The Spatial Diffusion of War: The Case of World War I

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전쟁의 공간적 확산에 관한 연구: 제1차 세계대전을 사례로

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Abstract : Conventional treatments of war diffusion focus extensively on dyadic relationships, whose impact is thought to be immutable over the course of the conflict. This study indicates that such conceptions are at best incomplete, and more likely misleading to explain the spatial diffusion of wars. Using social network analysis, we examine war joining behavior during World War I. By employing social network analysis, we attempted to overcome the dichotomous understanding of geography as space and network in the discipline of conflict studies. Empirically, networked structural elements of state relationships (e.g., rivalry, alliances) have explanatory and predictive value that must be included alongside dyadic considerations in analyzing war joining behavior. In addition, our analysis demonstrates that the diffusion of conflict involves different driving forces over time.

Key Words : conflict, diffusion, social networks, World War I, contiguity, alliances, rivalry

요약 : 전통적으로 전쟁의 확산에 관한 연구는, 전쟁에 참여하는 양국의 관계에 초점을 맞추어왔으며 국가 간의 관계가 전쟁의 과정에서 변하지 않는다는 가정에 기반하여 왔다. 본 연구는 기존의 접근방법이 전쟁 확산의 공간적 측면을 설명하기에는 부족함을 보여주고 있다. 네트워크 공간에서의 전쟁확산을 이해하기 위해, 사회연결망 분석을 이용하여 제1차 세계대전에 참전한 국가의 행위를 분석하였다. 사회연결망 분석기법의 적용은 기존의 갈등연구에서 나타나고 있는 물리적 공간과 네트워크의 이분법적 이해를 극복하는 시도가 된다. 연구의 결과는, 국가들이 맺는 관계(지속적인 갈등, 동맹)가 만들어내는 네트워크의 구조적 속성이 개별 국가 간의 관계만큼이나 중요하다는 것을 보여주고 있다. 또한 분쟁의 확산을 이끌어내는 요인이 전쟁이 진행되면서 변화한다는 점을 확인할 수 있는데, 지리적 인접성은 전쟁 초기에는 중요하지만 전쟁이 확산됨에 따라 동맹관계, 기존에 유지되어온 적대적 관계와 이로써 생성되는 국제관계의 네트워크 구조가 더욱 중요한 것으로 나타났다.

주요어 : 분쟁, 확산, 사회연결망, 제1차 세계대전, 인접성, 동맹, 경쟁

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1. Introduction

The diffusion of war has been an important topic of inquiry within international relations for some time (see for example Houweling and Siccama, 1985 and Siverson and Starr, 1991). Dyadic analysis, pioneered by Bremer (1992), made international relations scholars think of diffusion in terms of paired factors such as geographic proximity. One of the problems with dyadic analysis, however, is that it focuses on bilateral relations and thereby ignores the influences of external and broader contextual relationships. In this study, we use social network analysis as applied to war joining decisions in World War I to refine and extend the work on war diffusion with particular attention to several research questions. What factors lead two states to become embroiled in an ongoing war? Are dyadic relationships the key drivers of war joining behaviour or do contextual factors, indicated by networks, play a significant role? How does the influence of those factors change over time as the war expands?

Using the diffusion of World War I as a laboratory, we employ social network analysis to define the position of a state in a network of interstate relations and use such measures of context to identify the explanatory power of a state's network situation in explaining war-joining behavior during different phases of the diffusion process. In addition to contiguity, networks are constructed on the basis of dyadic relationships involving general alliances, targeted alliances, and rivalries; this allows us to evaluate the explanatory power of dyadic versus broader contextual relationships.

The study makes three distinct contributions to the study of war diffusion and international conflict more generally. First, we reconceptualize the concept "opportunity" to include more than just physical space by extending the concept to include political relationships. Second, the results demonstrate empirically that

to understand war joining behavior the explanatory power of dyadic considerations must be complemented by considering the additional explanatory and predictive power of networked elements of state relationships; indeed, in the last stage of the diffusion process the former effects disappear when the broader and multifaceted relationships are considered. Finally, our analyses show that the factors that influence diffusion change over different stages of conflict, leading to the conclusion that a "one size fits all" explanation based on the conditions at the outbreak of war is likely to be misleading.

The analysis begins by reconceptualizing context away from standard treatments of physical space and shared borders as reflected in the conflict diffusion literature. We then move to specifying some general expectations about diffusion as reflected in past studies. These are the bases of the empirical tests that follow. The tests compare the efficacy of dyadic and static models versus those reflected complex network relationships that change over the course of a war.

2. Reconceptualizing Diffusion and Opportunity: ConflictSpace as Context

The predominant theoretical framework to analyze conflict diffusion has been "opportunity" and "willingness" (Most and Starr, 1989). The former refers to the presence of interaction opportunities between a given state and other states; for war to spread, the political environment must be open to the possibility of diffusion, such as geogrphical proximity. Analyses of conflict diffusion, and indeed international conflict in general, have tended to focus on physical space as the basis for "opportunity." This has most often focused on shared borders (Most and Starr, 1980; Diehl, 1991)

defined dyadically and measured in a dichotomous fashion. There have been some incremental variations of this approach. Using GIS, border characteristics (e.g., permeability) can supplement obvious other elements such as boundary length (Starr, 2002; Starr and Thomas, 2002). Rather than the existence of a shared border, distance in miles or kilometers (Gleditsch and Ward, 2001) has also been adopted as a measure of proximity, and therefore opportunity for conflict.

The diffusion of international conflict remains a relatively rare event. Militarized interstate disputes are largely dyadic phenomena (approximately 85% - see Ghosn, Palmer, and Bremer, 2004), and indeed a number of multilateral disputes were so configured from the outset and therefore did not spread. After the outbreak of war, Siverson and Starr (1991) estimate a diffusion rate of 2.5% on a yearly basis, indicating that the puzzle of why wars do not spread is at least as important as a query that focuses on why they do. Thus, simple conceptions based on physical space tend to overemphasize "opportunity" and therefore studies using measures based on such conceptions inevitably produce a large number of false positives.

A focus on "opportunity" without consideration of "willingness" has magnified the problem. This myopic approach was largely driven by applying analogies and models of disease (e.g., "contagion," "infection") transmission to the spread of war (e.g., Davis, Duncan, and Siverson, 1978). The processes examined were primarily passive (similar to the spread of disease) and therefore ignored the purposeful motives that accompany the decisions of states to join a war. Such studies, however, were dedicated primarily to establishing the existence and magnitude of war diffusion rather than to providing a comprehensive model accounting for the process. Thus, further consideration needs to be given to willingness, or the preferences of states for joining the conflict. To the extent that this has been addressed, the agent of diffusion on this dimension has most

prominently been alliances (Siverson and Starr, 1991) as these agreements are said to signal the security preferences and obligations of states vis-à-vis others. Willingness may also be indicated on a regional level by the presence of common institutions and interdependence (or lack thereof) between states (Gleditsch, 2002) and there may be an independent "neighborhood effect" on behavior (see Senese and Vasquez, 2008).

Empirical findings and speculation on the specific factors associated with diffusion are limited (for a review of early diffusion studies, see Most, Starr, and Siverson, 1989; Simowitz, 1998). Not surprisingly, borders and alliances are associated with the spread of war, although the relationships are relatively weak in that most wars do not spread to neighbors or to countries allied to the belligerents. Nonetheless, contiguous states are more prone to diffusion (Siverson and Starr, 1991; Hammarstrom and Heldt, 2002), and such opportunity effects may extend to broader regional "neighborhoods" (Gleditsch, 2002) or even to a larger system (Kadera, 1998, see also Mitchell, 2002). In contrast, larger wars are associated more with alliance-generated diffusion and on third party states who have been the victim of attack by another state already at war. To a certain extent, prior alliances may act almost as a necessary condition of large wars (Vasquez, 2010). Beyond merely alliances, the extent to which actors have similar relations vis-à-vis a third party will determine not only whether a state will intervene in an ongoing conflict, but also against which states the actor will fight (Hammarstrom and Heldt, 2002).

In our view, the environment or context under which diffusion (and thereby decisions to join wars) is multifaceted and not defined solely by physical features. To capture these elements, it is necessary to expand what is meant by "context." The concept of ConflictSpace (Flint et al., 2009) is used to suggest that the contextual setting or situation of an actor is multifaceted and should be conceptualized as a combi-

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nation of political and physical geographic spaces that enable and constrain a state in its decision to enter or avoid an ongoing conflict. The ConflictSpace idea can be adopted to include physical space, network spaces, and multiple scales as a framework for situating the behavior of an actor. Furthermore, the concept emphasizes the recursive relationship between actors and their context as state boundaries, political networks, and regional political situations are made by the multiple actions of actors and, in turn, these elements of context frame the opportunities for new actions (Flint et al., 2009). In this analysis we use the concept of ConflictSpace to frame opportunity as a multifaceted setting that is constituted by position within a network of political relations as well as relative physical geographic setting, but a setting that may have different impacts over the course of the diffusion of the conflict. At the systemic level, changing patterns of network relationships developed into a context that facilitated the diffusion of World War I (Vasquez et. al., 2011). In this study, we integrate a social network approach into a dyadic analysis of the expansion of the war by focusing upon which states fought against whom.

3. Processes of Diffusion in ConflictSpace

Diffusion is a process in which a phenomenon spreads across space over time (Gould, 1969). The temporal aspect of diffusion requires more consideration, especially when the process is driven by the conscious decisions of actors. In contrast to flu epidemics, for example, in which the spread of the disease is not significantly altered by the behavioral choices of individuals, states make a clear decision as to whether they should declare war or not. The standard and ideal model of diffusion posits an S-curve of adoption behavior

(Gould, 1969). Initial adoption of a phenomenon is undertaken by a small group, the innovators. The subsequent widespread adoption is represented by the steep slope of the curve as much of the population, the early and late majorities, follow the example of the innovators. The S-curve then tails off as a few remaining potential adopters, the laggards, imitate the behavior of the preceding groups.

The key point to be taken from the S-curve concept for the study of context in the diffusion of war is that different aspects of context could have different weights in defining the opportunity surface for potential war-joiners at different stages of the diffusion process. We must avoid the assumption that the different aspects of context play recurring or equivalent roles over the course of the diffusion process. The opportunity surface changes as more states enter into a war, perhaps modifying the relative influence of geographic and network space on state behavior.

Using ConflictSpace as the context within which diffusion occurs, we need to define the individual components that constitute it. Our emphasis is upon three elements of ConflictSpace: physical contiguity, network position, and change over time. At this stage, we rely extensively on past research to point the way. The original contribution of this analysis does not come from identifying new factors, but rather in reconceptualizing them in networked spaces and in empirically indicating how they work together and how their effects vary as war unfolds. Thus, the focus is on traditional notions such as power and status, but also contiguity, alliances, and rivalry that form network relationships constituting the context for diffusion.

The contribution of a social network analysis of war diffusion is to identify a state's position within the complete set of relations such that the impact of rivalry, for example, is not just a state's rivalry relationships with other states but the latter's rivalries as well. Moreover, our contribution is to analyze a state's posi-

tion within a network in two ways: the comparative pattern of the relationships (known in the social network literature as structural equivalence (Wasserman and Faust, 1994; Maoz et al., 2006)) and its placement within the network as a whole (known as centrality (Freeman, 1977)). We are then able to hypothesize about the "opportunity" for diffusion, but in a way that shows it is constructed through the activities (or willingness) of states. Opportunity and willingness work together so that states create patterns of political relations and produce a network within which some states are similarly positioned as other states, but also are situated differently within the network than others. We expect that those states with different positions in a network are most likely to fight each other, and that this contextual position has explanatory value over and above dyadic relations. Furthermore, the role of position in a network should not be expected to act in the same way for different political relationships nor across different phases of the diffusion of a conflict.

We begin by noting that as war spreads to include a greater number of actors, the increased number of interconnections and interdependencies acting upon states should lead to an increasing role for structural position within a network to influence behavior. Over the course of an expanding war, more states should be "touched" by the imperatives and dynamics of the war, and will become more constrained or influenced by their network position. This is expected across specific network dimensions (e.g., alliances, rivalries).

These ideas lead to the following hypothesis:

H1: Position within a network will have greater explanatory value in the later rather than earlier stages of diffusion.

The ConflictSpace approach does not emphasize network position to the neglect of physical geographic situation. Contiguity facilitates the spread of war in that an increase in the stakes and effects of a war are greater for those states geographically proximate to the

fighting (Siverson and Starr, 1991). Contiguity works to spread war in two ways. First is through the simple proximity of states. Land armies require contiguity and if neutral states are in the way, they will be attacked by one or both sides. Second is through shared concerns and issues that enmesh neighbors in a web of interactions that can make for conflict. As the war spreads, additional states will share borders with a belligerent, and thereby become more likely to enter the war. Nevertheless, contiguity should not be thought of simply in terms of first-order neighbors. As Buhaug and Gleditsch (2008) showed, understanding spatial patterns in international conflicts needs an analysis of process.

One way of including process is to not just look at the relative physical location of a pair of states (or dyadic-contiguity) but how a state is situated within the complete map of physical location. Building upon the concepts of second and third-order contiguity, a network of contiguity builds a structure of neighbors, the neighbors of neighbors, and so on (see Maoz et al., 2007; Maoz, 2010). A state's position within such a network structure provides a measurable identification of its "betweenness" (Sheppard, 2002; Hess, 2004), but in the specific sense of its setting within the context of all neighbors. In other words, a state is not only identified as being central or marginal to other states but its situation within an expansive surface of neighboring units is also a function of all other states' centrality or marginality. When analyzing a war that has the potential to include all states across the expanse of the globe it is important to consider physical geographic setting as being relative to all possible actors rather than immediate neighbors. An a priori understanding of the role of contiguity is defined by concentrating only on simple dyadic physical neighbors. By analyzing relative geographic position as centrality in a network of contiguous actors the possibility of the role of a much broader geographic setting is included,

Table 1. Mechanisms of diffusion and related hypotheses

Mechanisms of diffusion	Expected impact on war joining		
	early stage	middle stage	late stage
Contiguities			
Simple physical contiguity (H2)	+	+	+
Centrality in network (H3)	+		
Alliance			
Alliance, dyadic level (H4)	-	-	-
Structural dissimilarity of alliance (H7)	+	+	
Targeted Alliance			
Targeted alliance, dyadic level (H5)	+		
Structural dissimilarity of targeted alliance (H8)	+	+	
Rivalry			
Rivalry, dyadic level (H6)	+		
Structural dissimilarity of rivalry (H9)		+	+

and one that should play a role in understanding the temporal process of war joining. Specifically, contiguity is expected to play a role in war joining behavior in the initial stages of the diffusion process but diminish through the following stages as the war spreads to include other states.

We retain the expectation that neighbors, reflected by dyadic contiguity, are more likely to join wars against one another than other pairs of states. In addition, we anticipate that greater geographic connectivity in a broader setting, or the centrality of states, promotes war joining behavior. Nevertheless, if a war spreads in a contagious fashion, then centrality should decline in importance over the course of the process as the war spreads through the network through more peripheral linkages. Hence, the following hypotheses, reflecting both dyadic and network (between states) conditions of geographic proximity:

H2: Contiguous states are more likely to fight each other.

H3: More "central" states will fight each other in the earlier stages of the war.

What about the political relations that establish the network surface through which wars spread? How do they interact with the diffusion process? Two sets of relations are expected to be particularly catalytic in facilitating the diffusion of war: targeted alliances (formal relations with a potential threat or target in mind) and rivalries (as a measure of latent or potential conflict). The dyadic expectation is that states in an alliance will not fight each other. States allied against a belligerent are more apt to be drawn into an ongoing war against that state than those not allied (Siverson and Starr, 1991). Formal obligations may require a state to aid its ally, but the presence of an alliance signals common security preferences and thus a state will likely join the war to promote its own interests, even if not legally obligated to do so by the formal alliance. Furthermore, states that are rivals to a belligerent have a greater probability of intervening into an ongoing war than those that are not. Rivals maintain vested interests in the actions of their opponents, and may choose to intervene in a war against a rival if doing so would prevent the rival from acquiring additional resources or territory. Rivalries are generally thought to be zero-sum games, so even if a war does not directly involve rivalry con-

cerns, its outcome may have important implications for future rivalry dynamics.

At the dyadic level we can hypothesize the following:

> H4: Alliance partners are not likely to join a war against each other.
>
> H5: In the earlier stages of the process, states in a targeted alliance relationship are more likely to fight each other.
>
> H6: In the earlier stages of the process, rivals are more likely to fight each other.

In terms of network relationships, the expectation is that certain configurations of alliances will promote war diffusion. This idea builds upon the notion of strategic affinity (Maoz et al., 2006), or the manner in which states have similar ties to other states in a network indicates shared strategic goals and interests. Maoz et al. (2006) found that strategic affinity was a significant indicator of dyadic conflict behavior. In this analysis we identify the role of strategic affinity across the stages of war diffusion and three strategic relationships (alliances, targeted alliances, and rivalries). We adopt the assumption (Maoz et al., 2006) that dissimilarity between two states in a network is an indication of different strategic affinities and hence two such states are more likely to fight each other as a war expands to include more participants.

Alliances may be seen as blocs of states tied together, and hence states in one bloc are likely to fight states in the other bloc. In the case of alliances, the identification of strategic affinity (Maoz et al., 2006) is clear: dissimilarity in network position is a reflection of two states' membership in different strategic blocs and leads to an expectation they would fight each other. Furthermore, different structural positions within the network of alliance should be a factor in the initial and medium diffusion process.

On the other hand, relationships based on rivalries and targeted alliances are, at the dyadic level, conflic-

tive and hence are more likely to capture different sides or blocs in a conflict. At the dyadic level, diffusion occurs, by definition, because one or more parties decide to join the war. These initial joiners are usually allies of belligerents, those bordering the belligerents, or rivals of the contending parties (see Vasquez, 1993). Because alliances encompass both rivals and non-rivals, as well as contiguous and non-contiguous states, it is the single most potent variable. Late joiners can be expected to be second-order neighbors, have less intense rivalries or be second-order rivals, or-- what is most likely--be cross-pressured by the above factors (the best example being Italy in World War I). Such complexities are best captured by the structural position of states within the various networks.

Different structural position in networks of rivalries and targeted alliances implies a relative state position that is a more complex manifestation of strategic affinity and reflects the constraining effect of network position that is likely to grow over the course of a diffusion of a conflict. War joining is brought about not so much by a direct rivalry but more often by a structure of rivalry linkages (Diehl and Goertz, 2000; Thompson, 2003) in which a given rivalry is linked to another rivalry either by a common foe, common dispute participation, and other factors. If one rivalry goes to war, it increases the probability that rivals linked to it will also go to war (see Thompson, 2003 on rivalries and World War I and Goertz and Diehl, 2000 on linked rivals). A network analysis operationalizes these rivalry structures in a way that allows for their changing role in war diffusion to be analyzed. At the outset of war immediate rivalries that can be coded in standard dyadic analysis are likely to be drivers of war joining behavior. The indirect relationships of rivalry structures that connect states through degrees of separation only make two states fight each in the wake of who has already joined. As war spreads, states are forced to calculate whether to join the war or not in the presence of a

greater number of belligerents. Hence, states with different structural positions within the targeted alliance and rivalry networks are expected to fight each other in the middle and later stages of the diffusion process.

> H7: In the earlier stages of the process, states with different structural positions in the network of alliances are more likely to fight each other.

> H8: In the earlier stages of the process, states with different structural positions in the network of targeted alliances are more likely to fight each other.

> H9: In the middle and later stages of the process, states with different structural positions in the network of rivalries are more likely to fight each other.

In sum, the ConflictSpace (Flint et al., 2009) approach requires simultaneous consideration of monadic, dyadic, geographic, and network scale factors and how these change over time (see Table 1 for a summary of the expected relationships). The capabilities of a state are expected to play a role in their relative ability to make decisions that are not determined by the context or opportunity structure. Over time, the roles of rivalries, targeted alliances, and alliances are expected to change. Dyadic relations and structural position are expected to each have effects, although their relative strength might vary over time.

4. Research Design

In analyzing the processes under which war diffuses to encompass more participants, we must first specify an appropriate spatial-temporal domain for our tests. We then move to provide operational measures for the factors discussed above, and finally construct the networks that constitute our ConflictSpace (Flint et al., 2009).

1) The Case

World War I provides a useful laboratory for our tests. That war began with the famous Sarajevo Crisis and represented at the time the largest and most deadly conflagration in modern history. As the war unfolded, various states joined the fray and indeed it can be argued that all state members of the international system were potentially combatants. Thus, World War I represents a case in which there were numerous instances of war joining as well as having states choosing not to join. There have been innumerable works that seek to explain the initial outbreak of World War I among the great powers (see Midlarsky, 1988 and most recently Zagare, 2010), but few treatments of its diffusion to a wider set of states, save for some idiographic treatments of individual state decisions (e.g., Aksakal, 2008; Abbenhuis, 2006). Furthermore, we concur with Bremer (1995) that the factors that bring about a war in the first place are likely to be different from the factors that facilitate its spread.

Joining behavior in World War I occurred across several years. This allows us the variation across space and time in the independent and dependent variables to assess diffusion processes. Our study includes all members of the international system (N=43) over the duration of World War I, 1914-1918. The total number of dyads in our dataset is 903 and 41 of them are war dyads. In order to pinpoint the causal factors behind states' war joining behavior at different moments of the war, we divided the war process into three stages to capture the dynamism of the war diffusion process. Following the incident in Sarajevo, a local war between Austria-Hungary and Serbia erupted and then expanded when seven countries joining in rapid succession: Germany, Russia, Belgium, France, United Kingdom, Japan, and the Ottoman Empire. We label this the first or early stage of diffusion, designated as the remainder of 1914. Almost 200 days after the Ottoman Empire

joined the war in 1914, Italy entered the war in May of 1915. Once Italy joined, Bulgaria, Portugal, and Romania successively joined the war through 1916. We label this the second or middle stage of diffusion. Finally the United States, Greece, Siam (Thailand), China, and Brazil entered the war in its final stage.

2) Data

Dependent Variable: The dependent variable is dichotomous, whether two countries are in the war during a given year (war=1, otherwise 0). This is done on a pair-wise or dyadic basis as not every state on a given side in World War I fought against every other state on the opposite side.

Independent Variables

Contiguity: To assess the role of geographical proximity, we tested several forms of contiguity, based on the different classifications in the Correlates of War (COW) dataset (Stinnett, et al., 2002). We settled on a dichotomous measure (0,1) on whether two states shared a homeland border, were contiguous by water up to 150 miles, and/or whether their colonies shared borders. The latter takes into consideration the global imperialist competition of the 19th century; this captures the possibility that many European imperial powers that did not share state borders could confront each other on the continents of Africa, Asia, and South America.

Alliances: We relied on the COW data set on alliances (Gibler and Sarkees, 2004). If two states shared a common alliance regardless of the level of agreements such as defense pact, neutrality, and entente it was coded as 1, otherwise 0.

Another alliance measure focused on targeted alliances, referring to a directional, negative relationship between states. Countries may have potential enemies in mind when they build alliances. We used the Leeds et al. (2002) Alliance Treaty Obligations and Provi-

sions (ATOP) dataset to build another dichotomous measure. For instance, the Germany-Ottoman Empire alliance signed in August 2, 1914 mentioned Russia as the object of the treaty. In this case, we coded Germany and the Ottoman Empire as targeting Russia. Because a targeted alliance is a directional relationship, the issue of reciprocity emerged requiring three different coding scores: 0 (there is no targeting between two states), 1 (one state targets another state), and 2 (two states are targeting each other). In the purely dyadic analyses, we collapsed codes 1 and 2 into a single category reflecting the idea that symmetry was not as important there as it would be in affecting networked relationships.

Rivalry: War may be ignited by the presence of historic layers of hostility, manifested as a sequence of militarized conflicts. The Klein, et al. (2006) rivalry dataset is a good proxy for ongoing military tension between states (they define a rivalry as two states that have had at least three previous militarized disputes). Here we measured this variable dichotomously, that is whether two states were engaged in a rivalry in a given year.

Beyond the three primary factors – contiguity, alliances, and rivalry – and their variations, we also included several other factors as control variables in decisions to join wars.

Trade Dependency: The role of trade dependency as a dampening influence on war joining behavior is debated (Keshk, Reuveny, and Pollins, 2010; Gleditsch, 2010). To include trade dependency as a control variable, we used the COW bilateral trade dataset (Barbieri, et. al., 2008). Trade dependency was simply calculated by dividing dyadic trade by the sum of the total trade for each state. To control for the instability of data, we used a ten year average of trade dependency. Unfortunately, trade data are not available during the course of the war, 1914-1918. Hence, the mean of trade dependency from 1904 to 1913 was used for all mod-

els.

Capabilities: We included Singer, Bremer, and Stuckey's (1972) combined capability index taken from the COW National Material Capabilities dataset, measured as a percentage of system share (proportion) for each state. This is consistent with the traditional interpretation that the most powerful states will be those most likely to enter the war, especially in its early stages. For the convenience of interpretation, we rescaled the capability index by a factor of 100.

Two additional variables were included to ensure that relationships beyond our theoretical focus were not influencing the results. Modeling war diffusion as a three stage process required a consideration of the impact of war joining behavior in the previous stage. The model of the second stage of the process included a variable to measure whether at least one of the states in a dyad had joined in the previous stage: coded 0 if neither of the states had joined in the previous stage and 1 if at least one of the states had joined in the previous stage. We were unable to include this variable in the modeling of stage three because the distribution of the variable produced a situation in which the congruence of war joiners in stages two and three prevented the calculation of correlation coefficients. This variable is labeled T-1 in the stage model.

3) Using Social Network Analysis to Define Structural Position

The core independent variables above are measured on a simple dyadic basis and indeed we use such measures in our analyses below. Yet our contention is that conflict context is made up of a broader space than the relations between neighbors. Thus, we take those same components and develop a multifaceted configuration of one state's relations with others, and thereby its propensity to intervene in a war against that potential opponent. In doing so, we use network analysis to define

a state's structural position vis-à-vis other states, which defines the surface of ConflictSpace.

Following Maoz et al. (2006), we use the structural equivalence measure in social network analysis (SNA) as a proxy for the similarity/dissimilarity of relational positions of states. Two actors are structurally equivalent if they have identical ties to and from all other actors in the network (Wasserman and Faust, 1994). For example, in our analysis the score between perfectly structurally equivalent states is 0, which happens between non-alignments themselves or states having exactly the same alliance portfolios, such as Austria-Hungary and Romania that have alliances with Germany and Italy in 1913. Hence at the dyadic scale, the relationship between alliance membership and whether two states fight each other is expected to be negative, but the structural equivalence variable is expected to show a positive relationship.

In this study, we use a Euclidean distance structural equivalence score to measure the positional similarity between two states. By definition EDSE can be expressed as below:

$$d_{ij} = \sqrt{\sum_{k=1}^{g} [(x_{ik} - x_{jk})^2 + (x_{ki} - x_{kj})^2]}$$

Where i and j are the nodes we are interested in and k are members in the network (k≠i and j). The Euclidean distance is the square root of the sum of squares in the difference, both in the rows and columns. For instance, if two states have four of the same ties and three different ties, the distance (dissimilarity) between the two states is the square root of 3 (1.732). The structural equivalence measure for each state for three core variables — alliances, targeted alliances, and rivalries — are included in our analyses below. It is important to note that the measure of similarity/dissimilarity between states' network position that we use is calculated by comparing the position of two states in a particular network of relations (alliances, targeted alliances, or

rivalries), and is then included in the model at a dyadic level.

We use a slightly different method for constructing a network-based measure of contiguity for each state in the dyad. Instead of looking at the dyadic contiguity, we use a network centrality measure to capture the position of an actor in the network. We use "betweenness centrality" (Freeman, 1977), a measure of centrality that shows how an actor is located between, or in relation to, other actors. The betweenness score is interpreted as a measure of the ability of an actor to control communication and interaction between non-adjacent actors (Wasserman and Faust, 1994). Mathematically, betweenness centrality is calculated as the portion of shortest paths between other actors that pass through a particular actor. In other words, it is a measure of how many links pass through a particular node and is, therefore, a measure of its importance in facilitating the overall connectivity of the network. The network betweenness score (CB) of actor ni can be expressed as:

$$C_B(n_i)=(\sum_{i<k} g_{jk}(n_i)/g_{jk})/[(g-1)(g-2)/2]$$

Where gjk(ni)/gjk refers to the portion of shortest paths including actor ni between actor j and k. To standardize the score, the maximum number of pairs not including ni is used as a denominator (Wasserman and Faust, 1994). According to the definition, actors located in the center of the network show high betweenness centrality score values. For example, just before the outbreak of the war the United Kingdom shows the highest score, followed by Germany, Ottoman Empire, Russia, France, and Austria-Hungary.

Methods of Statistical Analysis

The variables outlined above are included as explanatory factors in King and Zeng's (2001) rare event model that is calibrated to compensate for the biases in the probabilities of logit analysis that are inherent when events (i.e. war joining) are relatively rare. The model reports bias-corrected coefficients and relative risk (rather than probabilities) of the event occurring. Furthermore, we calculated robust standard errors that were clustered in an attempt to compensate for any intra-group correlations and to correct for possible heteroskedasticity in the data. Formal alliances were identified as the criteria for clustering because these formal arrangements clearly identify dyadic relations, have been identified in previous analyses as being strongly correlated with war joining behavior, and relate to the network relationships we included in the models. Three sets of dyads were designated based on dyads within the broader alliance network: isolates with isolates; isolates with non-isolates; and non-isolates with non-isolates. For example, when considering the UK-Germany and Germany-Russia dyads we are assuming that the possibility of war between these two dyads is not independent from other dyads composed of non-isolates. In contrast, the probability of war between Chile-Argentina is assumed to be independent from the Uruguay-Colombia dyad since they are isolated in the network of alliance ties.

We begin with a dyadic analysis, which is reflective of the standard way to examine diffusion processes. The second model includes only the structural equivalence and centrality measures and control variables before a final combined model including both dyadic and network variables is estimated. Separate statistical analyses are run for each of the three diffusion stages identified above. This approach allows for the evaluation of separate expectations as well as addressing the broader question of the explanatory role of structural context over the course of the diffusion process. In other words, are bilateral relations or structural positions more significant drivers of war diffusion at different stages of the expansion process?

5. Results

1) Diffusion in Stage 1

We begin with the first phase ("early joiners") in which nine states enter the conflict against various opponents. Table 2 provides a summary of the statistical results.

Looking at only the variables measured in a dyadic fashion, we find what might be termed as the conventional story for the outbreak of World War I (e.g., Sabrosky, 1975). Alliances with specific commitments (targeted alliances) are the driving forces behind the onset and initial expansion of the war; the Triple Entente(Alliance between Russia, France, and UK) and the Central Powers account for most of those who enter the war at this time. In addition, the major

powers enter the fight first, with the coefficients of the capabilities variables in the right direction and statistically significant at the .10 level (or at the .05 level in a one-tailed test, which is the appropriate test here because we specify direction). With respect to spatial proximity, the geographic contiguity of Austria-Hungary, Serbia, and Russia as well as the Germany-Russia border are notable. The spread of the war westward can also be identified in the contiguity of France and Belgium with Germany. Yet some states that neighbored the conflict did not enter, in the initial stage or indeed over the course of the whole war. For Denmark, the Netherlands, and Switzerland the risk, or opportunity, of joining the war from their physical location was not actualized. Despite these contrary cases, and with the inclusion of all states in the international system, geographic proximity does partially explain war joining behavior in the initial stage of the war.

Table 2. The Spread of World War I in Stage 1 (1914)

Level of measurement	Variables in Model	Dyadic Model	Network Model	Combined Model
Monadic	Capabilities A	0.12***(0.04)[1]	-0.01 (0.05)	0.04 (0.08)
	Capabilities B	0.14 (0.1)	-0.02 (0.06)	-0.01 (0.03)
Dyadic	Trade dependency	-0.06 (0.09)	0.37**(0.17)	0.03 (0.06)
	Geographic contiguity	1.11**(0.55)		1.23***(0.1)
	Alliance[2]	-	-	-
	Targeted alliance	2.63**(1.14)		2.49***(0.69)
	Rivalry	1.06***(0.34)		0.69 (0.64)
Network	Network contiguity A		0.02 (0.03)	0.02***(0.01)
	Network contiguity B		0.01 (0.04)	0.06***(0.01)
	(St. Eq.) Alliance		1.39 (1.27)	1.22 (0.99)
	(St. Eq.) Targeted alliance		2.8***(0.76)	2.7***(0.76)
	(St. Eq.) Rivalry		1.53***(0.27)	1.3***(0.09)
	Constant	-5.63***(1.1)	-14.52***(3.77)	-14.36***(4.6)
	N	903	903	903

1) Clustered robust standard error in parenthesis

2) The alliance variable at the dyadic level was dropped because of the matrix singularity in the logistic regression, which means an alliance has an obvious preventive impact in this stage.

In the combined model, targeted alliances and geographic contiguity are still statistically significant, and indeed one could probably not tell an accurate story about the outbreak of World War I without reference to the European focus of formal security agreements. Nevertheless, the networked measures of targeted alliances and rivalries are also significant, and therefore the story becomes more nuanced in that the dyadic alliance variable in combination with a state's position in networks of alliances and rivalries are also a factor in war joining behavior.

In the first stage of war diffusion, membership in a targeted alliance and contiguity to an initiator are major influences upon a state's decision to join the larger war. In addition, the networks of targeted alliances and rivalries promoted diffusion. Within the targeted alliance network Austria-Hungary plays a pivotal role in that it was a conduit for the connecting the alliances in the Balkans with the alliances across the great powers (see Vasquez et al., 2011). A war involving Austria-Hungary, unlike any other state, had the potential for spreading on either side of it. Furthermore, the network of rivalry relationships at the system level had been intensifying in the years leading up to the outbreak of World War I (Vasquez et al., 2011).

Compared to the importance of a state's membership in a targeted alliance at the dyadic level, network analysis makes it possible to examine the hostile relationship structure beyond direct linkages. Our calculation of the measure of structural equivalence identifies whether two states share common foes, which can be interpreted as a security preference (Maoz et al., 2006). In this sense, two countries can have similar security interests through sharing common foes (e.g. Austria-Hungary and Turkey share Serbia, and France and Russia share Austria-Hungary and Germany). A high structural equivalence score in our analysis indicates two states with very different positions in the overall network of targeted alliances, which may be

seen as different strategic affinities (Maoz et al., 2006). The same logic may be applied to rivalries. For targeted alliances and rivalries, the role of structural position, rather than direct dyadic relationship, expected to be a factor in explaining why states fight each other in the latter stages of the process of diffusion as the spread of the war creates ties between two states that had previously little or no connection when the war was in its infancy, was a factor at the outset. This result suggests that the development of networks can be seen as a precursor of war, and that a state's position in those networks is an important predictor of their likelihood to enter the war relatively early.

Geographic proximity is significant when taken in the context of networks; network contiguity is statistically significant for both states in a dyad going to war (or not). For example, the United Kingdom and Austria-Hungary, France and Austria-Hungary, and France-Ottoman Empire dyads are not geographically contiguous, but consist of states with high betweenness indices. In contrast, isolated states (such as the United States, Brazil, Spain) or those that are not prominent in the network (low scores of betweenness, such as Greece, Portugal, Norway, and Bulgaria) did not join the war in 1914. Contiguity promotes diffusion (i.e. contagious diffusion) in the first stage of the war as expected, and non-contiguous diffusion also played a role through the construction of networks of alliances and rivalries.

Overall, these results provide evidence consistent with several of our hypotheses. The combined model suggests that states that were geographically contiguous (H2) and most central in the broad network of physical connectivity fought each other in the first stage of the war (H3). The combined model also supports the hypothesis that states in targeted alliances will fight each other at this stage (H5), while the dyadic model finds a relationship at this stage between rivalry and war joining (H6). Hypothesis 8 (H8), that

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the structure of targeted alliances would account for early diffusion, is supported in the combined model. The similar finding for the structure of rivalries was not hypothesized to be present until later in the diffusion process (H9). However, this result does provide further evidence for the role of network structure in war diffusion, and suggests that the formation of networks prior to the outbreak of conflict are useful in leading to expectations of war diffusion (Vasquez et al., 2011).

2) Diffusion in Stage 2

Many analyses try to account for war diffusion with the same explanation or model, regardless of when a state joined (or did not join) the war (Hammarstrom and Heldt, 2002, Gleditsch, 2002, Vasquez, 2010). Our results for the group of states that entered the war in the second and third stages demonstrate that this is misguided. The simple dyadic analysis for middle stage joiners, reported in Table 3, shows that geographic contiguity is no longer significant while trade dependency becomes significant in the combined model. The targeted alliance variable is the only one that is positive and significant in the combined model, as it was in the previous stage. Once again, the combined model reveals some important factors that are obscured when only dyadic considerations are examined.

In addition, unlike the first phase of the war, middle stage joiners were concentrated among comparatively weaker states in terms of capabilities, such as Portugal and Bulgaria. Alliances play a role, but it is not the direct ties between two states that trigger additional entries into the war, or their absence reinforcing neutrality, but rather their networked position conditioned by the interconnection of these agreements.

In contrast to the first stage of the war there is no explanatory role for simple contiguity (meaning that H2 is dependent upon the process of diffusion), while the lack of significance for the network contiguity vari-

Table 3. The Spread of World War I in Stage 2 (1915-1916)

Level of measurement	Variables in Model	Dyadic Model	Network Model	Combined Model
Monadic	Capabilities A	0.01 (0.08)	-0.09***(0.03)	-0.14***(0.04)
	Capabilities B	-0.01 (0.07)	-0.22***(0.06)	-0.19 (0.15)
Dyadic	Trade dependency	-0.05 (0.21)	0.45***(0.07)	0.23***(0.09)
	Geographic contiguity	0.72 (0.53)		0.89 (0.54)
	Alliance	0.94 (0.91)		1.44 (0.93)
	Targeted alliance	1.46***(0.46)		1.69***(0.04)
	Rivalry	2.29***(0.65)		1.79 (1.13)
Network	Network contiguity A		0.01*(0.01)	0.03 (0.04)
	Network contiguity B		0.02 (0.08)	-0.02 (0.16)
	(St. Eq.) Alliance		2.02**(0.85)	2.44***(0.77)
	(St. Eq.) Targeted alliance		0.64 (0.56)	0.27 (0.79)
	(St. Eq.) Rivalry		1.29**(0.55)	1.97 (1.57)
	T-1	1.76***(0.65)	0.9 (1.01)	0.52 (1.41)
	Constant	-5.58***(1.47)	-10.82***(2.07)	-12.56***(1.57)
	N	887	887	887

Table 4. The Spread of World War I in Stage 3 (1917)

Level of measurement	Variables in Model	Dyadic Model	Network Model	Combined Model
Monadic	Capabilities A	0.1***(0.03)	0.05**(0.03)	0.04 (0.03)
	Capabilities B	0.08 (0.06)	-0.08 (0.1)	-0.12 (0.08)
Dyadic	Trade dependency	0.03 (0.09)	0.19***(0.05)	0.18 (0.13)
	Geographic contiguity	-0.28 (1.69)		-0.82 (1.61)
	Alliance	0.62 (1.07)		0.54 (0.97)
	Targeted alliance	1.7 (1.54)		1.47 (2.52)
	Rivalry	1.63**(0.66)		1.57 (1.61)
Network	Network contiguity A		0.01 (0.02)	0.02 (0.03)
	Network contiguity B		0.03 (0.1)	0.06 (0.12)
	(St. Eq.) Alliance		0.48 (0.62)	0.42 (0.61)
	(St. Eq.) Targeted alliance		0.86***(0.1)	0.82***(0.22)
	(St. Eq.) Rivalry		1.58***(0.07)	1.7***(0.07)
	T-1[1]	-	-	-
	Constant	-4.96***(0.77)	-9.48***(1.3)	-9.43***(1.46)
	N	832	832	832

1) The T-1 variable was dropped because of the matrix singularity problem

ables supports the expectation that more geographically peripheral states joined the war against more geographically central states that were already in the war (H3). It is in this middle stage of the diffusion process that structural position in the network of alliances becomes significant, rather than the first stage (H7). This implies that the alliances that have not "tightened" as much (those without a specified target) take longer to diffuse war, a finding that would lead us to reformulate H7.

3) Diffusion in Stage 3

In the final diffusion phase of the war only the network rivalry and targeted alliance variables are significant, as shown in Table 4. This is largely because most states that had particular commitments in the targeted alliance network had already joined the war; that is, the explanatory power of the dyadic relation-ship has largely been spent. Thus, individual alliances (including targeted alliances) as well as position in these networks account for entries in the late stage of the war. Narratives of World War I have often focused upon their role in initiating the conflict, but our analysis shows that the pattern of targeted alliances provides a context that was a driver for war joining behavior throughout the conflict. The difference is that the direct relationship, at the dyadic level, becomes replaced by position in the structure that is formed by the combination of targeted alliance dyads. In other words, the context of network structure that is built by individual state actions in the initial stages of the conflict becomes a driving force in the actions of states in the latter stages.

The structural equivalence measure of rivalry and its significance are especially enlightening in accounting for the US entry into the war in 1917. Prior to 1916, the US was not part of the key rivalry network, not linked

to any of those fighting on the European continent. Yet its hostile interactions with Germany during the early stage of the war (e.g., sinking of the Lusitania) brought the US into a militarized rivalry with Germany. Accordingly, the US moved from being an isolate to occupying the same rivalry network position as Germany's other major power rivals (France, UK, Russia), all of whom were already in the war (see Figure 1). Brazil's seemingly anomalous decision to go to war against Germany toward the end of World War I is explained in our framework by its alignment with the US. Similarly, Greece's position in the rivalry network tightened just before its war entry. It has had a pre-war rivalry with Turkey, but during the initial stages of World War I also developed a rivalry with Bulgaria and thereby made it a player in the web of the ongoing war.

The development of a US-Germany rivalry took place within a structure of rivalries that also saw the development of France-Greece and Romania-Bulgaria rivalries. Although there are only three new dyadic rivalries added between phases 2 and 3, the structural positions of actors in the whole network changed. The development of a rivalry with Germany marked a moment when the United States assumed a similar structural role (with similar structural equivalence scores) to other powerful states (the United Kingdom and Russia). In other words, the US became embedded within the structure of rivalries that the isolationists had long wanted to avoid, and had played such a role in the earlier spread of World War I.

The analysis of the last stage of the diffusion process offers mixed support for our hypotheses. The lack of significance for any dyadic variables but the significance of network variables suggests the validity of H1, as network position is the only predictor of war joining behavior in this stage of the process. The insignificance of the contiguity variable remains (H2), suggesting that geographic proximity is a driver of the

initial stages of war diffusion. The insignificance of the network contiguity variable confirms the expectation that the more peripheral states will join later (H3). The insignificance of the dyadic rivalry (H6) and targeted alliance (H5) variables in this late stage confirms our expectations.. The significance of the network rivalry in this stage helps confirm H9 but the significance of the targeted alliance at this stage runs counter to H8.

6. Conclusion

Conventional treatments of war diffusion focus extensively on dyadic relationships conditioned by geographic opportunity, whose impact is thought to be immutable over the course of the conflict. Our approach and findings indicate that such conceptions are at best incomplete, and more likely misleading. Dyadic analyses obscure the broader context under which state decisions to enter war are made. The comparison of variables at the dyadic and network levels show that understanding the diffusion of war requires simultaneous recognition of the actions of states, or their willingness, and the context, or opportunity structure within which they operate. That opportunity structure is a combination of relative geographic location and networks of political relations. Simple geographic contiguity was found to be a poor explanation of war joining behavior, while centrality and marginality within the whole geographic pattern were also important.

The results of our analysis also demonstrate that the diffusion of conflict involves different driving forces over time. In the case of World War I, the familiar story of great powers exercising animosities that had already been put in place through targeted alliances is confirmed by our analysis (Sabrosky, 1975). This story holds for the crucial period of the second round of joiners that made World War I a global conflagra-

tion. In this period, the structural positioning of states in targeted alliances is decisive. Rather than a simple linear progression in which network position becomes more important over time (H1), we provide evidence of a constant and complex relationship between dyadic relations and network position over the course of the diffusion of war. Even though the hypothesis is not supported, the more general theoretical claim that the surface of opportunity is altered through the stages of war diffusion remains; but the process is complex and recursive and is different for different types of political relations.

The other contribution of our analysis is illustrating how the use of social network analysis identifies the dynamic character of the opportunity structure that should be understood as the contextual background for the decisions of states. We are able to create an opportunity surface that integrates the structure of political relationships with relative geographic position. As the behavior of individual states changes so too does the structure of the totality of relationships which, in turn, will provide a new opportunity structure for states. Utilizing the analytical capabilities of social network analysis goes some way towards tackling the critique of the way context has been approached in quantitative analyses of war (O'Loughlin, 2000). The context of a state's actions is not just its situation in relation to other states, but a matter of its betweeness or situation within the totality of political relationships.

Social network analysis is a valuable tool for characterizing the surface along which diffusion processes operate. Yet this approach is not a substitute for effective theorizing. We have examined several factors (e.g., geography, alliances, and rivalries) associated with the spread of conflict, but this is by no means a full list of key influences, especially as one moves to later phases of the conflict. Thus, scholars must move beyond the standard concerns addressed in this article, and the literature more broadly, for a complete understanding

of war joining behavior. Social network analysis is also suggestive that theoretical arguments underlying the analyses might need to be revised. Indeed, that some of our expectations regarding the interaction of dyadic and network relationships were not supported by the analysis suggests that theorizing how the actions of states build a surface of opportunity, or context, while being simultaneously constrained by that context is very complex.

In summary, what we find is that in the initial stages of diffusion, the structure of contiguity, rivalry, and targeted alliances working with dyadic targeted alliances and geographic contiguity are the most prominent drivers of the initial joining of states in 1914. In the middle or second stage of diffusion, the structure of alliances in general (as opposed to targeted alliances) and working with dyadic targeted alliances come to the forefront. One of the capabilities measures is significant and negative, most likely indicating that most joiners are middle or weaker powers. In the late stages, only network level variables are significant. What is important about this finding is that the changing structure of rivalries in this late stage of diffusion is a product of the dynamics of the war which, in turn, has a significant impact upon states' war joining behavior.

Most of the logics about the spread of war are based on passive conceptions of diffusion in a dyadic context (see Goertz, 1994). As one moves to multifaceted and network conceptions, the rationale underlying those processes might also need to be modified. For example, being embedded in a tight network of alliances creates decision logics different than merely having an obligation to another state to come to its aid in the event of war. In this way, theorizing about social networks has lagged behind its applications. Finally, social networks might have path dependent or lagged effects on conflict behavior. In our study, we looked at the effects of network configurations on current behavior. Yet earlier structural arrangements and the patterns

of their evolution might condition future behaviors. Such relationships not only have theoretical and empirical import, but also potentially important policy consequences (e.g., whether alliance formation makes counter-alliances more likely, which in turn contribute to the spread of war once it occurs).

Acknowledgement

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