERGMs model networks as single draws from large multivariate distributions and estimate parameters corresponding to a vector of statistics computed on the observed network. An ERGM of the network $G$, where we defined $G$ as its adjacency matrix in which $G_{ij} = 1$ if state $i$ connects to $j$ and 0 otherwise, was specified as

$$ P(G, \theta) = \frac{\exp(\theta^T h(G))}{c(\theta)} $$

where $\theta$ is the vector of model coefficients, $h(G)$ is a vector of statistics computed on $G$ that includes both endogenous network structure factors (for example, degree and triangles) and exogenous covariates...
(for example, other network objects that could affect the response network), and the normalizing constant $c(\theta) = \sum_{G} \exp(\theta' (G))$. The ERGM then computed the probability of observing the observed network over all of the networks that could have been observed, which was denoted as $G$ (that is, the set of all possible permutations of the observed network with the same number of vertices). These statistics are computed as sums of subgraph products and can operationalize relational concepts such as popularity, sociality, transitivity, reciprocity, and more. See, for example, the study of Cranmer and Desmarais (27) for a more detailed discussion of ERGMs and their specifications.

The ERGM in Eq. 1 for network $G$ at time $t$, denoted $G^t$, can be modified to include dependencies on some number, $K = 0, 1, \ldots, T - 1$, where $T$ is the current time step of interest, of previously observed networks by introducing lagged networks and/or statistics with temporal dependencies into $h$. $K$ must be chosen such that it fully encompasses the order of the temporal dependencies present in the data. We can model the joint probability of observing the networks between times $K + 1$ and $T$ by taking the product of the probabilities of the individual networks conditional on the others, which we may do because they are independent if $K$ has been chosen properly.

The ERGM, as demonstrated in Eq. 1, may be equivalently expressed through the conditional probability of an edge from $i$ to $j$

$$
\pi_{ij}(\theta) = P(G_{ij} = 1 | G_{-ij, t}) = \logit^{-1} \left( \sum_{r=1}^{p} \theta_r s^{(r)}(G) \right)
$$

where $G_{ij}$ refers to the entire network $G$ except for the dyad $G_{ij}$, $\logit^{-1}(x) = 1/(1 + \exp(x))$, the subscript $r$ refers to any statistic included in $h$, of total number $K$, and $s^{(r)}(\theta)$ is equal to the change in $h_r$ when $N_j$ is switched from zero to one. The change statistic $s^{(r)}(\theta)$ was computed by subtracting $h_r(G_{ij}^{-1})$ from $h_r(G_{ij}^1)$, where $h_r(G_{ij}^{-1})$ indicates the network with the $ij$ dyad equal to 0, and $h_r(G_{ij}^1)$ indicates the network with the $ij$ dyad equal to 1. Because these change values were summed if included as an edgewise covariate in Eq. 2, one may compute the change statistics for a given element of the generative model and include them directly. This is useful because it is computationally faster to calculate change statistics for a given dependency than to code new structural parameters.

When a single TERGM is applied to a pooled time series of networks, it is implicitly or explicitly assumed that all change in the network is attributable to Eq. 1 or its equivalent Eq. 2. A bootstrap pseudodolkelikelihood approach based on change statistics was proposed by Desmarais and Cranmer (28). The procedure works as follows: take a sample of $s$ estimates of $\theta$ by drawing $s$ samples of independent (for example, more than $T - K$ periods removed) networks from the longitudinally observed series of networks $(G_1, \ldots, G_T - K)$ and by computing $h$. The distribution of $\theta$ is then used to draw unbiased confidence intervals. For more detailed methodological treatment and applications of TERGM, see previous studies (26, 27, 56, 57).

Beyond the appropriate selection of $K$, the TERGM requires no assumptions of statistical independence between states and ties, and it can obtain insight into the underlying processes that form and maintain the network-based international system with inclusions of network statistics.

**REFERENCES AND NOTES**


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