

Towards a Network Theory of Alliance Formation*

Skyler J. Cranmer Bruce A. Desmarais Justin H. Kirkland

Abstract

We propose the first network-based theory of alliance formation. Our theory suggests that, in addition to key state and dyad attributes already established by 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 node-level utility is greater than the sum of its dyadic parts. This idea can be generalized to n -node closure, and, when considered along with factors which make dyadic alliance formation more attractive such as military prowess and political compatibility, suggests that the network will evolve towards 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 SIENA model for longitudinal network analysis 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 more central role in the formation of alliance ties than has been previously understood in the literature.

*Sincere thanks to James Fowler, Justin Gross, Mark Pickup, Randolph Siverson, and Tom Snijders for their helpful comments on previous drafts of this paper.

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 which can best be described as punctuated equilibrium: periods of stasis followed by rapid and major 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 equilibrium state evolves. Our theory is network-based in so far 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.

We proceed by first arguing that the basic orientation of states to one another can be observed in the system of military alliances. We take military alliances – offensive and defensive pacts as well as consultation agreements – to indicate, at minimum, a signal of peaceful intentions between countries, a desire to coordinate foreign policies to some extent, and potentially the expectation of military support in the event it is needed. Second, we demonstrate that changes in the structure of alliances seem to operate by punctuated equilibrium. To do so, we identify periods of stasis and major transformation in the system of alliances by examining the year-to-year change in its structure; the periods we identify in this manner are in keeping with traditional interpretations of major changes in world politics. Third, we discuss the dyadic utility of alliances with particular attention to the role of military power and political compatibility between potential allies.

Fourth, we explicate foundational element of our theory: the idea 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. Next, 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.

We then empirically evaluate our theory. Because the theory involves the evolution of networks, we require a statistical method which can analyze dynamic change in networks. We find an ideal approach in a class of models developed by Snijders (2001, 2005) which is commonly called SIENA. We use SIENA 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.

In contrast to most of the alliance literature, the very structure of the alliance network, as opposed to state and dyad level covariates, seems to be the most critical predictor of alliance formation. Specifically, we find that our hypothesized network effects are significant predictors of alliance formation across all periods under study whereas the effects of the monadic and dyadic covariates varies substantially from period to period. We take the lack of a stable predictive relationship for the state and dyadic covariates (except for geographic contiguity) to indicate that historical nuance plays a greater role than the established literature suggests.

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 camaraderie which restructure themselves in response to shifts in power, but do so in an imperfect way.

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 (1999) argue that alliances are valid measures of a nation’s perceived probability of war with its allied partners. So, from both empirical and theoretic perspectives, alliances should indicate peaceful intentions and expectations. Beyond that, Fearon (1997) suggests that entering into alliances is a useful signal of the foreign policy interests of the state 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 clearly 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 suggest that changes in power and alliances go hand in hand; the role of alliances has long been discussed in the literature. While there have been many approaches to the study of alliances, one which has been particularly concerned with the role of power is realist theory. This extensive body of work traces its roots back at least to Machiavelli (1532) who offers advice on how states can ally to vanquish common enemies or support mutual interests. The idea that states – particularly major powers – band together to balance more powerful states and maintain an approximately even distribution of power in the international system is central to much realist thinking (Morgenthau 1956; Waltz 1954, 1979; Walt 1985). 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, p. 222). The argument goes 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 balance 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 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 which 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 (i.e. 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.

Punctuations in the Structure of World Politics

Now that we have justified our decision to focus on periods of major change, we need to identify the punctuations which will be the focus of our study. We believe that a careful reading of post-WWI history suggests three transitional periods for the international system:¹ World War II, decolonization, and the collapse of the Soviet Union. Despite the fact that these periods may seem rather obvious, they are central enough to our study that we take a moment to justify our choices.

The second World War is probably the most obvious sea change in the international system. Not only was it the bloodiest war in mankind'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 pre-war system to a bipolar post-war 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 which suggested that the new bipolar system was substantially more stable than the multipolar system which 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 maybe not quite as obvious a transition as World War II, saw a major transformation of international politics none-the-less. During the period of 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 lead to decreases in stability in less-developed regions of the world. More specifically, Pickering and Thompson (1998) and Värynen (1984) find

¹We are forced to restrict our analysis to the period after World War I because of data limitations.

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 which occur in the context of revolution, crisis or external imposition tend to result in the significant restructuring of a state's alliance portfolio. The change in the alliance network during decolonization is particularly striking. Figure 1 shows the alliance network as it existed in 1959, 1960, and 1961. The most dramatic change in the network, as one might expect, is in Africa. We thus select the years between 1959 and 1966 as our second period of study.

[Figure 1 about here.]

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 (Mastanduno 1997; Krauthammer 1991, 2002). While there has been much debate, including debate which preceded the realization of a unipolar system, over whether a unipolar system should be more stable than a bipolar system (see Gilpin (1981) and Organski (1968) for seminal theories suggesting unipolar stability and Waltz (1979) for a seminal theory suggesting unipolar instability), it is clear that the end of bipolarity represented 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. 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

2 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. We take this as further support for the validity of our chosen periods of study.

[Figure 2 about here.]

We restrict our analysis to these three periods of change – WWII, decolonization, and post-Soviet – for several reasons. 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 of conducting separate analyses of the major change intervals is that we will be able to compare and contrast the sets of factors that seem to be driving the realignment of world politics 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 major changes in world politics are quite different in nature, the magnitudes of effects may differ 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;² they 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,

²Duncan and Siverson (1982) used a data set expanded from Singer and Small (1967) original data and was restricted to major powers only.

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.

The Alliance System as a Network

We argue that alliances need 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. So, if alliances reflect the distribution and orientation of power in the international community (as we hope we have argued persuasively above) and states are fully aware of each other's alliances, then a more complex structure naturally emerges from the set of alliances. The set of dyadic alliance relations can be viewed as a complex network of interlocking treaties. States can be indirectly connected to one another through multiple degrees, they can sort themselves into clusters, and can strategically alter their positions in the network to their advantage.

[Figure 3 about here.]

Figure 3, which shows the alliance network in 1946, 1965, and 1993, illustrates several points. One is struck by the complexity of the web of alliances. The efficient placement of nodes in two dimensional space shows the network is a set of dense clusters which are sparsely connected to each other. This suggests that thinking about alliance relations as a set of conditionally independent and identically distributed dyads (an assumption techniques such as logistic regression require) would not be appropriate to study change in this system unless a set of state and dyad level covariates could *completely* explain the obviously non-random clustering pattern. We argue however that the configurations of the network seen in Figure 3 do not emerge randomly and cannot be fully explained by covariates; interdependency can have its advantages and

perils, and states are likely to position themselves to receive maximal benefit. The result is a configuration of the network which reflects benefit-seeking behavior. As such, the system can be thought of as a network and structural parameters that help to explain its configuration may capture integral parts of the alliance formation process.

We are hardly the first to note that alliances are naturally viewed as complex networks. Prevailing wisdom among heads of state and diplomats prior to World War I was that dense entanglement in alliances provided incentives to diffuse serious conflicts and maintain the status quo (Levy 1981). While the qualitative literature on alliance networks is vast (far too vast to begin citing here) and a number of empirical researchers have noted the network attributes of alliances (Duncan and Siverson 1982; Kim 1991; Li and Thompson 1978), we are unaware of any previous treatments of alliance formation as a network phenomenon.³

The paucity of large n network-based empirical models is almost surely due to the fact that appropriate technology for conducting such analyses has not been available until very recently. The statistical evaluation of network data poses a variety of non-trivial challenges and classical techniques are simply not able to accommodate such data because they must assume that observations are conditionally independent; whereas in networks, the relations are, by definition, non-independent. Erroneously assuming independence can lead to a variety of serious statistical problems and compromise the validity of any findings (see Cranmer and Desmarais (2009) for a detailed discussion). As we discuss below, we solve this problem by taking advantage of recent statistical work on networks by Snijders (2001, 2005) and applying his model to the study of the alliance network.

The pivotal theoretical expansion made possible by considering alliance networks 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

³During the review process for this article, we have found a working paper by Warren (2009) which uses the SIENA network method to analyze alliance formation but does not incorporate any network effects.

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 nodes in the network. Accordingly, we argue that 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.

State and Dyadic Determinants of Alliances

As we move towards the development of a network theory of alliance formation, we begin naturally by considering the state and dyad level factors which are likely to drive the creation of alliances. The consideration of state and dyad level determinants is not antithetical or even in competition with the idea of a network-based theory; rather, they operate in tandem with the network characteristics we develop in the next section.

By our reading of the literature, most determinants of alliance formation relate to one of two major theoretical objectives: security and political fellowship. Because these objectives are quite different, and extensive work has been done on each, we treat each separately.

Capability Aggregation and Increases in Security

We begin by considering the utility states derive (or lose) by either seeking out or extending military support through alliances. While alliances surely indicate a positive tie between two nations, their implications run much deeper. The existence of a military alliance between two states indicates perceptions of reliability, effective capability aggregation, expectations of strategic gains, and, usually, expectations of low costs.

The basic premise of a military alliance is a promise of aid, or at least consultation, between countries i and j in the event that either country comes into conflict (activation criteria will vary depending on the terms of the specific agreement). A core concern here, is the question of whether the promises of one's alliance partners are reliable.

It makes little sense for states to enter into alliances, or any sort of international commitment, if they do not expect fruitful cooperation; indeed, a respectable body of empirical evidence indicates that states consider this and take their assessments into account when forming such agreements (Downs, Rocke, and Barsoom 1996; Leeds 1999; Crescenzi et al. 2009). The most obvious form of reliability states ought to be concerned with is whether, when called upon, alliance partners actually come to the aid of their allies. Leeds, Long, and Mitchell (2000) suggest that most promises, though they vary depending on the specific stipulations of the alliance, are honored. More specifically, democracies seem to be more reliable partners than autocracies (Leeds 1999) and failures to honor alliances are generally produced by major changes in the structures of governments (making them less likely to honor past agreements) or when the costs of renegeing are especially low (Leeds 2003). In fact, there is evidence to suggest that states consider the reputations for reliability of prospective allies in the alliance formation process (Crescenzi et al. 2009; Miller 2003; Gibler 2008) and rivals consider the reliability of a state's allies before initiating hostile action (Gartner and Siverson 1996; Smith 1996).

Assuming that the alliances formed by states are in fact reliable, states realize a number of benefits from having alliances. Alliances have long been considered to be a method of capability aggregation across states (Morgenthau 1956; Liberman 1996); though some have questioned the extent to which alliances add to the military might of member nations (Brooks 1997). The logic behind viewing alliances as capability aggregation devices is that, by sharing defensive resources across several states, each of the signatories is able to bolster their state's level of security while spending a smaller portion of the state's resources on said security (thus freeing up state resources for other purposes) (Altfeld 1984; Conybeare 1994*a,b*; Lake 1999; Morrow 1993). In other words, the chief gain a country can realize from an alliance is an increase in security; the most useful and successful alliances will allow nations to mount more effective defenses (Waltz 1979; Walt 1987).

The effects of increases in power and security realized from successful alliances have a number of important implications. First, 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). Not only is the alliance portfolio of a nation a signal of its power, but in the eyes of an adversary, the alliance is also a signal of support (diplomatic and potentially military) from all its allies (Sorokin 1994). Thus, whether as signals of support or actual increases in power, alliances can be used, and are often formed, to balance rival powers (Liska 1962; Morgenthau 1956; Walt 1987; Powell 1999). In other words, alliances can have benefits ranging from a simple showing of intentions, to increases in security, to strategic balancing.

However, the benefits realized by states from alliances do not come without costs. Some costs are realized regardless of whether the alliance is ever activated, but the most substantial costs are prospective costs.

Alliances or treaties of any kind carry costs for their signers because they necessarily restrict their foreign policy options (and sometimes even restrict their domestic policy options) (Altfeld 1984; Morrow 1989, 1991, 2000). Morrow (1991) argues that these restrictions represent a loss of autonomy on the part of the member nations because they allow extra-state forces/considerations to limit their set of available actions. The effects of this loss of autonomy can range from diplomatic inconveniences to having to endure the costs of wars the state did not wish to join. When the gains from alliances (as discussed above) are greater than the costs in terms of limited autonomy, participation in alliances is still clearly in the interest of the nation.

Morrow (2000) notes that alliances operate in the shadow of war. That is, the costs of alliances to member states are generally relatively small unless the alliance is activated. At the point of activation, members of an alliance must either come to the aid of their allies and incur potentially high costs in terms of blood and treasure or they must renege on their commitment and incur reputational costs, the loss of any

positive externalities afforded them by their alliance, and potentially military reprisals for their betrayal. As already discussed, damage to the reputation of a state can make it a less attractive candidate for alliances with other countries (Crescenzi et al. 2009) and can make it more likely that it will be attacked (Gartner and Siverson 1996). This suggests that the reputational costs incurred from reneging on an alliance are non-trivial and the interdependent structure of alliances imposes even stiffer penalties on alliance shirkers.

The greatest potential consequence 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 (Siverson and King 1980; Siverson and Tennefoss 1984; Oren 1990). 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 support 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 willing to join when opportunity and willingness are both high. Taken together, these findings suggest that states are at the greatest risk of joining wars when their capability and reputational costs of reneging are both high. This indicates that alliances are more than cheap talk, states bear real costs from participating in alliances.

This discussion allows for the derivation of two constituent hypotheses. We consider these constituent hypotheses because they do not reflect our network theory directly, but rather prevailing wisdoms in the literature which should be easily replicable. The general claim here is that the expected utility of a given state should be higher when the expected benefits are high and the expected costs are low. Thus, *(H₁) alliance formation will be more likely when the ability of an alliance partner to provide military aid is high.* Because alliances will be less appealing to states when they have a high

probability of being activated (thus forcing the ally to either incur the cost of joining the conflict or reneging on the alliance), we expect alliance formation to be less likely if it seems the alliance is likely to be activated. As such, *(H₂) alliance formation will be less likely when the expectation of activation is high.*

Politically Compatibility

Aggregating military capabilities to increase security, as described above, is not the sole driving force behind alliance formation. When considering which states to ally with, a degree of political compatibility can often be an attractive property of a potential alliance. The simple idea here is that states are unlikely to ally with likely political opponents. As such, political similarity – while not strictly necessary – may often be a helpful condition for alliance formation for a number of reasons.

First, 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 over long periods of time, cooperation through alliances can lead to “shared institutional structures over time that will provide incentives and/or mechanisms to avoid conflict” (p. 74).

Second, some basic level of political compatibility between potential allies may be necessary for the leaders of the respective states to keep the support of their constituents. Bueno de Mesquita et al. (2003) argue that states, regardless of their government type, have some set of people whose support is necessary to keep the leader in power; they call this the “winning coalition.” Winning coalitions will be large in democracies and small in autocracies, but the basic idea is that the leader cannot retain his office if the winning coalition removes their support. We argue that political compatibility is often necessary to get the winning coalition to support a prospective alliance. For example consider a prospective alliance between the US and Iran. Suf-

ficient political tensions exist that it is likely neither winning coalition, 50% of US voters and the Supreme Council respectively, would approve of such an alliance and both executives would risk losing office if they pursued it. Conversely, if we consider a prospective alliance between the US and Canada, it is unlikely that a majority of voters in either state would object and thus the alliance would be viable.

Third, states might prefer to ally with other states close to themselves in ideological/normative/cultural space. This is akin to the idea of what network researchers often call homophilous selection: the preference for partnering with others like oneself. This effect, may be particularly pronounced in democracies because democracies, often, have strong norms of individual liberty and equality which may manifest in the idea of close ties to a non-democracy being repugnant to the winning coalition.

Political compatibility may have additional benefits as well. While these may be largely coincidental, the fact that politically compatible states often have similar foreign policy objectives may make alliances between such states attractive. Similar positive externalities may also be realized in terms of trade. What is more, political norms, such as democracy, tend to be spatially clustered. 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.

A likely mitigating factor for political compatibility is the presence of a common foe. An imminent mutual threat may cause states to put aside their political differences to balance, or even combat, the common enemy; such was clearly the case with the alliances between the USSR and many western democracies during the Second World War. However, such an argument is not antithetical to the idea of political compatibility: the presence of a common threat lowers the threshold for basic political compatibility if only temporarily. In the shadow of a common threat, otherwise politically incompatible states may find themselves politically compatible for the purposes of countering that threat.

Beyond reinforcing support for the roles of a common enemy and geographic contiguity in alliance formation, this discussion suggests a further constituent hypothesis: *(H₃) political compatibility between two states should make alliance formation more likely.* As discussed above, the primary challenge involved in testing this hypothesis is that the threshold for political compatibility may vary quite a bit across dyads and even within a single dyad over time.

A Network Theory of Alliance Formation

We now lay out our network theory of alliance formation. To be clear on what is meant when we say 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 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, for the first time, on a network concept. 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 the states alone. 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 not only a higher probability that either state will come to the aid of the besieged state, but also that the besieged state will receive more military aid than it would from two separate but unconnected alliances and the besieged states is likely to receive some benefit from the allies coordinating. While our formulation in terms of triangle closure is novel, there is some suggestion already in the literature that this is an important attribute of a potential alliance: Siverson and King (1980) find 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 which 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.

This point can be illustrated with a simple expected utility setup. Consider some of the possible configurations of relations between four states as displayed in Figure 4. If we consider each dyadic alliance (represented by lines in Figure 4) 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.⁴ This implies that, when a state has two allies which are not

⁴By “order of utility” here we refer simply to ordinal values. However, cardinal values could be substituted and, as long as the utility of being in a triangle is at least ϵ higher than the utility of having two dyadic alliances, the equilibrium will hold.

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. This leads to the first of our network hypotheses: (H_4) *the potential for triadic closure will make alliances more appealing to the prospective allies.*

[Figure 4 about here.]

With dyadic utility and a synergy effect conceptualized in this way, states have an incentive to continue forming alliances with a preference to form alliances which close triangles until the system is completely connected (every state is allied to every other state). In a completely connected system (illustrated in the lower right-hand corner of Figure 4), no state can become unilaterally better off by breaking an alliance and no further alliances can be formed, so such a system is an equilibrium. Because the synergy effect lowers the utility of all states in a triangle where one of the edges is dissolved, a completely connected system is also Pareto optimal. Though we have illustrated this concept here with a trivial example of four states and no constraints on the dyadic utility of alliances, the model can be further complicated without changing the result.

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 and capability aggregation, 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 move towards complete connectivity. This is a concept we will apply directly to our network theory of alliance formation.

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 to the new distribution of world power. In a thought experiment starting from this initial condition and the assumptions that synergy effects exist, states prefer to ally with strong states that are unlikely to rope them into a conflict, and states desire some basic level of political compatibility with potential alliance partners, we can deduce a network-based theory of alliance formation.

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 place more value on. For example, if a state feels particularly insecure, it is likely to be more driven by security maximization 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. In the network literature, this is called having high *degree*, 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. We expect each of our constituent hypotheses to apply in this stage and also, because we expect only a few fit states to have high degrees, most states will have low degrees. Because 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 (H_5) *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 an additional edge 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 non-linearly as the density of the cluster increases. These nonlinear gains from synergy drive the cluster towards a state of complete connectivity where, within a community of states, every state is allied to every other state. This completely connected condition is a Nash equilibrium (within the community) and is also Pareto optimal as shown above. 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 H_4 (triadic closure).

Because, in a completely connected segment of the network (a cluster evolved out of a star), every state has the same number of alliances as every other state, degree no longer matters as it did in the star formation phase immediately following the power-transition. But that is not to say that the powerful state no longer matters because all states have the same degree; 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.

This suggests that 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've gotten to it from a different perspective, this idea is in keeping with most of the international relations 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 US 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 US 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 World War II.

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.

A Statistical Model for Network Evolution

Snijders (2001, 2005) has developed a general empirical framework for studying longitudinal networks which is commonly referred to by the name of its software imple-

mentation: SIENA.⁵ Unlike the great majority of statistical methods, this method was developed with social science theory in mind and is easily applied to a wide variety of political networks (Berardo and Scholz 2005; Scholz, Berardo, and Kile 2008; Manger, Pickup, and Snijders 2008) including, in our case, alliance formation. While it is not our intention to review Snijders’ model,⁶ it does warrant some discussion because it represents a significant departure from the traditional regression framework and its basic assumptions are theoretically relevant to the case of alliance networks.

Our data are such that we observe the alliance network on an annual basis, but states will form or dissolve alliances in between observations of the network (i.e. alliances are formed at time $t : t_{\text{year}} < t < t_{\text{year}+1}$). When states choose to alter their alliance relations (either by forming new alliances or dissolving existing alliances), they do so satisfying a simple utility-maximizing decision theoretic rule: they restructure their alliances so as produce the highest expected utility for themselves based on their attributes and their preferences over the network.

SIENA has a number of specific formulations of Snijders’ general model suited to several different types of data. In the following section, we implement a SIENA model for undirected networks which is called the *Unilateral Initiative and Reciprocal Confirmation* (UIRC) model. In the interval between two time periods, t and $t - 1$, state i is randomly⁷ given the opportunity to reconsider the status of its edges (denoted \mathbf{x}_i). State i will then stochastically select another state j with whom it will attempt to change its edge x_{ij} . If an edge x_{ij} currently exists, it will be dissolved. If x_{ij} does not exist, state i will attempt to create the edge, but the creation of edge x_{ij} must be

⁵The stand-alone version of SIENA as well as its implementation in the R language (which we use in this research) are freely available at <http://www.stats.ox.ac.uk/~snijders/siena/> and <http://www.r-project.org/> respectively.

⁶Interested readers should consult Snijders (2001, 2005); Snijders, van de Bunt, and Steglich (2009); Ripley and Snijders (2009) or his contribution to this issue.

⁷State i receives this opportunity with a frequency given by a Poisson process with rate λ . Technically, λ can be subscripted by i , rendering it dependent on covariates and network effects, but we don’t utilize this functionality and thus λ is treated as a constant in the current discussion. However, we do estimate a different rate for each change period ($t \rightarrow t + 1$)

confirmed by state j . The preferences that states i and j hold for the possible changes in the network (X) are derived from their expected utility for the networks that will be created via the changes. The formula for the value, or utility function, over any network is a linear combination of k scalar-valued functions ($g_j(X)$, $j \in 1, 2..k$) defined on the network. The utility function is given as

$$f_{\beta}(X) = \sum_{j=1}^k \beta_j g_j(X), \quad (1)$$

where the coefficients, β , of the linear combination are the effect parameters to be estimated.

The function $g_j(X)$ is quite flexible. It can be a network statistic such as the number of closed triangles in the alliance network, or it can capture a covariate effect such as the sum of the levels of democracy in the states that comprise the edges in X . It can even be an interaction term between covariates and network statistics. Randomness is added to the model by assuming states make a stochastic decision rather than deterministically choosing the highest utility option. In the UIRC model there are two important probability functions related to the utility function (also called the objective function): that which generates the choice of the initiator (i) and another that generates j 's confirmation decision. Given that i has the opportunity to change one tie, the probability that tie x_{ij} is selected is given as

$$p_{j|i}(\beta, X) = \frac{\exp(f_{\beta}(X^{-ij}))}{\sum_{\forall h \neq i} \exp(f_{\beta}(X^{-ih}))}, \quad (2)$$

where X^{-ij} is the network X with the ij^{th} node toggled. If the requested change is the addition of an edge to X , the probability that j confirms the change is given as

$$p_{j \text{ confirm}}(\beta, X) = \frac{\exp(f_{\beta}(X^{-ij}))}{\exp(f_{\beta}(X^{-ij})) \exp(f_{\beta}(X))}. \quad (3)$$

There are common two common ways that effects enter the $f(\cdot)$ function. First,

consider the case of state-level covariates (i.e. Polity score, CINC, etc. . .). In order to include the covariate effects in the objective function, the variable must be “scaled up” to the dyad level. Specifically, let $Z^{(s)}$ be a state-level covariate, such that if there are n states in the international system there can be at most n unique values of $Z^{(s)}$. The standard formula ($g(\cdot)$) through which a state-level covariate enters $f(\cdot)$ is given as

$$g_{Z^{(s)}}(X) = \sum_{\forall(i \neq j)} x_{ij}(Z_i^{(s)} + Z_j^{(s)}), \quad (4)$$

where $Z_i^{(s)}$ is the value of the covariate for state i and $Z_j^{(s)}$ is state j ’s covariate value.

Alternatively, if $Z^{(d)}$ were a dyad-level covariate such as a contiguity indicator, the covariate would enter the objective function in a slightly different way. If $Z^{(d)}$ is a dyad-level covariate such that if there are n states in the international system there can be at most $\binom{n}{2}$ unique values of $Z^{(d)}$, it enters $f(\cdot)$ as follows:

$$g_{Z^{(d)}}(X) = \sum_{\forall(i \neq j)} x_{ij}Z_{ij}^{(d)}, \quad (5)$$

where $Z_{ij}^{(d)}$ are the values of the dyadic variable.

The simplest case is when the effect of interest is a global network statistic, such as degree or triadic closure; in that case $g(\cdot)$ is a scalar-valued function of the adjacency matrix.

Independent variables in SIENA models consist of interactions between covariates and network effects (such as indegree, outdegree, transitivity, etc.). State-level covariates are entered as matrices in which each row represents an actor and each column represents a new time point. Dyad specific covariates (such as common enemy and physical contiguity) are entered similarly to the dependent variable. Each time point represents a new sociomatrix⁸ in an array and each dyad specific measure is entered into the relevant sociomatrix at the appropriate ij location in the matrix.

⁸A sociomatrix is a $n \times n$ matrix where each cell can be coded 0 or 1 indicating a link or not.

Data and Measures

Before beginning our empirical analysis, we consider the operationalization of the theoretical concepts we developed above.

Dependent Variable: Alliances. Data for our outcome variable of military alliances – which we define as offensive, defensive and consultation agreements – comes from the Alliance Treaty Obligations and Provisions (ATOP) data collected by Leeds et al. (2002). Because of the collection design of the ATOP data, some minor recoding was necessary. The original data only account for dyads in which an observation of some sort of alliance exists; while this is not problematic for many studies of alliances, in network analyses, these dyads indicate existing edges and do not capture potential edges. In other words, using only realized edges in our analysis would mean selection on the dependent variable to the point that the dependent variable does not vary at all. For our analysis, we require the *complete* alliance network, by which we mean data for every dyad in every year coding whether or not an alliance exists.

In order to construct the complete alliance network we produced a blank array of sociomatrices for the complete state system from the Correlates of War Project (2005b) state system dataset. Each sociomatrix in the array represents a new (annual) period of observation. This yields a 216 X 216 matrix for each year we wish to study and a matrix for each year from 1940 to 2004. We are able to model state entry or exit from the system through the use of structural zeros, thus if one of the 216 potential actors has yet to enter the state system in a particular year, their entire row and column of the sociomatrix is coded 10 (structural zero code). For any alliance from one country to another in a given year, we code the relevant sociomatrix in our array 1 for observations of an alliance and 0 otherwise. This provides a complete array of undirected relational matrices indicating the existence of any alliance between two countries. This array is the dependent variable in our model.

We require independent variables for the hypotheses derived above. To begin, our constituent hypotheses can be seen as reflective of the dyadic utility of alliances. As such we require measures which allow us to test whether alliances will be more attractive when military capabilities are high (H_1) and the expectation of alliance activation is low (H_2).

State Capabilities. To test the hypothesis that states with greater military capabilities will be more likely to form alliances (H_1) – they will be attractive to potential partners because of their greater ability to come to the aid of their allies and will seek alliances in order to project their power – we require a single measure of such capability. For such a measure we turn to the composite index of national capabilities (CINC) from the Correlates of War Project (2005c). 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. As discussed more generally above in Equation 4, CINC must be “scaled up” to a dyadic measure and enters the objective function as:

$$g_{CINC}(X^{(t)}) = \sum_{\forall(i,j)} x_{ij}^{(t)}(CINC_i^{(t)} + CINC_j^{(t)}). \quad (6)$$

Expectation of Alliance Activation. We must also operationalize the potential costs of an alliance (H_2). 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 a reliable 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 given state in the previous ten years. The data

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

for this variable come from the Correlates of War Project (2005a) inter-state conflict dataset and enter the objective function as

$$g_{CONFLICT}(X^{(t)}) = \sum_{\forall i} \left(\sum_{k=t-9}^t \sum_{\forall j} WAR_{ij}^{(k)} \right) \left(\sum_{\forall j} x_{ij}^{(t)} \right), \quad (7)$$

where t indicates time and WAR is a binary sociomatrix where values of 1 indicate a war between the column and row states in the preceding ten years.

Political Compatibility. We also require a measure for whether a dyad of states is politically compatible or not (H_3). 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 will use here is the absolute difference in Polity III scores between the two states in a dyad and it is included in the model as

$$g_{POLITY.DIFF}(X^{(t)}) = \sum_{\forall (i,j)} x_{ij}^{(t)} |POLITY_i^{(t)} - POLITY_j^{(t)}|. \quad (8)$$

We call this measure crude in so far 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 which might also influence the degree to which states are compatible: economic differences, trade relations, cultural and religious differences, and a history of 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 explain cluster formation.

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. 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 and include it in the model with

$$g_{COMMON\ ENEMY}(X^{(t)}) = \sum_{\forall(i,j)} I \left[\left(\sum_{k=t-9}^t \sum_{\forall h \notin (i,j)} WAR_{ih}^{(t)} WAR_{jh}^{(t)} \right) > 0 \right] x_{ij}^{(t)}. \quad (9)$$

Democracy. 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. Specifically, we expect democracies to be less likely to dissolve their alliances with other democracies. To control for this possibility, we include the state's Polity III score for the lost-ties network¹⁰ as

$$g_{POLITY.LOSS}(Y^{(t)}) = \sum_{\forall(i,j)} y_{ij}^{(t)} (POLITY_i^{(t)} + POLITY_j^{(t)}), \quad (10)$$

where POLITY is defined as the difference between autocracy and democracy.

Also, 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. Additional support for this idea is given by the fact that democracies are spatially clustered and, as discussed above, there is reason to suspect that democracies prefer to ally with one another. As such, we include dyadic indicator for physical contiguity:

$$g_{CONTIGUITY}(X^{(t)}) = \sum_{\forall(i,j)} CONTIGUITY_{ij}^{(t)} x_{ij}^{(t)}. \quad (11)$$

Ours being a *network* theory of alliance formation, our most important predictors are neither state-level nor dyadic covariates, but instead are network parameters.

¹⁰The lost-ties network is a change network much the same as we have been dealing with, except that instead of forming alliances, alliances are being dissolved. Functions of the lost-ties network can be added into the adjacency matrix. The lost ties network is represented by an adjacency matrix ($X_{\Delta t}^-$) where an edge between nodes i and j is drawn if $x_{ij} = 1$ in X and $x_{ij} = 0$ in some proposed network. This functionality permits the analyst to focus certain effects only on the dissolution, and not creation of ties. The $g(\cdot)$'s defined on $X_{\Delta t}^-$ are the same as those defined on X .

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 (H_4). Capturing our hypothesized synergy effects is actually a rather straightforward process. We include in the objective function as a predictor, the number of triangles in the network. Specifically, 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. This network parameter is included in the objective function as

$$g_{TRIAD\ CLOSURE}(X^{(t)}) = \sum_{\forall(i,j,k)} x_{ij}^{(t)} x_{jk}^{(t)} x_{ik}^{(t)}. \quad (12)$$

As described above, a critical element of our theory suggests that triadic closure will have a substantial positive effect on alliance formation.

Alter Degree. Lastly, in H_5 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 the degree (number of alliance ties) of the other state. Formally, this is called alter-degree and is included in the objective function as

$$g_{ALTER\ DEGREE}(X^{(t)}) = \sum_{\forall i} \left[\sum_{\forall j \neq i} x_{ij}^{(t)} \right]^2. \quad (13)$$

We expect that alter-degree will be a negative predictor of alliance formation.

Results

We estimated our model using SIENA for the three periods major shocks in the distribution of power discussed above: World War II, decolonization, and the collapse of the Soviet Union. The results are displayed in Table 1 with standard errors in parentheses. The coefficients can be interpreted in a straightforward manner as the change in log-odds of alliance formation for a unit change in the independent variable.

[Table 1 about here.]

Considering first the effect of a nation’s capabilities, which relates to the first constituent hypotheses that states with higher capabilities will be more attractive alliance partners (H_1), we find surprisingly uneven results. For the World War II period, we observe that capabilities have a coefficient of 14.2, indicating that the log-odds of alliance formation increase by 14.2 for each additional unit of CINC. This high magnitude, positive, and statistically significant result is in perfect keeping with our theory. However, for the decolonization and post-Soviet periods, the effect is still positive, but cannot be described as statistically significant at any traditional threshold. Under closer inspection however, this result makes some sense. During the second World War, the Allied Powers banded together to defeat the Axis Powers. This fight was so desperate and central to world politics that a wide swath of nations, with substantial variation in their geographic locations and political systems, joined together to vanquish the Axis. So during this period, we would expect states to be less selective in their choice of allies than usual. States engaged in the war needed allies who could fight and were willing to fight; capabilities should have been of paramount importance during this period. This line of reasoning also does much to explain why political similarity and state-level democracy failed to achieve statistical significance at traditional levels during the World War II period. The fact that national capabilities do not achieve anything close to statistical significance in the decolonization and post-Soviet periods suggests that the features of states which make them attractive alliance partners may have been different in those periods. For instance, state-level democracy and political similarity respectively seem that they might have been the most desirable properties for an alliance during the decolonization and post-Soviet periods.

For the effect of a history of recent war, which relates to the hypothesis (H_2), that alliance formation should be less likely when the expectation that alliances will be activated is higher, we find a similar imbalance in the results across periods. We find

the significant negative effect (-0.0603) we theoretically expected in the decolonization period, but not in the World War II or post-Soviet period. During decolonization, the Cold War was going strong and the possibility of a large-scale military confrontation was very real. As such, it is intuitive that states would prefer not to ally with conflict prone partners and that they would prefer to form peaceful ties with their neighbors (as supported by the positive significant effect of contiguity during this period). Beyond that, the lack of an effect during World War II is easily explained: a great many nations were engaging in wars with many other countries during that period and so – because the general level of war in the system was the highest in history – it is not the least bit surprising that a history of war would not affect alliance formation. What is somewhat more surprising is nearly complete lack of an effect in the post-Soviet period: the coefficient only takes on a non-zero value in the fourth digit past the decimal and the standard error is larger than the coefficient. This suggests that the shift in power and subsequent realignment of nations had little if anything to do with their conflict behavior. In the post-Soviet period, neither a recent history of war, the capabilities of one’s allies, nor the presence of a common foe seem to drive alliance formation. On the other hand, similarities in government have a significant negative effect (-0.952) because so many ties between the democratic West and newly-non-communist East were formed during that period.

Another interesting finding relates to our measure of political similarity (absolute difference of polity scores in a given dyad). We would expect that, when the political differences between two states grow, they become less likely to form an alliance. Indeed, we do find a negative and significant effect in the post-Soviet period as we would have expected. What we did not expect however are the positive significant effect we find in the World War II period and the lack of a significant effect during decolonization. These results may be explained through an appeal to historical nuance: during World War II, when alliances were driven primarily by capabilities and a desperate need to counter fascism, the threshold for what could be considered “basic political compatibility” was

much lower than in other periods.

We also note that geographic contiguity is a significant positive driver of alliance formation in each period. Its effect is particularly pronounced during the post-Soviet period (1.65), probably because the end of the Cold War provided an opportunity for contiguous cross-Iron-Curtain alliances in Europe which had not been politically possible beforehand.

More importantly however, we must consider the effects of our network parameters: alter-degree and triadic closure.

First, the effect of a state's degree – its connectivity in the alliance network – is a consistent negative predictor of alliance formation in accordance with H_5 . It is worth noting however that in the decolonization and post-Soviet periods, the effect just barely fails to achieve the traditional 0.05 level of significance. Yet since significance levels in those periods are close to 0.05 and well within 0.1, we consider the effects substantively significant. The findings suggest that prospective allies 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 robust support for H_5 .

Our primary theoretical claim was that synergy effects should be produced when groups of states become closely allied. We find robust support for this idea. In all three periods, triadic closure is a positive significant predictor of alliance formation. The coefficients for triadic closure are 0.151 for the WWII period, 0.367 for decolonization and 0.914 for the post-Soviet period. Substantively, triangle closure increases the log-odds of alliance formation by as much as 0.914. While the magnitude of triadic closures effect varies by period, it seems to be a consistent positive driver of alliance formation as our theory had predicted.

These results are particularly interesting when one considers the variance in the effects traditionally analyzed in the literature: it seems that network statistics like

alter degree and triadic closure number among the few effects which are reliable and consistent across periods. We take this to be both support for our idea of synergy effects as well as a suggestion that empirical analyses of alliances which do *not* account for network effects are missing key pieces of the puzzle.

Concluding Thoughts

Our research has shed light on several previously unexplored aspects of alliance formation. First, we have shown that the system of alliances may be conceptualized as a complex network rather than a series of conditionally independent dyads, and that the network conceptualization of the system of alliances may have important theoretical implications. Positing that alliances indicate at least the general political orientation of states towards 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 which contribute to alliance formation, in the three periods of major change, we found that network effects – alter degree and triangle closure specifically – are the only consistent predictors of the tendencies of states to form alliances with one another other than geographic contiguity.

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 and differences in Polity. While our network theory worked in harmony with these constituent hypotheses, it did not rely on them. Our results with respect to the constituent hypotheses seem to suggest that historical context plays a major role in the alliance formation process and varies non-trivially over time. This, in turn, suggest that perhaps future work should be cautious not to pool over long periods of time.

One of the constituent hypotheses for which we did find the results troubling however was that of political compatibility (H_4). It seems our apprehension about the degree to which the threshold of political compatibility varies across states and over time within particular dyads was warranted. We only find our operationalization of political compatibility – absolute difference in Polity III score – to be significant in the expected direction in the post-Soviet period. This could indicate that our measure of political compatibility was too simple.

Far and away our most important findings, however, relate to network effects. We found that alter degree and triadic closure were significant negative and positive predictors respectively and both had consistent effects across all time periods considered. These results strongly support our network-based theory and suggest that analyses which 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 parts when simple network parameters do so much to explain alliance formation.

We should also point out that the empirical evaluation of our theory is not possible in the traditional regression framework. The ability to statistically treat the alliance network as a network and to include network structures in our analysis was made possible by the SIENA method and software (Snijders 2001, 2005). Without this new technology we could not have properly gauged empirical support for synergy effects or star-formation.

Our analysis constitutes the first statistical examination of alliance formation as a complex network of interdependent relations. Our research provides a foundational model for the empirical investigation of the network of alliances. This innovation in the study of alliance formation, naturally, raises at least as many questions as it answers. For example, our model analyzes change in the alliance network during periods of radical transition, but does not address the onset of such transitions. Also, we postulate

many potential explanations for the cross-period variation in the estimated effects; future analyses could specify more rigorous tests of the causes of said variation. We hope that the findings presented here serve as a catalyst for the further consideration of alliance formation as a network phenomenon.

References

- Altfeld, Michael A. 1984. "The Decision to Ally." *The Western Political Quarterly* 37: 523–544.
- Bennett, D. Scott, and Allan C. Stam. 2004. *The Behavioral Origins of War*. Ann Arbor: University of Michigan Press.
- Berardo, Ramiro, and John T. Scholz. 2005. "Micro-Incentives and the Dynamics of Policy Networks." (September).
- Brooks, Stephen. 1997. "Dueling Realisms." *International Organization* 51(Summer): 554–577.
- Bueno de Mesquita, Bruce. 1981. *The War Trap*. New Haven: Yale University Press.
- Bueno de Mesquita, Bruce, Alastair Smith, Randolph M. Siverson, and James D. Morrow. 2003. *The Logic of Political Survival*. Cambridge: MIT Press.
- Conybeare, John A. C. 1994a. "Arms versus Alliances: The Capital Structure of Military Enterprise." *Journal of Conflict Resolution* 38(2): 215–235.
- Conybeare, John A. C. 1994b. "The Portfolio Benefits of Free Riding in Military Alliances." *International Studies Quarterly* 38(3): 405–419.
- Correlates of War Project, . 2005a. *Extra-State War Data, 1816-1997 (v3.0)*.
- Correlates of War Project, . 2005b. *Interstate System, 1816-2004 (v3.0)*.
- Correlates of War Project, . 2005c. *National Material Capabilities (v3.02)*.
- Cranmer, Skyler J., and A. Desmarais, Bruce. 2009. "A General Class of Models for Inference on Network Data." *Under Review* .
- Crescenzi, Mark J. C., Jacob D. Kathman, Katja B. Kleinberg, and Reed M. Wood. 2009. "Reliability, Reputation, and Alliance Formation." *Unpublished* .
- Deutsch, Karl W., and J. David Singer. 1964. "Multipolar Power Systems and International Stability." *World Politics* 16(3): 390–406.

- Downs, George W., David M. Rocke, and Peter N. Barsoom. 1996. "Is the Good News about Compliance Good about Cooperation." *International Organization* 50(3): 379–406.
- Duncan, George T., and Randolph M. Siverson. 1982. "Flexibility of Alliance Partner Choice in a Multipolar System: Models and Tests." *International Studies Quarterly* 26(4): 511–538.
- Fearon, James D. 1997. "Signaling Foreign Policy Interests: Tying Hands versus Sinking Costs." *The Journal of Conflict Resolution* 41(1): 68–90.
- Fruchterman, Thomas M.J., and Edward M. Reingold. 1991. "Graph Drawing by Force-Directed Placement." *Software- Practice and Experience* 21(11): 1129–1164.
- Gartner, Scott S., and Randolph M. Siverson. 1996. "War Expansion and War Outcome." *The Journal of Conflict Resolution* 40(1): 4–15.
- Gibler, Douglas M. 2008. "The Costs of Reneging: Reputation and Alliance Formation." *Journal of Conflict Resolution* 52(3): 426–454.
- Gilpin, Robert. 1981. *War and Change in World Politics*. New York: Cambridge University Press.
- Kadera, Kelly M., and Gerald L. Sorokin. 2004. "Measuring National Power." *International Interactions* 30: 211–230.
- Kim, Woosang. 1991. "Alliance Transitions and Great Power War." *American Journal of Political Science* 35(4): 833–850.
- Krauthammer, Charles. 1991. "The Unipolar Moment." *Foreign Affairs* 70(1): 23–33.
- Krauthammer, Charles. 2002. "The Unipolar Moment Revisited." *The National Interest* Winter.
- Lake, David A. 1999. *Entangling Relations: American Foreign Policy in Its Century*. Princeton, NJ: Princeton University Press.
- Leeds, Brett Ashley. 1999. "Domestic Political Institutions, Credible Commitments, and International Cooperation." *American Journal of Political Science* 43(4): 972–1002.
- Leeds, Brett Ashley. 2003. "Alliance Reliability in Times of War: Explaining State Decisions to Violate Treaties." *International Organization* 57(4): 801–827.
- Leeds, Brett Ashley, Andrew G. Long, and Sara McLaughlin Mitchell. 2000. "Re-Evaluating Alliance Reliability: Specific Threats, Specific Promises." *Journal of Conflict Resolution* 44(5): 686–699.

- Leeds, Brett Ashley, Jeffrey Ritter, Sarah McLaughlin Mitchell, and Andrew Long. 2002. "Alliance Treaty Obligations and Provisions, 1815-1944." *International Interactions* 28: 261–284.
- Lemke, Douglas, and William Reed. 1996. "Regime Types and Status Quo Evaluations: Power Transition Theory and the Democratic Peace." *International Interactions* 22(2): 143–164.
- Levy, Jack S. 1981. "Alliance Formation and War Behavior: An Analysis of the Great Powers, 1495-1975." *Journal of Conflict Resolution* 25(4): 581–613.
- Li, Richard P.Y., and William R. Thompson. 1978. "The Stochastic Process of Alliance Formation Behavior." *American Political Science Review* 72(4): 1288–1303.
- Liberman, Peter. 1996. *Does Conquest Pay? The Exploitation of Occupied Industrial Societies*. New Haven: Princeton University Press.
- Liska, George. 1962. *Nations in Alliance: The Limits of Interdependence*. Baltimore, MD: Johns Hopkins University Press.
- Long, Andrew, Timothy Nordstrom, and Kyeonghi Baek. 2007. "Allying for Peace: Treaty Obligations and Conflict between Allies." *Journal of Politics* 69(4): 1103–1117.
- Machiavelli, Niccolo. 1532. *The Prince*. Chicago, IL: University of Chicago Press (1998 reprint).
- Manger, Mark S., Mark A. Pickup, and Tom A. B. Snijders. 2008. "When Country Interdependence is More Than a Nuisance: The Longitudinal Network Approach." (August).
- Maoz, Zeev. 1989. "Joining the Club of Nations: Political Development and International Conflict, 1816-1976." *International Studies Quarterly* 33(2): 199–231.
- Mastanduno, Michael. 1997. "Preserving the Unipolar Moment." *International Security* 21(4): 49–88.
- Miller, Gregory D. 2003. "Hypotheses on Reputation: Alliance Choices and the Shadow of the Past." *Security Studies* 12(3): 40–78.
- Morgenthau, Hans J. 1956. *Politics Among Nations*. 2 ed. New York: Alfred A. Knopf.
- Morrow, James D. 1989. "On the Theoretical Basis of a Measure of National Risk Attitudes." *International Studies Quarterly* 31(4): 423–438.
- Morrow, James D. 1991. "Alliances and Asymmetry: An Alternative to the Capability Aggregation Model of Alliances." *American Journal of Political Science* 35: 904–933.
- Morrow, James D. 1993. "Arms Versus Allies: Trade-offs in the Search for Security." *International Organization* 47(2): 207–233.

- Morrow, James D. 1994. "Alliances, Credibility, and Peacetime Costs." *Journal of Conflict Resolution* 38(2): 270–297.
- Morrow, James D. 1999. "The Institutional Features of the Prisoners of War Treaties." .
- Morrow, James D. 2000. "Alliances: Why Write Them Down?" *Annual Review of Political Science* 3: 63–83.
- Oren, Ido. 1990. "The War Proneness of Alliances." *Journal of Conflict Resolution* 34(2): 208–233.
- Organski, A.F.K. 1968. *World Politics*. New York: Knopf.
- Pickering, Jeffrey, and William R. Thompson. 1998. "Stability in a Fragmenting World: Interstate Military Force, 1946-1988." *Political Research Quarterly* 51(1): 241–263.
- Powell, Robert. 1999. *In the Shadow of Power*. Princeton, NJ: Princeton University Press.
- Ripley, Ruth, and Tom A. B. Snijders. 2009. *Manual for SIENA version 4.0 (provisional version, October 5, 2009)*. Oxford, UK: University of Oxford, Department of Statistics; Nuffield College.
- Scholz, John T., Ramiro Berardo, and Brad Kile. 2008. "Do Networks Solve Collective Action Problems? Credibility, Search, and Collaboration." *Journal of Politics* 70(2): 393–406.
- Simon, Michael W., and Erik Gartzke. 1996. "Political System Similarity and the Choice of Allies." *Journal of Conflict Resolution* 40(4): 617–635.
- Singer, J. David, and Melvin Small. 1967. "Alliance Aggrigation and the Onset of War, 1815-1945." In *Quantitative International Politics: Insights and Evidence*, ed. J. David Singer. New York: Free Press pp. 247–286.
- Siverson, Randolph M., and Harvey Starr. 1990. "Opportunity, Willingness, and the Diffusion of War." *The American Political Science Review* 84(1): 47–67.
- Siverson, Randolph M., and Harvey Starr. 1991. *The Diffusion of War: A Study of Opportunity and Willingness*. Ann Arbor, MI: University of Michigan Press.
- Siverson, Randolph M., and Harvey Starr. 1994. "Regime Change and the Restructuring of Alliances." *American Journal of Political Science* 38(1): 145–161.
- Siverson, Randolph M., and Joel King. 1980. "Attributes of National Alliance Membership and War Participation." *American Journal of Political Science* 35(2): 285–306.
- Siverson, Randolph M., and Michael R. Tennefoss. 1984. "Power, Alliance, and the Escalation of International Conflict, 1815-1965." *American Political Science Review* 78: 1057–1069.

- Smith, Alastair. 1995. "Alliance Formation and War." *International Studies Quarterly* 39(4): 405–425.
- Smith, Alastair. 1996. "To Intervene or not to Intervene: A Biased Decision." *Journal of Conflict Resolution* 40(1): 16–40.
- Smith, Alastair. 1998. "Extended Deterrence and Alliance Formation." *International Interactions* 24(4): 16–40.
- Snijders, Tom A. B. 2005. "Models for Longitudinal Network Data." In *Models and Methods in Social Network Analysis*, ed. P. Carrington, J. Scott, and S. Wasserman. New York: Cambridge University Press p. 2005.
- Snijders, Tom A.B. 2001. "The Statistical Evaluation of Social Network Dynamics." *Sociological Methodology* 31: 361–395.
- Snijders, Tom A.B., Gerhard G. van de Bunt, and Christian E.G. Steglich. 2009. "Introduction to Actor-Based Models for Network Dynamics." *Social Networks* preprint.
- Snyder, Glenn H. 1984. "The Security Dilemma in Alliance Politics." *World Politics* 36: 461–495.
- Sorokin, Gerald L. 1994. "Alliance Formation and General Deterrence: A Game-Theoretic Model and the Case of Israel." *Journal of Conflict Resolution* 38(2): 298–325.
- Väyrynen, Raimo. 1984. "Regional Conflict Formations: An Intractable Problem of International Relations." *Journal of Peace Research* 21(4): 337–359.
- Walt, Stephen M. 1985. "Alliance Formation and the Ballance of World Power." *International Security* 9(4): 3–43.
- Walt, Stephen M. 1987. *The Origins of Alliances*. Ithaca: Cornell University Press.
- Waltz, Kenneth N. 1954. *Man, The State, and War*. New York: Columbia University Press.
- Waltz, Kenneth N. 1979. *Theory of International Politics*. New York: McGraw Hill.
- Warren, Camber. 2009. "The Geometry of Security: Modeling Interstate Alliances as Evolving Networks." *Working Paper* Accessed 11-06-2009.

41

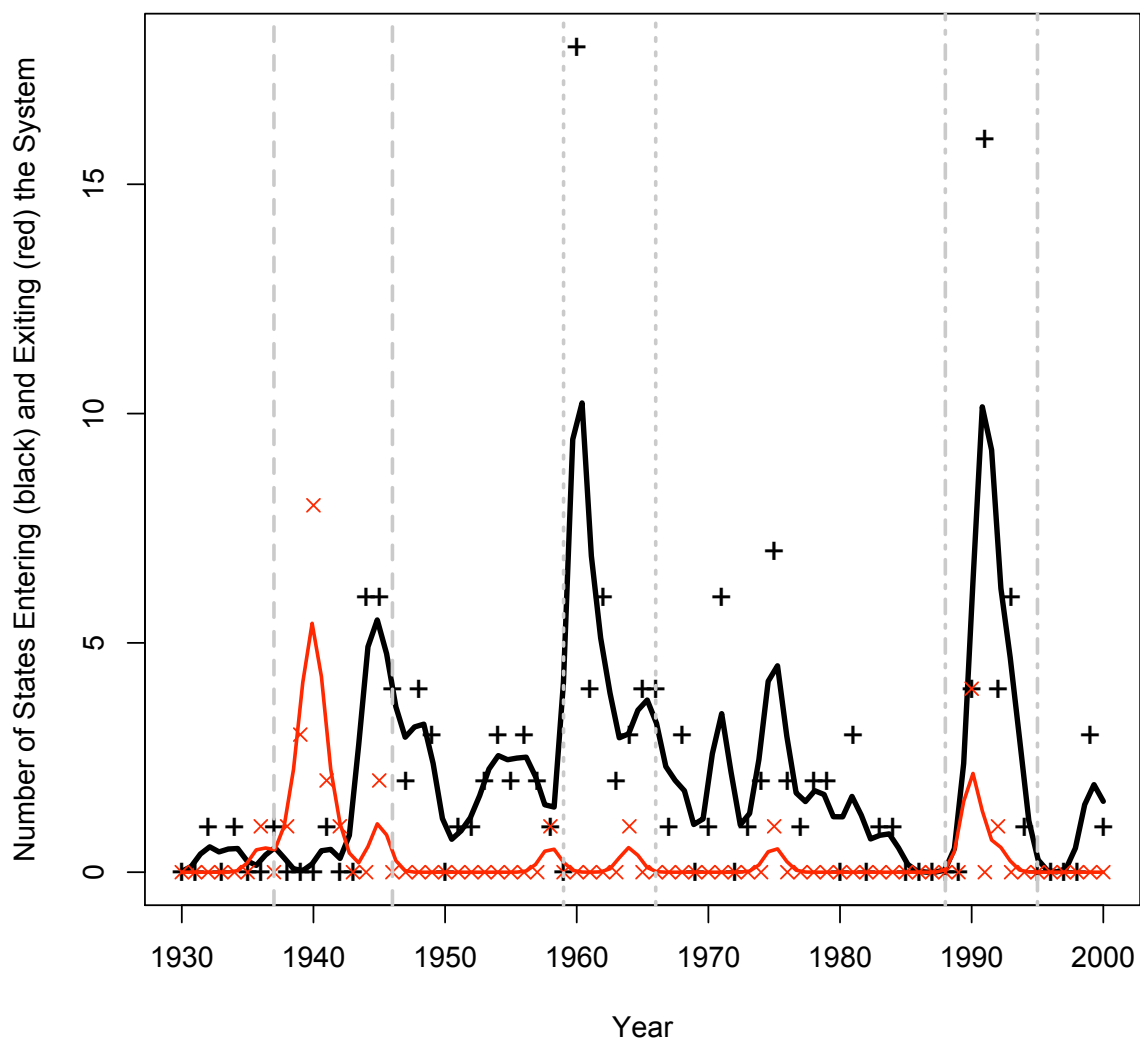


Figure 2: Entry and Exit from the International System, 1930-2000. State entry is indicated with a black + while state exit is indicated with a red x. The black and red lines are kernel smoothers for entry and exit respectively, both with bandwidth set to 2. The vertical lines of varying types indicate the start and end of our chosen time periods: 1937-1946, 1959-1966, and 1988-1995.

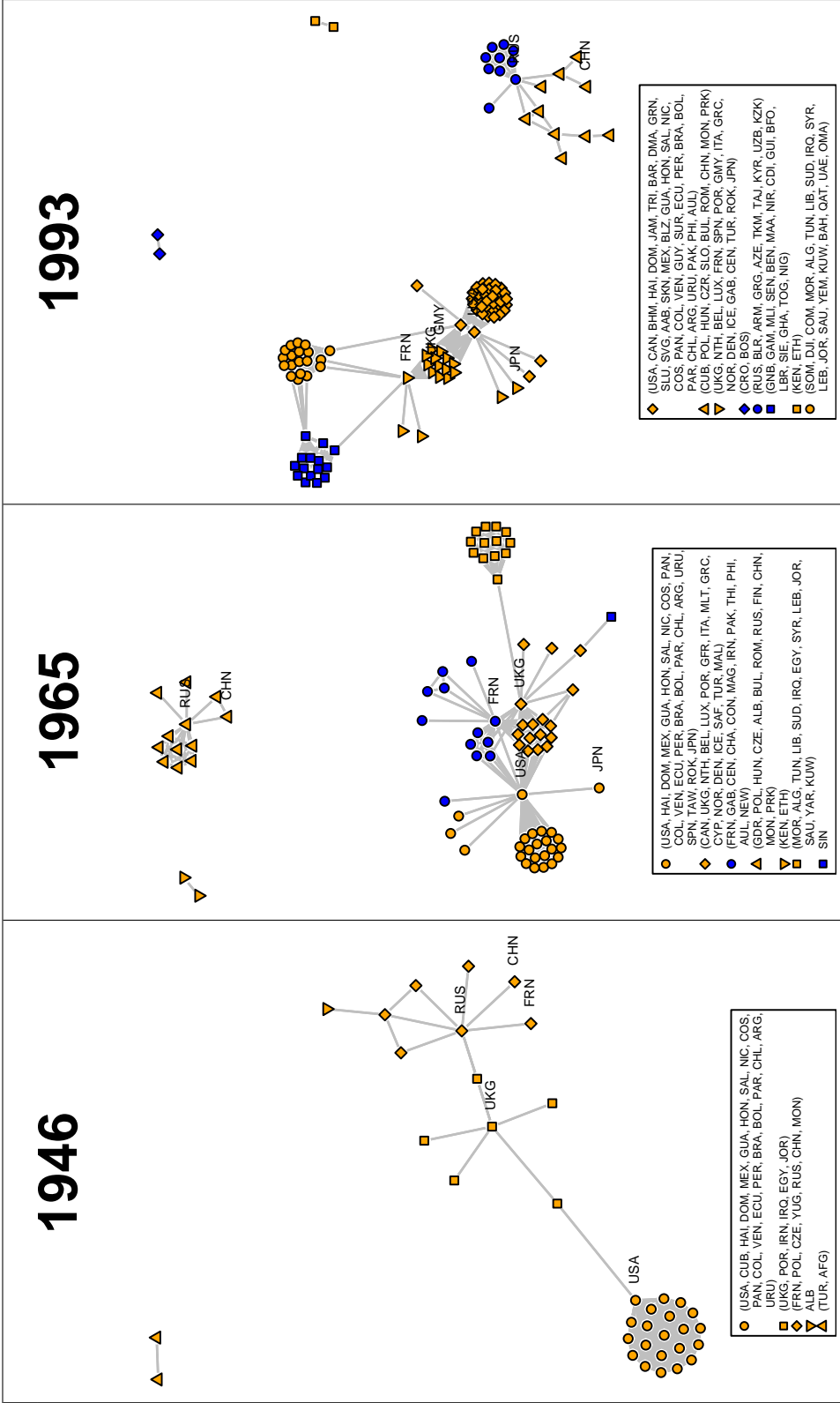


Figure 3: The Alliance Network in Several Periods. This figure illustrates both that (a) the system of alliances may naturally be thought of as a network and (b) the structure of the network seems nonrandom. Visually, the states in the network seem clustered. Further support for these clusters is obtained using a k-means decomposition of the spatial positions returned by the Fruchterman and Reingold network plotting algorithm (Fruchterman and Reingold 1991); the discrete communities are indicated by the shape and color of the nodes. The major powers are identified in the plot and all others are identified in the legend. Isolates (states with no alliances) have not been plotted.

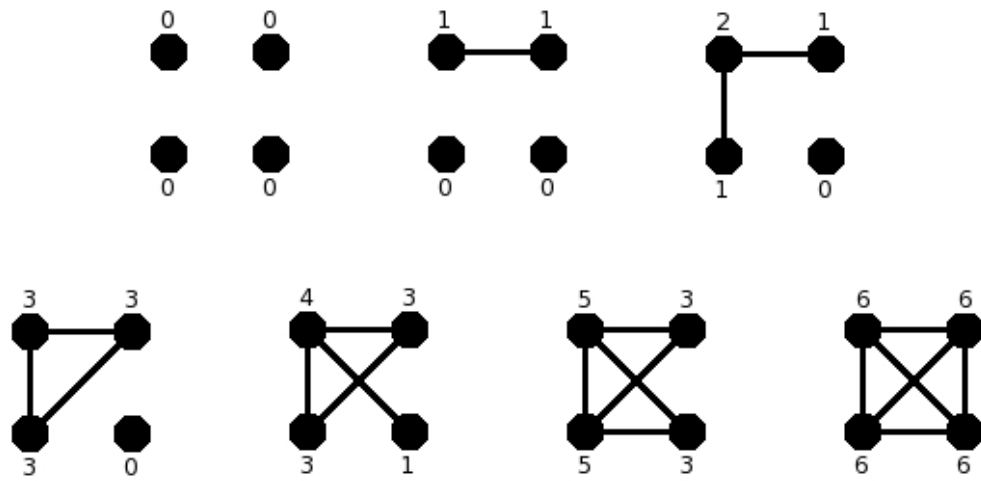


Figure 4: Simple illustration of synergy effects. One order of utility is gained with each alliance a state is party to, and an additional order of utility is gained by every state in a triangle when it is closed. The completely connected network in the lower right-hand side of the figure is the sole equilibrium and is also Pareto optimal.

	(1937-1946)	(1959-1966)	(1988-1995)
	WWII	Decolonization	Post-Soviet
<i>Density</i>	-0.324 (0.261)	-1.71 (0.0774)	-2.21 (0.217)
<i>Triangles</i>	0.151 (0.0032)	0.367 (0.0383)	0.914 (0.321)
<i>Degree of Alter</i>	-6.24 (0.983)	-4.15 (2.3)	-4.27 (2.4)
<i>Contiguity</i>	1.00 (0.225)	1.01 (0.126)	1.65 (0.292)
<i>Common Enemy</i>	-0.258 (0.0597)	0.19 (0.106)	-0.0075 (0.225)
<i>Polity Similarity</i>	0.551 (0.299)	-0.255 (0.203)	-0.952 (0.422)
<i>CINC</i>	14.2 (2.5)	8.88 (6.08)	-6.54 (5.74)
<i>Conflict History</i>	-0.0035 (0.0159)	-0.0603 (0.0073)	-3e-04 (0.0071)
<i>Same Region</i>	-0.541 (0.229)	— —	— —
<i>Democracy in Lost Ties</i>	-0.141 (0.111)	-0.0431 (0.0023)	— —

Table 1: SIENA Results for the WWII, Decolonization, and Post-Soviet Periods with standard errors in parentheses. The coefficients are interpreted as the change in log-odds of alliance formation for a unit increase in the covariate. We have not reported the baseline rate parameters for each year.