International Interactions: Empirical and Theoretical Research in International Relations

Toward a Network Theory of Alliance Formation

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We propose a network-based theory of alliance formation. Our theory implies that, in addition to key state and dyad attributes already established in the literature, the evolution of the alliance network from any given point in time is largely determined by its structure. Specifically, we argue that closed triangles in the alliance network—where i *is allied with* j *is allied with* k *is allied with* i *— produce synergy effects in which state-level utility is greater than the sum of its dyadic parts. This idea can be generalized to* n-*state closure, and, when considered along with factors that make dyadic alliance formation more attractive, such as military prowess and political compatibility, suggests that the network will evolve toward a state of several densely connected clusters of states with star-like groupings of states as an intermediary stage. To evaluate our theory, we use the temporal exponential random graph model and find that the roles of our network effects are robustly supported by the data, whereas the effects of non-network parameters vary substantially between periods of recent history. Our results indicate that network structure plays a greater role in the formation of alliance ties than has been previously understood in the literature.*

Alliances have long been studied as dyadic phenomena; a relationship that can exist at several levels of commitment between two states. While dyadic alliances are indeed the fundamental building block of the alliance system, the system itself is a complex network of interconnecting alliances. Theoretically, the importance of complex interconnections in the network of alliances has been suggested for some time, but the technology to empirically evaluate network theories of alliances and alliance formation is just becoming available. As a result, relatively little work has, thus far, considered the effects of endogenous structures in the alliance network; the possibility that the structure of connectivity in the alliance network may be a significant determinant of the network's evolution.

We propose a network-based theory of alliance formation with the goal of explaining how the global alliance network evolves during and following major shifts in the distribution of power. We show that the structure of international political alignments, reflected in the system of alliances, operates in a manner that can best be described as punctuated equilibrium: periods of stasis followed by rapid shifts in the configuration of the system. We observe that the system of alliances undergoes major changes during and immediately following punctuations in world politics and propose a network-based theory to explain the means by which a new period of stasis evolves. Our theory is network-based insofar as we draw not only on monadic and dyadic determinants of alliances, but focus our theoretical contribution on the complex interdependencies of the alliance network. This formulation allows the indirect effects of alliance ties to be felt throughout the network and makes specific predictions for how the structure of the network affects tie formation. The central element of our theory is the claim that triadic closure—a condition where three states are all allied to each other—produces a synergy effect among the member states such that the utility derived by each is more than the sum of their dyadic connections. Building on this claim, we lay out our theory of how the alliance network restructures itself to reflect major shifts in world politics; we describe several stages of network evolution and how the evolved network reflects, if not colors, the nature of international politics during the ensuing period of stasis.

Our theory builds upon the literature on alliances generally and on the contributions of Maoz et al. (2007) and Warren (2010) specifically. These recent works have found that "extra-dyadic" network effects in triads of states were significant determinants of the structure of the alliance network. We ground this finding in a firm theoretical basis. Furthermore, we characterize the effects of the accumulation of a state's alliance obligations as a network effect. This component of our theory, which receives robust

empirical support, predicts that alliances discourage additional alliances by stretching a state's potential conflict commitments.

Because our theory involves the evolution of networks, we require a statistical method that can analyze dynamic change in such a system. We find an ideal approach in a class of models developed by Hanneke, Fu, and Xing (2010) and introduced to political science by Cranmer and Desmarais (2011): the temporal exponential random graph model (TERGM). We use the TERGM to analyze the manner in which the alliance network restructures itself to reflect three punctuations in world politics: World War II and the onset of the Cold War, decolonization, and the collapse of the Soviet Union. A key advantage of modeling these periods of transition separately is that we are then able to compare the driving forces of alliance formation and dissolution across the periods. This approach not only allows us to evaluate our theory, but also allows for period-to-period heterogeneity in parameter values. We find that our hypothesized network effects are significant predictors of alliance formation across all periods under study whereas the effects of the state and dyadic covariates vary substantially from period to period. We take the lack of a stable predictive relationship for many state and dyadic covariates to indicate that historical nuance plays a greater role than the established literature suggests. Our results suggest that the very structure of the alliance network seems to be a major predictor of alliance formation.

ALLIANCES AND THE BEHAVIOR OF STATES

While our theory focuses on the effects of the broader network structure of alliance relations, the basic unit of alliances is dyadic and allied dyads are only possible as a result of state behavior. As such, a network analysis of alliances is incomplete without consideration of the state and dyad level determinants of alliances: principally capability aggregation and political fellowship.

Assuming that the alliances formed by states are generally reliable,[1] states realize a number of benefits from having alliances. Alliances have long been considered to be principally a method of capability aggregation

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[1]It makes little sense for states to enter into alliances if they do not expect fruitful and reliable cooperation; there is evidence to suggest that states consider the reputations for reliability of prospective allies in the alliance formation process (Crescenzi et al., forthcoming, 2012; Downs, Rocke and Barsoom 1996; Gibler 2008; Leeds 1999; Miller 2003) and rivals consider the reliability of a state's allies before initiating hostile action (Gartner and Siverson 1996; Smith 1996). Leeds, Long, and Mitchell (2000) suggest that most promises are honored, that democracies are more reliable partners than autocracies (see Leeds 1999; see Gartzke and Gleditsch 2004 for a challenge to this finding), and failures to honor alliances are generally produced by major changes in the structures of governments or when the costs of reneging are especially low (Leeds 2003).

across states in order to increase their collective security (Altfeld 1984; Cony-beare 1994a,b; Lake 1999; Liberman 1996; Morgenthau 1956; Morrow 1993; Walt 1987; Waltz 1979); though some have questioned the extent to which alliances add to the military might of member nations (Brooks, 1997). The aggregation of power has important implications for deterrence: because any particular state in an alliance gains power, it increases its deterrent ability (particularly when closely allied with major powers) and thus its ability to bargain successfully in crisis situations (Morrow, 1994; Smith, 1995, 1998) and balance rival powers (Liska 1962; Morgenthau 1956; Powell 1999; Walt 1987).

However, the benefits realized by states from alliances do not come without costs. Some costs, such as a loss of autonomy and limitation of available actions (Altfeld 1984; Morrow 1987, 1991, 2000), are realized regardless of whether the alliance is ever activated, but the most substantial costs are prospective costs at the time the alliance is formed. The greatest potential cost of entering into an alliance is that a state will be roped into a conflict in which it did not wish to participate. Indeed, there is evidence that alliances are mechanisms for the diffusion of war (Oren 1990; Siverson and King 1980; Siverson and Tennefoss 1984). Specifically, Siverson and King (1980) find that allies will be most likely to join a conflict if their alliance is new, defensive, with a minor power, and they have other allies already in the war. These findings are consistent with the idea that states are more likely to join a conflict under conditions where they would bear the highest reputational cost for reneging. Further, Siverson and Starr (1990, 1991) use borders and alliances as indicators for opportunity and willingness to join wars; they find that states are more likely to join when opportunity and willingness are both high.

When considering which states to ally with, a degree of political compatibility may also be an attractive property of a potential alliance for two reasons. First and foremost, states may prefer to ally with other states close to themselves in ideological/normative/cultural space. Siverson and Emmons (1991) began a somewhat contentious literature with their finding that democracies are disproportionately likely to ally; a finding that has been generally supported in later studies (Lai and Reiter 2000; Leeds 1999; Warren 2010) but has also been criticized as being an artifact of the Cold War (Gibler and Wolford 2006; Simon and Gartzke 1996). Second, the existence of an alliance can indicate the intersection of real common interests and satisfactory bilateral relations (Bueno de Mesquita 1981; Lemke and Reed 1996). Simon and Gartzke (1996) posit that alliances reflect a similarity of cultural norms and domestic political institutions. This idea is expanded by Bennett and Stam (2004) who argue that cooperation through alliances can lead to "shared institutional structures over time that will provide incentives and/or mechanisms to avoid conflict" (p. 74). What is more, political norms, such as democracy, tend to be spatially clustered (Gleditsch and Ward, 2006). This carries with it the benefit of often being friends with one's

neighbors. Because few states are capable of long-range power projection, friendly relations with bordering states increase the security of the state and may even help smooth over local disputes (Gibler and Wolford 2006; Gibler and Vasquez 1998).

Likely mitigating factors for the need for political compatibility are political tension and the presence of a common foe. Lai and Reiter (2000) point out that, intuitively, states that may be likely to come into conflict have no incentive to ally with one another. However, a mutual threat may cause states to put aside their political differences to balance, or even combat, the common enemy (Walt 1987). Lai and Reiter (2000) find empirical support for this claim.[2]

ALLIANCES AND THE STRUCTURE OF WORLD POLITICS

We argue that the configuration of the alliance network reflects the basic orientation of geopolitics. Specifically, we posit that alliance ties are signals of interstate attitudes that restructure themselves in response to shifts in power, but do so in an imperfect manner.

At their most basic levels, alliances are signals of peaceful intentions between signatories, the expectation of peaceful relations to come, and, potentially, military support. The idea that alliances reflect peaceful intentions is supported by Long, Nordstrom, and Baek (2007) who find—perhaps not surprisingly—that the prospects for long-term peace between two states improve when they sign a treaty. From realist and game theoretic perspectives respectively, both Walt (1985) and Morrow (2001) argue that alliances are valid measures of a nation's perceived probability of war with its allied partners. Beyond that, Fearon (1997) suggests that alliances are a useful signal of foreign policy interests in so far as states are forced to act in accordance with their alliances or endure international and domestic audience costs; as such, leaders have no incentive to bluff. While the implications of alliances go beyond these simple signals of intentions and expectations, we take these signals to be the cardinal communicative quality of alliances.

We expect major changes in the network of alliances to correspond to major changes in the global distribution of power. We are hardly the first to suggest that changes in power and alliances go hand in hand. While there have been many approaches to the study of alliances, one that has been particularly concerned with the role of power is realist theory. The idea that states—particularly major powers—band together to balance more powerful states and maintain an approximately even distribution of power in the

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[2]Note however, that such an argument is not antithetical to the idea of political compatibility: it simply suggests that the presence of a common threat may lower the threshold for basic political compatibility, if only temporarily. An obvious example of this are the World War II alliances between communist and capitalist states in order to counter the common foe of fascist states.

international system is central to much realist thinking (Morgenthau 1956; Walt 1985; Waltz 1954, 1979). Waltz (1954) argues that when power is relatively balanced between any two states, high costs and uncertain outcomes lead states to cautious behavior, which, in turn, leads to peace. The implication here is that when power is not balanced, "it behooves the state that desires peace as well as safety to become neither too strong nor too weak" (Waltz 1954: 222). The argument posits that as one state becomes more powerful, other states, if not capable of balancing it without alliances, will form alliances in order to balance the more powerful state (Waltz 1979). By this line of reasoning, states restructure their alliances to adapt to changes in the distribution of power and thus ensure stability. As such, we would expect the system of alliances to undergo its most radical changes as the underlying distribution of power undergoes its most radical changes.

We must, however, draw a distinction between the configuration of alliances and the distribution of power in the international system. Power often changes slowly over time; most changes in power are incremental and do not affect the stability of the system in a noticeable way. As such, marginal changes in the distribution of power do not require a restructuring of alliance relations to maintain stability. However, when radical changes in power (or major events that radically alter the distribution of power) occur, the system of alliances will need to restructure itself to reflect the new political environment. Sometimes, the alliance network may even begin changing radically during periods of major power transition when it becomes clear that the post-transition distribution of power will look very different than the pre-transition distribution (for example, World War II). In other words, without relying on any particular theoretical paradigm, we expect the system of alliances to be characterized by punctuated equilibrium, changing radically during periods of radical change to the distribution of global power and remaining largely stable during periods of system stability even though the underlying distribution of power is constantly changing. As such, understanding the periods of change in the alliance network allows us to understand the state of the alliance network at any given point in time.

THE ALLIANCE SYSTEM AS A NETWORK

Alliances need not, and indeed should not, be conceived of independently of the network context in which they exist. Formal alliances are public matters and it is reasonable to assume that all states are aware of the set of existing alliances at any given time. Secret alliances, while they may exist, are difficult to enforce and other states do not consider them as part of a given state's alliance portfolio because they are unaware of their existence. So, if alliances reflect the distribution and orientation of power in the international community and states are fully aware of each other's alliances, then a more complex structure naturally emerges from the set of alliances.

Some empirical work has noted the network attributes of alliances. In early work, Li and Thompson (1978) suggest that clustering in the alliance system is driven by system polarity. Siverson and Emmons (1991) find that democracies are more likely to ally with one another than would be expected by chance, suggesting that the common attribute of democracy causes democratic clusters in the network, a phenomena known as homophily in the network literature. More recent work has adopted an explicit network perspective: Maoz et al. (2006) introduced the concept of "structural balance" in conflict and cooperation ties, Maoz et al. (2007) investigated tendencies toward friend-of-my-friend triadic alliances, and Warren (2010) finds that triadic "friend of friend" or "friend of enemy" relationships influence alliance formation and maintenance.

The pivotal theoretical expansion made possible by considering the alliance system as a network is that the actions of states, or the relationship between a specific pair of states, may have effects beyond that state or dyad. The actions of one state may affect other states in the network, even if they are separated from the acting state by several degrees. The alliance network as a whole may be reshaped by the behaviors of one or a few states in the network. Accordingly, theories about alliance formation need not assume away the structure of the network in which the alliances are formed, but rather can use an understanding of the network to better form and test theories.

A NETWORK THEORY OF ALLIANCE FORMATION

We now lay out our network theory of alliance formation. To be clear on what we mean by a "network theory," we mean a theory in which the structure of the alliance network is an intrinsic element; the structure of the network affects the actions of states and the actions of states affect the structure of the network. As we discussed above, many have theorized that state-level and dyadic attributes are key drivers of alliance formation, and we too argue that they play a role, but we seek to move beyond a strictly monadic/dyadic theory of alliance formation to one in which states view themselves as part of a larger network.

Synergy Effects

A central component of our theory is what we call "synergy" effects. With synergy effects, we leave the realm of theory on the monadic and dyadic predictors of alliance formation and draw on a concept of network-based endogeneity. In its simplest sense, a synergy effect means that the utility of alliance ties between three or more states will be more than the utility gained by the sum of the ties. In more general terms, we will expect a closely knit community of allied states to provide more security than the sum of

their dyadic connections would indicate. One can think of this as alliances becoming stronger than the sum of their dyads—which may manifest in terms of expected honoring of agreements, levels of conflict support, and the rapidity of conflict support—when groups of states become densely connected.

Formally, the process of interest is called triangle closure. Triangle closure occurs when two states, unallied to each other but each allied to a third state, decide to ally. One can think about this as drawing the last edge of a triangle, thus its name. Why might triangle closure be an appealing network attribute of a potential alliance? A triadic alliance implies that if any one of the states comes under attack, the allies to whom it will look for help are allied with one another and thus are not only more likely to act, but are more likely to act together. The result is a higher probability that either state will come to the aid of the besieged state, that the besieged state will receive more military aid than it would from two separate but unconnected alliances, and the besieged state is likely to receive some benefit from the allies coordinating.

Some support for this idea may be found in the literature. Coalition effects are a central element of Snyder's (1997) theory of alliance formation and recent empirical work by Maoz et al. (2007) and Warren (2010) suggest triadic effects may affect alliance formation. Perhaps most centrally relevant is the finding from Siverson and King (1980) that states are more likely to join the conflicts of their allies if they have other allies who have joined the fight. In other words, there is the potential for a synergy effect brought on by triadic closure such that potential alliances that would result in triadic closure will be more attractive to both potential allies (higher expected utility to each than would be generated from a dyadic alliance that did not close a triangle), and also increases the utility of the third state to which they are both allied but which is not forming any new alliances.

Consider a simple illustration with three states—A, B, and C—where A has alliances with B and C, but B and C are not allied to each other. Were an alliance to form between states B and C, state A would benefit because, if it were to come under attack, both of its allies would be allied and thus not only more likely to both come to its aid, but to do so in a coordinated manner. As such, state A gains utility from a B – C alliance even though A's alliance portfolio does not change. State B (or equivalently state C) also benefits from triadic closure: were it to ally with C, not only would it gain utility from an additional alliance partner, but it would gain additional utility from the existing A – C alliance; were B ever to come under attack, it would receive the benefit of allied allies coming to its aid.

From this illustration, we see that all states in a closed triangle of alliances benefit equally: they all have two dyadic alliances and the synergy bonus to their utilities of having allied allies. This leads to the first of our hypotheses:
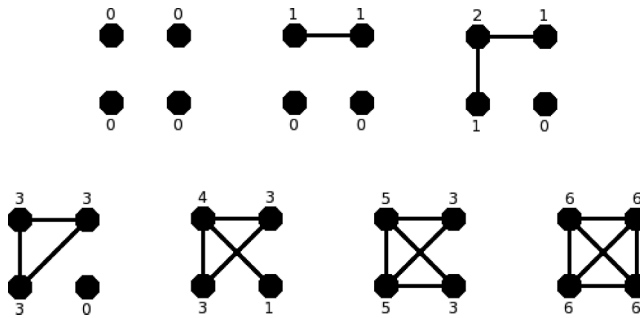
FIGURE 1 Simple illustration of synergy effects. One order of utility is gained with each alliance a state is party to, and an additional order of utility is gained by every state in a triangle when it is closed. The completely connected network in the lower right-hand side of the figure is the sole equilibrium and is also Pareto optimal.

H1: *The potential for triadic closure will make alliances more appealing to the prospective allies.*

The scope of the hypothesis can be expanded and further illustrated with a simple expected utility setup. Consider some of the possible configurations of relations between four states as displayed in Figure 1. If we consider each dyadic alliance (represented by lines in Figure 1) to increase the utility of each member state by one order of utility, we can capture synergy effects by increasing the utility of each member of a triangle by an additional order every time a triangle is closed. This implies that, when a state has two allies that are not allied to each other, its utility will increase if its two allies ally to one another. Such an alliance would close the triangle and provide each member of the triangle with an order of utility above the sum of their dyadic ties.

The operationalization of synergy effects to the triadic closure hypothesis (H1) neglects two important caveats: the risk of a state being pulled into an unwanted conflict and the implication that clusters of alliances should grow to encompass the entire system.

First, consider the extent to which a state is at increased risk that it will be pulled into a conflict in which it did not wish to participate as a result of triadic closure and the associated synergy effect. It is important to realize, first, that synergy effects do not increase the number of alliance obligations held by a state: triadic closure is not possible without each state in the triad agreeing to be allied with the other two. As such, it is not possible for synergy effects to push a state into an unwitting alliance with another state. The probability that an ally in a closed triad pulls a state into a conflict should not be appreciably greater than it would be if the triad were not closed because states are expected to exercise their usual prudence when choosing who to ally with (that is, not allying with states at high risk of

alliance-activating conflict unless they are willing to bear such risk).[3] What triadic closure and synergy effects do however, is raise the cost of breaking an alliance: a state's reputation with other elements of the triad will come into doubt if it shirks its obligations in the face of conflict, thus possibly leaving it without allies if it does not honor its alliances. A higher cost of shirking in closed triads (or clusters of closed triads) should strengthen the deterrent effect of the alliance and thus lower the probability that any of the allies will be attacked. In sum, synergy effects raise the cost of shirking alliance obligations, thus potentially increasing the risk of unwanted conflicts from which the state would otherwise have shirked, but otherwise lower the risk of conflict from what it would be if the state had the same number of dyadic alliances.

Second, with dyadic utility and synergy effects conceptualized as above, states have an incentive to continue forming alliances, with a preference to form alliances that close triangles, until the system is completely connected (every state is allied to every other state). In a completely connected system, no state can become unilaterally better off by breaking an alliance and no further alliances can be formed, so such a system should be stable. Clearly however, we do not expect every state in the world to become allied to every other state. The point we wish to illustrate with this argument is that—independent of political compatibility, capability aggregation, and changes in the global balance of power—synergy effects should be present in any triad. As such, states willing to participate in dense alliance communities reap the rewards and the system as a whole should increase its connectivity. This is a concept we will apply directly to our theory of alliance network dynamics.

The Dynamic Alliance Network

To put our theory in motion, begin by considering the international system immediately after a major shift in world power. That is, when power has just been radically restructured and the alliance network must adapt. In a thought experiment starting from this initial condition and the assumptions that synergy effects exist, states prefer to ally with strong states, and states desire some basic level of political compatibility with potential alliance partners, we can deduce a network-based theory of alliance formation.

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[3]We should also emphasize that we have limited ourselves theoretically (and empirically below) to defensive alliances (offensive alliances are quite rare historically, particularly since the infamous "blank check" Germany provided to Austria-Hungary at the opening of World War I), thus negating any obligation of allied states to support an ally who comes into conflict as a result of its own antagonism and limiting a given state's exposure to unwanted conflicts to the case in which one of its allies is attacked without alliance-voiding provocation.

In this initial condition, states will likely seek to increase their security by forming alliances with militarily strong partners who are perceived as unlikely to rope their allies into conflicts. However, security-seeking states will not form alliances indiscriminately; states likely prefer alliances with militarily strong partners that are also politically compatible. In other words, following a major shift in the distribution of power, each state will identify its set of potential alliance partners and seek an alliance with the state it perceives to be the most "fit." Fitness in this context is intentionally defined somewhat vaguely: it could be driven by capabilities, compatibility, contiguity, or some combination of factors. Usually, the composition of fitness will be related to what states perceive as valuable. For example, if a state feels particularly insecure, it is likely to be driven by security maximization more than political compatibility.

States seeking alliances with the fittest potential partners in their set of possible allies leads to a system in which one or a few states becomes highly connected. This is called having high *degree* in the network literature, where the degree of a state is the number of connections (in this case alliances) it has. Consider a cluster of politically compatible states where one among them is militarily the strongest by an order of magnitude. Most states in the compatible cluster will prefer an alliance with this strong state. This is because, as discussed above, an alliance with a strong partner will lead to the greatest possible marginal gain in security. The result is that the powerful state will form alliances with many other states in order to propagate its influence, but at this early stage of network evolution, the less powerful states will have few alliances among them. The cluster of states allying with this powerful state now comes to look like what network scientists call a star: one powerful state at the center and radiating from it are ties with many other less powerful states. So, in this first period of network evolution, we expect stars to form around the fittest states in the system. Because we expect only a few fit states to have high degrees, most states will have low degrees. Since we expect most states to have low degrees and comparatively unfit states with many alliance commitments will be less able to honor their alliances, we expect

H2: *The degree of a state is a negative predictor of alliance formation.*

From the star condition, less fit states realize that there are synergy gains to be had by allying among themselves. As such, bilateral alliances begin to form between states already allied with the hub state so as to close triangles and increase the utility of their alliances based on additional alliance as well as synergy gains. But because every time an additional triangle closes the utility of all states involved in the triangle (including the one not actively forming the closing link) is increased, utility is gained nonlinearly as the density of the cluster increases. These nonlinear gains from synergy drive the

cluster toward a state of complete connectivity where, within a community of states, every state is allied to every other state. System wide, this will look like dense clusters or communities forming out of the several stars. This phase of alliance network evolution is captured perfectly by H1 (triadic closure).

In a completely connected segment of the network every state has the same number of alliances as every other state. As such, degree will no longer matter as it did in the star formation phase. But that is not to say that the powerful state no longer matters; quite the opposite, in fact. All this suggests is that as the density of the segment increases, the importance of degree in measuring the influence of states decreases. Once the segment is in its completely connected state, the star-hub should still play a prominent role in the alliance. The fittest state (or states) has agenda-setting power because it and its political ideal point were the hub around which the densely connected segment formed. In other words, dense segments form around major powers; they are the hub of the segment and thus do much to set the political tone for the allied segment. Though we have arrived at it from a different perspective, this idea is in keeping with most of the literature: it implies that the high-end of military prowess affords states the ability to have great political influence across wide swaths of the international system.

The implication here is that tensions between *different* dense segments of the network will be colored primarily by tensions between the power-hubs. Several historical cases where this seems to hold true are immediately apparent. By way of example, during the Cold War, competition between the U.S. and USSR as well as their alliance networks (NATO and the Warsaw Pact respectively) did much to shape the nature of international politics. We would expect the U.S. and USSR to set the tone of the security issue for their allies because they were the hubs around which stars formed following the major restructuring of power during and immediately after World War II.

Our theory, which addresses the means by which stable clusters of densely allied states form, also has implications for the stability of the international system as a whole. Clusters of allied states have competing effects on the stability of the system. On one hand, alliances have been shown to be mechanisms of war diffusion (Oren 1990; Siverson and King 1980; Siverson and Tennefoss 1984), suggesting that small wars between states in different clusters are more likely to escalate and spread into big wars involving many states. An environment conducive to war diffusion would seem to undermine the stability of the system. However, if states are aware of the increased risk of war diffusion and behave strategically, there exists an incentive for cautious behavior: the danger of larger conflicts may act as a deterrent suppressing smaller conflicts, particularly between clusters in the network. As such, it is possible that the stability of the international system may be enhanced by the evolution of the alliance network into several densely connected clusters, but that same structure may contribute to the severity of those conflicts it does not deter.

It is worth being explicit about the fact that we do not aim to, nor do we accomplish, an explanation of why or even when major transitions in world power occur. Our theory is limited to an explanatory model of how the alliance network adjusts to accommodate shifts in power. Major transitions in world power will usually determine which states become the power-hubs around which stars and then dense clusters are formed, but our simple theory does not account for the degree to which a state's alliance network going into a power transition can affect its probability of coming out on top.

EMPIRICAL ANALYSIS

Punctuations in the Structure of World Politics

Given the need to focus on periods of major change, we must identify the punctuations that will be the focus of our study. We believe that a careful reading of post-World War I history suggests three transitional periods for the international system:[4] World War II, decolonization, and the collapse of the Soviet Union. Despite the fact that these periods may seem rather intuitive, they are central enough to our study that we take a moment to justify our choices.

World War II is probably the most obvious sea change in the international system. Not only was it the bloodiest war in humankind's history but there is consensus in the literature that it changed the face of world politics. Perhaps the most studied effect of World War II was the transition from a multipolar prewar system to a bipolar postwar system in which the two new super powers would hold each other in check for the next four decades. Waltz (1979) laid out a theory suggesting that the new bipolar system was substantially more stable than the multipolar system that preceded it and debates about the relationship between system polarity and system stability became the focus of a large body of scholarly work (this literature is far too voluminous to cite here, but readers are referred to Deutsch and Singer (1964), Waltz (1979), and Snyder (1984) for seminal works). As such, we take the World War II era (1937–1946) as our first period of study.

Our second period of study, the decolonization period, while perhaps not quite as obvious a transition as World War II, saw a major transformation of international politics nonetheless. During the period of

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[4]We are forced to restrict our analysis to the period after World War I because of data limitations. Prior to World War I, the sparsity of the alliance network is such that reliable statistical inferences cannot be drawn. Said more simply, there is too little variation in alliances prior to World War I for reasonable statistical inference. Additionally, as Achen (2002, 2005) points out, there is a great deal of causal heterogeneity over such long time periods that would be difficult to control for in a statistical analysis. The fact that the data are so sparse prior to World War I suggests a very different set of causes may be at work in that time period. To combine such distinct samples into a single sample is to invite a host of statistical problems into our model.

decolonization—approximately 1959 to 1966—many of the great powers of Europe lost their empires, a large number of new states entered the system, and the pressures of Cold War competition along with the normal tribulations of fledgling states led to decreases in stability in less-developed regions of the world. More specifically, Pickering and Thompson (1998) and Väyrynen (1984) find that imperial dissolution drives conflict on the periphery of international relations as newly-formed states attempt to establish their place in the international community. Maoz (1989) finds that state formations and regime changes brought on by revolutions (as opposed to gradual evolutions) are prone to international disputes. Moreover, Siverson and Starr (1994) find that regime changes that occur in the context of revolution, crisis, or external imposition tend to result in the significant restructuring of a state's alliance portfolio.

Lastly, even though it was not born of war, the collapse of the Soviet Union represents a major change in world politics for some of the same reasons as World War II: the polarity of the international system underwent radical change. With the collapse of the USSR, the international system transitioned from a bipolar system to a unipolar one (Krauthammer 1991, 2002; Mastanduno 1997). While there has been much debate, including debate that preceded the realization of a unipolar system, over whether a unipolar system should be more stable than a bipolar system,[5] it is clear that the end of bipolarity was a transitional moment in international politics. Accordingly, we study the period including and immediately following the collapse of the Soviet Union (1988–1995) as our third period of study.

To further validate our interpretation of the periods of greatest change, we can examine the entry and exit of states from the international system and changes in the system-wide number of alliances. While obviously not perfectly correlated with major shifts in power, high degrees of state entry and exit are indicative of instability in the system and large-scale shifts in power. Figure 2A shows entry and exit from the international system between 1930 and 2000. The vertical lines indicate our chosen time periods. One can easily see that the periods we have selected represent the periods of greatest change in the state system according to this measure.

Figure 2B shows year-to-year change in the number of alliances in the system. Our three chosen time periods correspond to three of the largest change-regions in the time series, each producing changes in excess of one standard deviation. Note also that there is a spike in this plot that is not contained within one of our chosen time periods. This spike is caused, almost exclusively, by the 1975 establishment of the Organization for Security and Co-operation in Europe (OSCE), an organization with 56 members that functions as a nonbinding consultation pact. Because the establishment of the

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[5]See Gilpin (1981) and Organski (1968) for seminal theories suggesting unipolar stability and Waltz (1979) for a seminal theory suggesting unipolar instability.
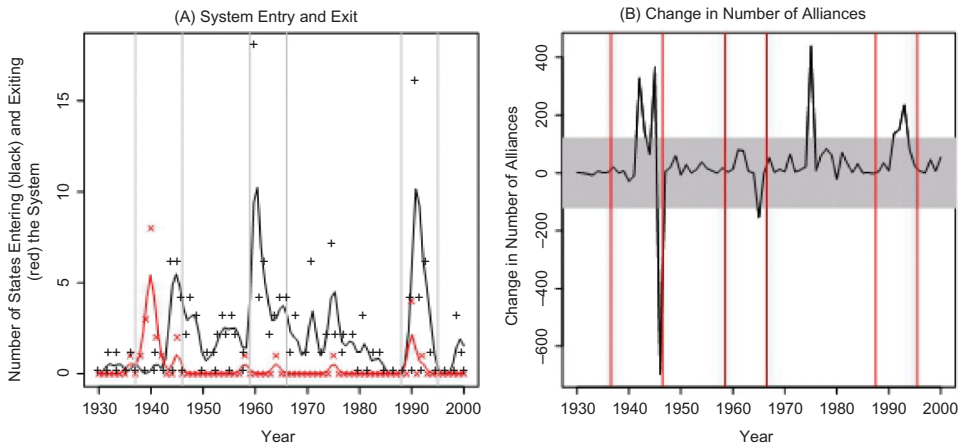
FIGURE 2 Punctuations in the international system. (A) Entry and exit from the international system from 1930 to 2000. State entry is indicated with a black +; state exit is indicated with a red ×. The black and red lines are kernel smoothers for entry and exit respectively, both with bandwidth set to 2. The vertical lines of varying types indicate the start and end of our chosen time periods: 1937–1946, 1959–1966, and 1988–1995. (B) Change in the number of alliances (of all types) from 1930 to 2000. The grey bar indicates the region plus or minus one standard deviation. The red lines of varying types indicate the start and end of our chosen time periods: 1937–1946, 1959–1966, and 1988–1995 (color figure available online).

OSCE represents a single event rather than a change-region in world politics, we have not included a time period dedicated to it.

Restricting our analysis to these three periods of change carries several benefits. First and foremost, these are the periods where the most radical changes in the international system occur and, thus, where we should logically focus our analysis if our aim is to understand *how* the system changes (as opposed to *when* the system changes). A secondary benefit is that we will be able to compare and contrast the sets of factors that seem to be driving the realignment of the alliance system in each of these intervals. While we aim to develop a general theory of alliance formation, we do not want to restrict the magnitudes of the effects to be equal across the punctuations; it may well be the case that, because the events corresponding to these changes in world politics are quite different in nature, the magnitudes of effects may differ substantially across periods. If our theory is supportable by the data, even though the magnitudes of these effects may differ across periods, their signs should be the same across periods.

There is some precedent for such a treatment of alliance formation. Duncan and Siverson (1982) focused on similar periods (less the post-Soviet period obviously) with alliance data restricted to the major powers;[6] they

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[6]Duncan and Siverson (1982) used a data set expanded from Singer and Small's (1967) original alliance data and was restricted to major powers only.

noted that "the bipolar alliance structures have been so stable that, outside of the initial choices made shortly after the end of World War II, there has been very little change" (p. 529). Additionally, Kadera and Sorokin (2004) note the same periods of instability we do—World War II, decolonization, and the end of the Cold War—in their analysis of variation in national power, providing further evidence to suggest that the configuration of international power changes considerably during these periods.

Statistical Model

The statistical evaluation of the alliance network (and indeed all network data) poses a variety of challenges. Classical regression techniques are simply not able to accommodate such data because they must assume that observations are conditionally independent, whereas in the alliance network the relations are, by definition, nonindependent. Erroneously assuming independence can lead to a variety of serious statistical problems, including the false attribution of the explanatory power from network effects to covariates, and compromise the validity of any findings (see Cranmer and Desmarais 2011 for a detailed discussion).

We address the statistical challenges of analyzing the alliance network by using a recently developed statistical model designed for longitudinally observed networks: the temporal exponential random graph model (TERGM; Hanneke, Fu, and Xing 2010). The TERGM models the probability of the observed alliance network(s) out of every possible alternative network (that is, every possible permutation of alliances in a network with the same number of states) given a set of statistics on the network; it treats each network as a single observation and thus drops all assumptions about the independence of dyadic alliances. The set of statistics can measure dependencies endogenous to the network as well as the effects of exogenous covariates at the state or dyadic level. As such, we are able to simultaneously model the endogenous effects associated with H1 and H2 while controlling for well established state and dyadic variables.[7] We apply a bootstrap maximum pseudolikelihood estimation method developed by Desmarais and Cranmer (2012) that has been shown to be unbiased in simulation studies.

Warren (2010) used a slightly different method to analyze the alliance network: the stochastic actor-oriented model of network evolution proposed by Snijders (2001), which is commonly referred to by the name of the software designed to estimate the model — SIENA. While we do not observe substantial differences in results that derive from the different methodology, we view it as useful to justify our use of TERGM rather than SIENA.

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[7]A detailed technical review of the TERGM is beyond the scope of the present discussion. See original work by Hanneke, Fu, and Xing (2010) and reviews by Cranmer and Desmarais (2011) and Desmarais and Cranmer (2012) for technical details.

The structure of the alliance data conforms more closely to the structure for which the TERGM was designed than for that which SIENA was designed. The TERGM is derived to analyze within-period networks constructed by indicating whether two nodes (states) are tied (allied) within a time interval (year) (Hanneke, Fu, and Xing 2010), where it is assumed that all ties are observed.

The assumption about the data structure underlying the SIENA model is that the researcher observes the current state of the network at discrete time points, but does not directly observe the creation and dissolution of ties between observation points. Though a perfect abstract structure for networks such as friendship networks collected through several surveys, the structure assumed in SIENA is inappropriate for most international relations data, including the alliance network. SIENA assumes that many, technically infinite, edges can be created and/or dissolved between observation points without being observed. In application to the alliance network, this would imply that there are a substantial number of defense pacts created and dissolved that are not observed. This is not a realistic assumption.[8]

DATA AND MEASURES

We now turn our attention to the operationalization of the theoretical concepts developed above.

Alliances

Data for our outcome variable of defensive military alliances comes from the Alliance Treaty Obligations and Provisions (ATOP) data collected by Leeds et al. (2002). Using the ATOP data, we create a network of alliances for each year in which the states (called nodes or vertices in the network literature) are connected (linked or share an edge) when they have one or more alliances between them in a given year. The dyadic connection in these networks is defined to be binary: two states either have an alliance connection in that year or they do not.

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[8]We note one additional common misperception about SIENA vis-a-vis ERGM. Snijders (2001) derives a model whereby the network evolves by one actor changing the network by one tie at a time. When an actor has the opportunity to change a tie, a change (including the option of no change) is selected, with some error, to optimize an "objective function." In the literature on political networks, this is often characterized as a "utility function" in the game-theoretic sense. The objective function that is optimized in SIENA is defined on the entire network and is proportional to the loglikelihood in the ERGM. It is misleading to interpret this objective function as an actor-specific utility function in that each actor derives the exact same utility from the creation or dissolution of a particular tie in the network—the change in the network-level objective function. Though Snijders (2001) provides a useful framework for the actor-level decomposition of a dynamic process that results in an ERGM-like network distribution, it is not analogous to the equilibrium of actor-specific stochastic utility maximization.

Ours being a *network* theory of alliance formation, our most important predictors are not covariates exogenous to the alliance network, but rather network statistics that capture the endogenous effects related to the hypotheses.

Triangle Closure

The formation of dense clusters in the alliance network, we theorized, was due to synergy effects brought on by the closure of alliance triangles (H1). Capturing our hypothesized synergy effects is a rather straightforward process. We include in the TERGM function as a predictor a statistic that counts the number of closed triangles in the network. This parameter counts the number of triangles defined by state i having alliances with state j and state k, while j and k are also allied with each other. As described above, a critical element of our theory suggests that triadic closure will have a substantial positive effect on alliance formation.

Two-Stars

In H_2 we laid out our reasons for expecting that the number of alliance connections a state had would be a negative predictor of further alliance formation. As such, we include a statistic called two-stars. Two-stars occur when state i is connected with states j and k, thus forming a simple "star" with two connections radiating from state i. This statistic captures the tendencies of certain states to be "popular," thus having many connections. Because we expect most states not to be popular in the alliance network, we expect a negative effect for this statistic.

Tie Loss

We also include a dynamic term that captures alliance dissolution. This statistic is the sum of the ties existing in the network at time $t - 1$ that no longer exist at time t. The tie loss statistic serves to model the tendency of the network to change. A positive estimate for this parameter would indicate that the alliance network is highly dynamic, whereas a negative estimate would suggest a degree of inertia in the network's evolution.

Edges

Lastly, we include a statistic for the number of alliance connections (edges) in the network. This parameter is the ERGM/TERGM equivalent of an intercept term in a regression.

We also control for several variables that previous work has shown to be important predictors of alliances and alliance formation. These control variables serve to capture the state-level and dyadic utility of alliances.

State Capabilities

Because much of the literature on alliances revolves around the idea of capability aggregation, we control for the composite index of national capabilities (CINC) (Singer, Bremer, and Stuckey 1972). CINC is an index reported for each country-year and is composed of iron and steel production, military expenditures, military personnel, energy consumption, total population, and urban population. Because CINC provides a measure of state-level capabilities in each year, it is an ideally suited measure for the security increasing component of dyadic alliance utility described above.

Expectation of Alliance Activation

We must also operationalize the potential costs of an alliance. To do this, we seek a measure of the probability that an alliance will be activated. We consider the recent history of war to be an indicator of the future likelihood of alliance activation. This is a reasonable measure, in part, because autocorrelation in the conflict network is extremely high.[9] In this spirit, we record the number of wars participated in by each state in the previous ten years as indicated in the Correlates of War interstate conflict dataset (Sarkees, 2000).

Political Compatibility

We also control for whether a dyad of states is politically compatible or not. A direct measure of political compatibility is not established in the literature and it is not obvious how such a measure might be constructed. The admittedly crude measure we use here is the absolute difference in Polity III scores between the two states in a dyad. We call this measure crude insofar as it operationalizes only part of the concept of political compatibility we developed above. Specifically, it does capture the idea that similar governments will be compatible with one another, but it does not account for a number of other factors that might also influence the degree to which states are compatible: economic differences, trade relations, cultural and religious differences, and a history or camaraderie or strife to name a few. We do, however, believe that governmental similarity is central to the concept of political compatibility and so we use it as a measure here in the hopes that it captures enough of the concept of interest to help explain cluster formation.[10]

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[9]Autocorrelation in the conflict network is greater than 0.7 when estimated by dyad-year GEE logistic regression.

[10]For the sake of robustness with respect to our measurement of political compatibility, we ran a model to which we added the measure of interstate policy "Interest Similarity" from Gartzke and Hewitt (2010). This measure is derived from the similarity of voting records in the United Nations General Assembly. Including it changes the coefficients on the other terms in the model very little, and does not in any way

Tie Loss of Democracies

Related to the above measure of political compatibility, we had reason to believe that whether a state is a democracy or not may affect its propensity to dissolve alliances (Gibler and Wolford 2006; Lai and Reiter 2000; Warren 2010). Specifically, we expect democracies to be less likely to dissolve their alliances with other democracies. To control for this possibility, we include the sum of the dyad's Polity III scores, where "polity" is defined as the difference between autocracy and democracy scores, times a statistic to capture tie loss (discussed above). The resulting statistic captures the tendencies of democratic dyads to preserve their ties for longer than autocratic or mixed dyads.[11]

Common Enemy

We also control for the presence of a common enemy. The idea is that the bilateral utility of an alliance is increased when a common enemy exists (Gibler and Wolford 2006; Lai and Reiter 2000; Walt 1987). To capture this idea, we create a dyadic indicator coded 1 if the two states in a given dyad have both engaged in a war with the same third country (any third country) at any point in the previous ten years.

Physical Contiguity

The literature on capability and willingness to join conflicts (Siverson and Starr 1990, 1991) suggests that we should include a control for the physical contiguity of states. Beyond the capability and willingness literature, it makes intuitive sense that states would seek peaceful relations with their neighbors to increase their own security (Gibler and Vasquez 1998). Additional support for this idea is given by the fact that democracies are spatially clustered (Gleditsch and Ward 2006) and, as discussed above, there is reason to suspect that democracies prefer to ally with one another (Lai and Reiter 2000; Siverson and Emmons 1991). As such, we include a dyadic indicator for physical contiguity.

RESULTS

We estimated our model using a TERGM for the three shocks in the distribution of power discussed above: World War II, decolonization, and the

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alter the substantive conclusions derived from the results. The results including the U.N. vote similarity measure are available from the authors upon request.

[11]This statistic is measured as, $\sum \forall_{(i,j)} y_{ij}^{(t)}(POLITY_i^{(t)} + POLITY_j^{(t)})$, where POLITY is defined as the difference between autocracy and democracy scores of a country and $y_{ij}^{(t)}$ is a dummy variable coded one if two countries dissolved a tie and zero otherwise.

collapse of the Soviet Union. The results are displayed in Table 1 with 95% confidence intervals in brackets.

We begin with consideration of the effects of our network parameters: two-stars, tie loss, and triadic closure.

First, note the consistent, statistically significant, and large negative effects of the tie loss statistic across periods. This indicates substantial memory in the alliance network, even during its reaction to punctuations in world politics. The negative effect indicates that, once alliances are formed, they tend not to break, at least during the time periods we examined.

Second, the effect of a state's number of two-stars — its popularity in the alliance network—is a statistically significant negative predictor of alliance formation in the World War II and Post-Soviet periods, in accordance with H2. Its effect is insignificant in the decolonization period. The findings suggest that states with many existing alliances are indeed less attractive as prospective allies, but they do not allow us to distinguish between this effect as caused by a lower expectation of being able to aid an ally, or a higher expectation of getting roped into a conflict. In either case, the results indicate support for H2, except for during decolonization. It is not immediately clear why there is no significant effect during decolonization. One candidate explanation is that decolonization did not involve a restructuring of great power alliances, but did involve many former colonies linking to their already well connected colonial power. Future research would benefit from developing a model specifically designed to examine the dynamics of decolonization. If anything, though, the lack of a significant effect for decolonization validates our choice to analyze the three punctuations separately because the effect appears heterogenous across periods; a heterogeneity that may be buried in a pooled model.

Our primary theoretical claim was that synergy effects from triadic closure should result in substantial clustering in the alliance network (H1). We find robust support for this hypothesis. In all three periods, triadic closure is a positive significant predictor of alliance formation. While the magnitude of triadic closure's effect varies by period, reenforcing the need to allow heterogeneity in effects across time, it seems to be a consistent positive driver of alliance formation as our theory had predicted. TERGM parameters represent the change in the natural logarithm of the probability of observing a particular configuration of a network given a unit increase in the respective network statistic, holding the other statistics in the model constant (Cranmer and Desmarais 2011). We interpret the transitivity of the networks using a more substantively intuitive metric in Figure 3. Using the TERGM estimates in each period, we randomly select 1,000 dyad/years. We then calculate the change in the probability of an alliance in that dyad when the number of triangles that alliance closes is increased by one. The barplots depict the average percentage change in the probability of an alliance due to the unit increase in the number of triangles closed. The results of this interpretation exercise support our proposition that the optimal sub-network outcome in

TABLE 1 TERGM results for the World War II, Decolonization, and Post-Soviet periods with 95% confidence intervals in brackets

	World War II (1937–1946)		Decolonization (1959–1966)		Post-Soviet (1988–1995)	
Edges	**−5.82**	**[−8.29, −5.31]**	**−9.35**	**[−14.33, −7.25]**	**−6.83**	**[−8.11, −6.31]**
Two Stars	**−0.09**	**[−0.13, −0.02]**	0.01	[−0.12, 0.07]	**−0.03**	**[−0.05, −0.00]**
Triangles	**0.77**	**[0.52, 2.54]**	**1.28**	**[1.15, 1.85]**	**0.83**	**[0.72, 1.03]**
Tie Loss	**−4.77**	**[−8.98, −3.76]**	**−8.35**	**[−15.69, −7.23]**	**−11.45**	**[−14.40, −10.59]**
Conflict History	0.85	[−0.11, 1.80]	**−1.41**	**[−2.32, −0.22]**	−0.49	[−1.71, 0.85]
Common Enemy	0.28	[−1.46, 0.94]	−0.24	[−1.48, 0.38]	0.13	[−0.61, 1.01]
Contiguity	**1.76**	**[0.30, 2.24]**	**2.16**	**[1.38, 2.70]**	**1.87**	**[0.75, 2.63]**
Polity Distance	−0.01	[−0.08, 0.01]	−0.03	[−0.09, 0.00]	−0.01	[−0.05, 0.03]
CINC	**4.04**	**[1.32, 10.79]**	**10.86**	**[1.56, 37.37]**	−0.62	[−11.61, 8.05]
Tie Loss of Dems.	0.04	[−0.20, 0.07]	**−0.13**	**[−0.39, −0.08]**	0.06	[−0.12, 0.22]
AUC	0.94		>0.995		0.99	
Dyadic Analysis (Logistic Regression)						
Edges	**−3.11**	**[−5.02, −1.93]**	**−5.26**	**[−7.98, −4.32]**	**−6.35**	**[−7.59, −5.66]**
Allied (t−1)	**3.04**	**[2.15, 6.51]**	**9.89**	**[8.94, 18.93]**	**12.68**	**[12.05, 15.22]**
Conflict History	−0.74	[−1.67, 0.13]	−0.12	[−1.38, 0.76]	−0.32	[−1.39, 0.68]
Common Enemy	**0.95**	**[0.02, 2.20]**	0.79	[−0.71, 1.92]	−0.03	[−0.98, 1.07]
Contiguity	**0.67**	**[0.03, 1.31]**	**1.42**	**[0.60, 2.24]**	**2.15**	**[1.06, 2.89]**
Polity Distance	−0.00	[−0.01, 0.01]	−0.07	[−0.11, 0.05]	−0.03	[−0.15, 0.07]
CINC	**1.15**	**[0.01, 2.60]**	−4.21	[−35.87, 8.86]	0.84	[−6.03, 7.84]
Dem X Allied (t−1)	−0.03	[−0.06, 0.12]	**0.18**	**[0.05, 0.46]**	**−0.08**	**[−0.15, −0.04]**
AUC	0.314		>0.995		0.981	
Analysis with UN Affinity						
Edges			**−8.76**	**[−16.78, −7.41]**	**−8.88**	**[−18.68, −7.24]**
Two Stars			**−0.08**	**[−0.17, −0.00]**	−0.02	[−0.07, 0.26]
Triangles			**1.76**	**[1.45, 2.32]**	**1.30**	**[0.87, 1.59]**
Tie Loss			**−8.86**	**[−20.93, −7.71]**	**−11.61**	**[−21.59, −10.94]**
Conflict History			−1.31	[−3.94, 0.27]	−0.03	[−3.48, 1.81]
Common Enemy			0.08	[−1.31, 1.50]	**0.94**	**[0.08, 2.62]**
Contiguity			**2.48**	**[1.75, 3.35]**	1.23	[−0.01, 4.15]
Polity Distance			0.02	[−0.08, 0.19]	0.03	[−0.15, 0.08]
CINC			**23.94**	**[13.87, 37.59]**	17.11	[−27.16, 24.27]
Dem X Tie Loss			**−0.21**	**[−0.58, −0.09]**	**0.17**	**[0.07, 0.31]**
UN Affinity			−0.02	[−1.16, 4.74]	−0.34	[−1.79, 2.31]

Note. Effects statistically significant at the traditional .05 level (those in which the confidence intervals do not include zero) are bolded. The confidence intervals are based on 1,000 bootstrap iterations using Desmarais and Cranmer's (2012) estimation technique.
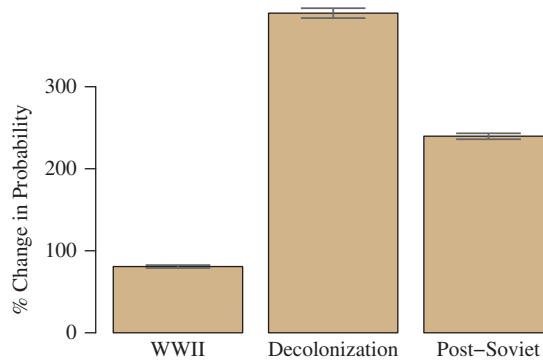
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FIGURE 3 Transitivity of the defense alliance network by period. The barplot gives the average percentage change in the probability of an alliance within the respective period when the number of triangles that alliance closes is increased by one. For example, if closing an additional triangle increases the probability of an alliance from 0.25 to 0.5, then this would be counted as a % Change of 100. Quantities are computed using the TERGM estimates reported in Table 1, and the conditional probability algorithm described in Desmarais and Cranmer (N.d.). We randomly select 1,000 dyads/network-years within each period and depict 95% confidence intervals with gray whiskers in the barplot (color figure available online).

the alliance network is a completely connected sub-network. We see that, on average, the probability of an alliance increases by 80–350% when that alliance closes an additional triangle in the network.

These results are particularly interesting when one considers the variance in the effects of state and dyad-level predictors: it seems that network statistics like tie loss, two-stars, and triadic closure number among the few effects that are reliable and consistent across periods (except two-stars during decolonization). We take this to be both support for our idea of synergy effects as well as a suggestion that empirical analyses of alliances that do not account for network effects are missing key pieces of the puzzle.

Turning now to the control variables, the effect of a nation's capabilities produces somewhat uneven results. For the World War II and decolonization periods, we observe that capabilities have statistically significant coefficients of 7.43 and 23.89 respectively, indicating that higher capabilities make states more likely to form alliances. However, for the post-Soviet period, the effect is still positive, but cannot be described as statistically significant at any traditional threshold. This result suggests that allying with powerful states was not as important during this latter punctuation in the international system as it was during the previous two punctuations. This may be explainable by the fact that the system moved from a bipolar to a unipolar configuration during this period and, while the political changes were great, may not have produced great insecurity for the Eastern bloc nations. At the same time, the Western bloc was reluctant to alter its NATO configuration, which

provides a number of positive externalities to member-nations and persists in a structure today similar to that which it had during the collapse of the Soviet Union.

For the effect of a history of recent conflict, we do not find consistent results across the three punctuations. We find a statistically significant positive effect (1.56) in the World War II period, but not in the decolonization or post-Soviet periods. The positive effect during World War II is explainable by the prevalence of war during that time period, making it near impossible for states seeking allies (especially powerful ones) that did not have a recent history of war. More surprising is the lack of statistically significant effects in the the decolonization and post-Soviet periods. We are left to conclude, counter to what we would have expected given the literature on the subject, that the shift in power and subsequent realignment of nations had little if anything to do with their conflict behavior.

A surprising, but interesting, result relates to our measure of political similarity. We would expect that, when the political differences between two states grow, they become less likely to form an alliance. However, we find (positive) coefficients that are close to zero in magnitude and are never statistically significant at conventional levels for all periods. The uneven effects for having a common enemy and physical contiguity are equally unexpected given the existing literature.

Lastly, we must consider the fit of the models we have specified. To address model fit, we ran a predictive experiment in which we reestimated the three TERGMs excluding the middle years of the periods (1942, 1962, and 1992 respectively) and used these estimates to simulate 500 networks for each of the three periods. We then use the area under the curve (AUC) of the receiver operating characteristic (ROC) to assess fit. The ROC plots the true positive versus false positive rate of binary predictions and its AUC describes the probability that the model will correctly predict a given observation (Pete, Pattipati, and Kleinman 1993); thus, AUC values closer to 1 indicate better fit. We used the middle-network-excluded edge values and the empirical probability of a tie over the 500 simulations to compute the out-of-sample AUC. The out-of-sample AUCs are reported in Table 1. As a baseline for assessing the TERGMs' AUC values, we also include results from a logistic regression predicting alliance formation, estimated on the same data as our TERGMs, but excluding the network parameters. In each period, the TERGM fits better than the dyadic logit, and this difference is dramatic in the World War II period—the formative period for the modern system of international defense alliances. Note that, unlike in-sample measures of model fit, out-of-sample measures, such as that which we use, will decrease if adding additional parameters does not improve model fit (Desmarais 2012). Thus, the fact that the out-of-sample AUC scores of the TERGMs are higher than the AUC scores of the logit models indicates that the logit models are misspecified in omitting the network statistics.

We also examined the fit of the models by comparing several statistics of the simulated networks based on the middle-network-excluded TERGM results with the observed middle network of the relevant period. This allows us to examine the degree to which statistics based on out-of-sample predictions fit the network they were trying to predict. The results of these comparisons are presented in Figure 4, where the boxplots capture the distribution of the statistic and the points capture the observed value from the middle network. We conducted comparisons based on three features of the network. The first is the degree distribution. The degree distribution is the distribution (that is, histogram) of the number of alliances in which each state is involved, over all states in the system. Conceptually, the degree distribution summarizes node-level activity in the network. For each alliance between states i and j, there are anywhere from zero to the number of states in the system (less two) shared partners k, such that i and j are also allied with k. Our second comparison metric is the edgewise shared partner distribution—the distribution of the number of shared partners by edge. The
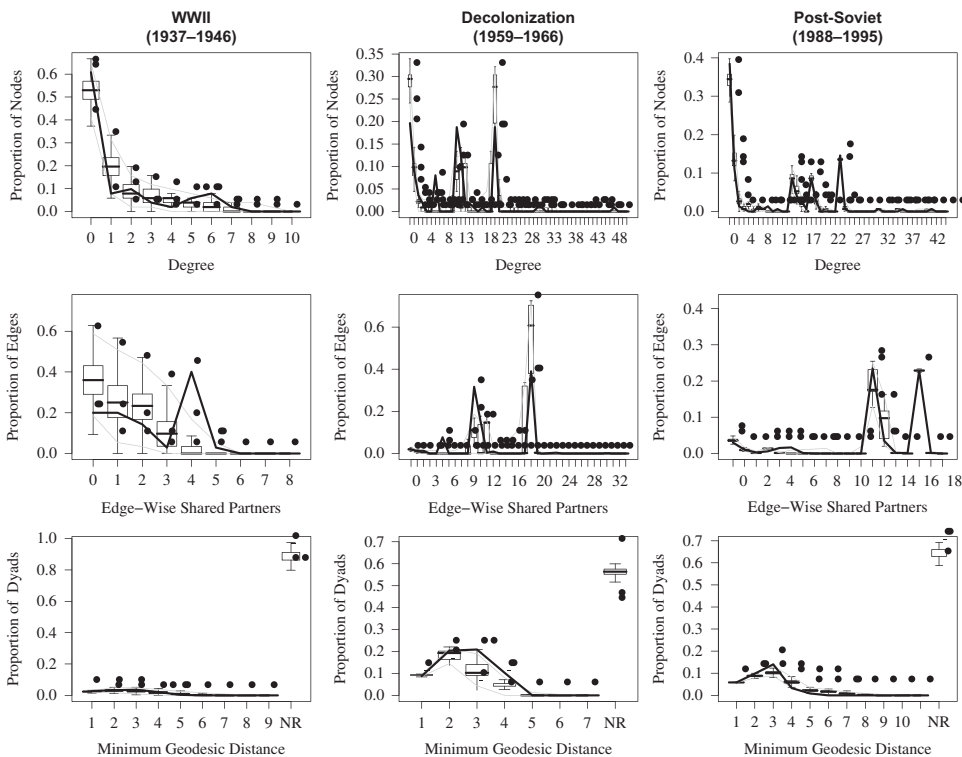

FIGURE 4 Out-of-sample prediction. This figure compares the degree, edgewise shared partners, and geodesic distance distributions of 500 simulated networks based on TERGMs with the middle network omitted, represented by the boxplots, and the observed value of the middle network of each period, represented by the points.

edgewise shared partner distribution measures transitivity of the network. The third comparison metric is the geodesic distance distribution, which is the minimum number of alliances connecting the states in each dyad, by dyad. The geodesic distance distribution measures the general connectivity in the network. Overall, the simulated networks compare well with the empirical networks, indicating that our TERGM models accurately recover these general features of the alliance network.

CONCLUDING THOUGHTS

Our research has shed light on several systemic aspects of alliance formation. First, we have shown that conceptualizing interstate alliances as a complex network provides the theoretical framework for formulating precise and falsifiable theory regarding the dependencies in the system. Positing that alliances indicate at least the general political orientation of states toward one another at any given point in time, we found that the system of alliances goes through periods of major change and periods of relative stability. Analyzing the factors that contribute to alliance formation in the three periods of major change, we found that network effects—inertia (tie loss), two-stars, and triangle closure specifically—are the only consistent predictors of the tendencies of states to form alliances with one another.

To round out our network theory of alliance formation, we considered a variety of ways in which the characteristics of states or dyads of states could drive alliance formation. The empirical analysis revealed, somewhat surprisingly, wide variation in the roles of things like national capabilities, a history of war, the presence of a common enemy, differences in polity, and physical contiguity. While our network theory worked in harmony with these control variables, it did not rely on them. Our results with respect to the controls seem to suggest that historical context plays a major role in the alliance formation process and varies nontrivially over time. This, in turn, suggests that perhaps future work should be cautions not to pool over long periods of time.

Our most important findings relate to network effects. We found that two-stars and triadic closure were significant negative and positive predictors respectively and both had consistent effects across nearly all time periods considered. These results strongly support our network-based theory and suggest that analyses that do not consider the effects of network structure generally and these network structures specifically would seem to be missing some rather large pieces of the puzzle. It is both interesting and indicative of the power of our findings that covariates studied so carefully in the existing literature play such unreliable roles when simple network parameters do so much to explain alliance formation.

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