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Network Embeddedness and the Rate of Water Cooperation and Conflict

James Hollway

Introduction

Managing water resources across borders of any scale is challenging (Lubell 2013; Ingold et al. 2016), but international basins present a special challenge. Comprehensive governance of international basins is rare (Wolf et al. 2003; Conca 2005) and many practitioners and scholars remain concerned that demographic dynamics, agricultural pressures, and climate change (Fischhendler 2004; Tir and Stinnett 2012) may make international "water wars" more common in the future (Hensel and Brochmann 2009). While studies have repeatedly found that water-related cooperation is more common than conflict (Wolf et al. 2003; Kalbhenn 2011), many country dyads do slip into water-related conflict. This chapter asks: why is cooperation more frequent than conflict?

To date, the literature on international water management has focused on three main areas: the establishment of international water agreements

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or organizations (e.g. Dinar et al. 2011; Zawahri and Mitchell 2011; Tir and Stinnett 2012); the relationship of freshwater scarcity to militarized interstate disputes (e.g. Furlong et al. 2006; Gleditsch et al. 2006); and the frequency of water cooperation or conflict events (e.g. Yoffe et al. 2003; Hensel and Brochmann 2009; Kalbhenn 2011; Bernauer and Böhmelt 2014). This latter “basin at risk” literature is particularly advanced in collecting, coding, and analyzing date-stamped data on water-related cooperative and conflictual events between countries.

However, though these literatures regularly employ statistical models in addition to case studies (Wolf et al. 2003; Zeitoun and Mirumachi 2008; Brochmann and Gleditsch 2012), there are few applications of network models (Berardo and Gerlak 2012, being a rare exception). While statistical network models are increasingly used to study water policy networks (e.g. Ingold et al. 2016) and complex networks of international institutions in other environmental fields (Biermann et al. 2020), the author is not aware of any that model water events as a network. This is lamentable, since three central dependencies in these “basin at risk” datasets lend themselves to network theories and methods. First, cooperation and conflict are not mutually exclusive (Zeitoun and Mirumachi 2008), as sometimes treated in this literature, but may prompt or suppress the other. Second, states’ cooperation and conflict over water resources are often public, which may allow states to condition their behavior on the behavior of others that they observe. Third, because these events are date-stamped, there is information about the sequencing and, indeed, timing of cooperation and conflict within and across dyads that can be exploited to support inference about not only with whom states cooperate or come into conflict but also when.

This chapter demonstrates that network mechanisms can help explain why some states act cooperatively and conflictually more often than others as well as with whom they cooperate or come into conflict. While the social networks literature to date has been more interested in the latter, regarding actors’ choices, we should also begin to explore the corollaries most network mechanisms have for the rate of network activity of different types. The chapter argues, for instance, that a state’s embeddedness in triangles of local cooperative or conflictual behavior affects its rate of cooperation and conflict.

This chapter makes four main contributions. First, it complements other chapters in this volume by offering an example of applying social network theory and models to study *international* water cooperation and conflict. Second, it offers a first application of statistical *network* models to international water events. It models international water events as network events using dynamic network actor models (DyNAM; Stadtfeld et al. 2017a) to model not only the location but also the timing of cooperation and conflict events. Third, it demonstrates for the first time the use of DyNAMs for coevolving, signed networks. Fourth, it represents one of the first empirical emphases by an actor-oriented network model of the rate rather than choice part of the model.

The rest of the chapter is structured as follows. The next section outlines key expectations from network theory about where and when cooperation and conflict should take place, and summarizes typical theoretical expectations about international water cooperation and conflict from the literature on political geography, political economy, and political institutions. The following section describes the International Rivers Cooperation and Conflict (IRCC) water event data used here. Next, I introduce the DyNAM model and briefly explain how coevolving signed DyNAMs can be modeled. The penultimate section presents and interprets the results obtained by fitting this model to both water cooperation and conflict events. Finally, I conclude by reflecting on the main findings and their generalizability, the practical policy advice that can be drawn from them, and potential next steps for scholarship in the area.

Theory

This section introduces the insights political networks can offer on what makes international water cooperation more frequent than conflict, before recounting typical expectations currently highlighted in three main literatures related to water events: political geography, political economy, and political institutions.

Theories of Political Networks

The "basins at risk" literature conceives of cooperation and conflict as events that occur on a particular date from one state to another. Although these events are associated with particular date-stamps, they have more enduring salience, persisting in the memory of the actors that experienced them and, when public, beyond. As these events accumulate, they can be conceived of as constructing a network of events between actors that structures and informs when and where future events occur. This is important, since these events are not independent but cluster in dyads and triadic configurations. Political networks encourage us to not only account for such clustering, which would otherwise lead to underestimated standard errors, but also associate such configurations with endogenous processes and mechanisms of interest. As Soliev et al. (2017, p. 148) argue, "network effects […] form the so-called 'baggage' in riparian relationships". Such "baggage" can slow or accelerate further cooperation and conflict. In this chapter, I outline three basic network configurations, oriented around monads, dyads, and triads, and outline expectations for how they affect both cooperative and conflictual timing (rate) and location (choice). This paper emphasizes the third set of effects as most illustrative of a network approach and most interesting for water management.

First, cooperation and conflict tend to follow past cooperation and conflict. Actors regularly repeat past events, establishing well-worn patterns (Uzzi and Lancaster 2003): we would expect a cooperative actor to continue cooperating (and, perhaps, avoid conflict) and an actor that has been in conflict recently to repeat this (and avoid cooperation). This activity effect is outlined in Fig. 4.1(a), where the dashed line represents a new event and the solid lines the recent events. We would also expect repetition in a state's choice of cooperation or conflict partner. In the international water management literature, this has been operationalized as "peace history" (e.g. Brochmann and Gleditsch 2012), but here we measure this as the entrainment of past cooperation and conflict on recent behavior (see Fig. 4.1(d)).

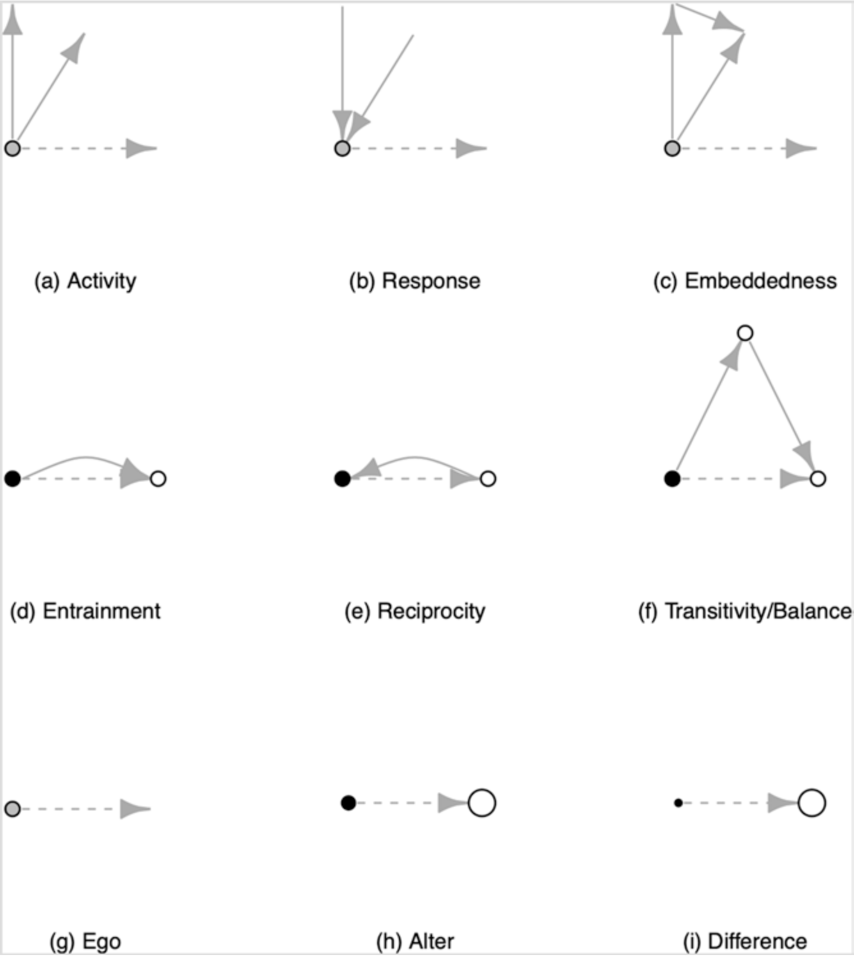

Fig. 4.1 Effects

Second, incoming network ties are also important for when and with whom states cooperate or come into conflict. Directed events demand a response (Fig. 4.1(b)) from the recipient actor while the event is still salient, though not necessarily in kind. Being on the receiving end of conflictual behavior may demand a cooperative response, if not with the sender then with others. Where the target chosen is specified as the sender of a previous event, we speak of reciprocation (Fig. 4.1(e)). Failing to respond directly would be to implicitly accept status inferiority (Gould 2002, p. 1151). Wolf (1997) highlights how a lack of recognition in Palestine and Kurdish examples blocked cooperation. But we might also expect events to be exchanged, with actors reciprocating conflict with cooperation, as they seek to settle issues. For example, responding to a conflict-inducing action with a timely cooperative move, such as information-sharing or financing, can defuse the situation and restore cooperation (Wolf 1997, p. 350).

Perhaps the classic social networks dependencies, however, are those that involve triadic configurations where an actor's partners are themselves connected. These are most commonly elaborated in the context of partner choice (transitivity, Fig. 4.1(f)): we are more likely to befriend a friend's friend, for example (see Granovetter 1985, p. 490). Since the current network is signed, including both positive (cooperative) and negative (conflictual) events or ties, "structural balance theory" may also be applicable (Cartwright and Harary 1956). This theory argues that unbalanced configurations, such as being in conflict with a cooperative partner's other partner, induces cognitive dissonance for the actors involved that demands resolution through, for example, cooperating with this other partner or expanding the conflict. Third parties can support the restoration of a cooperative relationship by potentially brokering the resolution of any disagreements (Wolf 1997, p. 350; Simmel 1950). We would thus expect balanced configurations to be more likely than unbalanced configurations:

H1 *Actors are more likely to cooperate with cooperative partners' cooperative partners*

H2 *Actors are less likely to be in conflict with cooperative partners' cooperative partners*

H3 *Actors are more likely to cooperate with conflict partners' conflict partners*

H4 *Actors are less likely to be in conflict with conflict partners' conflict partners*

Expectations for the application of triadic configurations on rate are less well elaborated, at least directly. Granovetter (1985) argued that actors' embeddedness in their local networks affected how they perceived and acted within the network. Sets of cooperative partners can reinforce cooperative norms and sets of conflict partners may reinforce norms of conflict too. Therefore, one might argue that the more an actor is embedded in cooperative triads (Fig. 4.1(c)), the more it will cooperate, and the same with conflict. This can be contrasted with structural holes theory, in which Burt (2004) argues that those who are less embedded are freer to exploit opportunities in the network afforded by their brokerage positions, and consequently act more often. We would thus expect the relationship between embeddedness and rate to be inverted. Here I outline the main expectations of embeddedness:

H5 *Actors are more likely to cooperate when embedded in recent cooperative triads*

H6 *Actors are less likely to act conflictually when embedded in recent cooperative triads*

H7 *Actors are less likely to cooperate when embedded in recent conflictual triads*

H8 *Actors are more likely to act conflictually when embedded in recent conflictual triads*

These eight expectations relate triadic configurations of past cooperation and conflict to the timing (rate) and location (choice) of further cooperation and conflict and represent the main hypotheses investigated in this chapter. To support identification of these network effects however requires that we also control for common explanations in the three literatures that have treated water-related cooperation and conflict to date.

Theories of Political Geography

A common factor expected to provoke or ameliorate conflict is the availability or scarcity of water. This is in line with a neo-Malthusian perspective that expects resource scarcity to provoke conflictual behavior (Hensel and Brochmann 2009). Zawahri and Mitchell (2011) find that greater dependence on cross-border freshwater resources makes cooperation more likely, while higher precipitation levels make it less likely. I therefore expect water availability or scarcity to drive both cooperation and conflict.

Another factor is the dependency of a downstream state on an upstream state for appropriate water quantity and quality (Mitchell and Keilbach 2001). Scholars have put considerable effort into measurement here (Furlong et al. 2006; Gleditsch et al. 2006; Beck et al. 2014), perhaps driven by mixed results. Furlong et al. (2006) and Gleditsch et al. (2006) were unable to distinguish whether upstream/downstream geography impacted militarized interstate disputes, Dinar et al. (2011) found that the riparian configuration was significant in only part of the estimates, and Munia et al. (2016) found no direct relationship between upstream water use and the number of conflictive and cooperative events. Brochmann and Gleditsch (2012) argue that any specific riparian relationship simply confounds the overwhelming effect of contiguity on the frequency of interstate relations, conflictual or cooperative, noting that only 17 contiguous dyads do not share a river. I therefore expect no relationship for water dependency, but for contiguity.

Theories of Political Economy

An abiding expectation for interstate cooperation is that democratic countries behave more cooperatively. A neo-Kantian perspective maintains that democracies cooperate more together (Mansfield et al. 2002), and Brochmann and Gleditsch (2012) find that political regime type significantly affects water cooperation and conflict. But democracies also better govern water resources internally, leading to fewer internal water-related conflicts that can spill out (Wolf 1997).

More developed countries are also expected to be more cooperative. Like democracies, developed countries may have better governance and the capacity necessary to resolve conflicts. Dinar et al. (2011) find that more developed states are in a position to provide incentives, such as financial transfers, to less-developed states so as to facilitate an international agreement. But developed countries may also have access to alternative sources of water to mitigate water dependency, and Wolf (1997) argues that different levels of development can exacerbate conflict.

Theories of Political Institutions

While there is currently no overarching water convention (Dellapenna and Gupta 2008)—though the United Nations Watercourses Convention of 1997 has been in force since 2014, many key riparian states have not ratified or acceded—there are hundreds of bilateral and multilateral water agreements currently in place (Zawahri and Mitchell 2011). The literature on institutional design and effectiveness in International Relations have classified a range of institutional features (see Koremenos et al. 2001), five being most common in the literature on water cooperation (Mitchell and Keilbach 2001; Berardo and Gerlak 2012; Tir and Stinnett 2012): delegation, allocation, enforcement, dispute resolution, and flexibility.

Some riparian states have delegated governance functions to regional basin organizations (RBOs) (Wolf 1997). RBOs' secretariats play various roles that can help states absorb stresses from competing water uses. Secretariats can reduce transaction costs to further cooperation (Wolf 1997; Zawahri and Mitchell 2011) through what Schmeier and Shubber (2018) call "institutional anchoring". For example, the Mekong River Commission Secretariat has been key in mitigating conflicts around parties' infrastructure projects (Schmeier et al. 2015).

Water institutions also vary in how explicit and clear water allocation rules are, though the effect is not as clear. On the one hand, unclear or contested terms have been found to lead to conflict (Hansen et al. 2008), and clear allocation rules should mitigate disputes since there is less space for debate. On the other hand, clear allocation rules can also constrain parties leaving conflict the only recourse. Rayner et al. (2005) argue that while water managers' prefer highly specified institutionalized systems to ensure reliable water access under typical scenarios, these systems can falter when challenges, such as flow variability, occur. Though managers usually seek cooperation in response, unreciprocated cooperative moves can lead to blame, disputes, and conflict.

Strong enforcement mechanisms are generally thought to consolidate cooperation and stave off conflict. Institutions can consolidate cooperation by enforcing a pattern of cooperation that helps preclude disputes (Wolf 1997, pp. 349–350), but Hansen et al. (2008) argue this depends on the enforcement capabilities of the institution itself. One challenge with all these institutional features, however, is their political feasibility (Fischhendler 2004). Instituting cooperation with strong enforcement mechanisms may not be possible where it is needed, and instituted where it is not.

Institutions endowed with dispute resolution processes are also thought to facilitate cooperation and conflict resolution. Mechanisms to settle disputes vary, from binding arbitration or adjudication to non-binding mediation, though in practice, many are "innocuous", requiring little more than meetings (Wolf 1997). Still, the ability to even facilitate agreement over scientific data can have important ramifications for a conflict's resolution. Hensel and Brochmann (2009) find that, although river agreements do not prevent conflict, they provide a starting point for negotiations over disputed river claims and can more speedily return a relationship to a more cooperative setting.

Lastly, designing flexible institutions can support cooperation in the face of conflict. Since one stressor in riparian relationships is fluctuation in resource availability, institutions that can adapt to changing circumstances will be more resilient (Yoffe et al. 2003). Fischhendler (2008) discusses the utility of ambiguities left in the original arrangement to allow for flexibility as problems and preferences change. Though it can lead to protracted disagreement, Fischhendler argues that institutional adaptations do not happen in a vacuum, but depend on the roles and preferences of the actors around the institution.

Case

To identify lessons on water cooperation and conflict that might generalize to international river basins around the world, scholars have sought to complement existing case studies with the analysis of datasets that record interaction *events* between countries (Zeitoun and Mirumachi 2008). Event databases have a long history in International Relations. Originating in the early 1960s, event databases scrape news media sources for day-to-day interstate interactions, and then manually or automatically code them to some scale of cooperation and conflict.

International water governance has seen some of the most extensive and targeted efforts in this area, certainly more so than in other environmental fields. Here I consider two of the most recently developed datasets, the Transboundary Freshwater Disputes Water Events Database (TFDD; Yoffe et al. 2003; Wolf et al. 2003) and the International Rivers Cooperation and Conflict event database (IRCC; Kalbhenn 2011; Kalbhenn and Bernauer 2012; Bernauer and Böhmelt 2014). Unlike earlier efforts, both collect both cooperative and conflictual events and are specifically water-related. This issue focus and type scope enables more complete, precise inference on international interactions.

This chapter uses the IRCC data for two main reasons. First, the IRCC data are transparently coded from a more homogenous set of sources. Though the TFDD offers data for a longer time period (1948–2008 compared to 1997–2007), as Bernauer and Böhmelt (2014, p. 121) explain, "major changes in the availability of news media texts over time (notably the advent of the digital revolution) make it problematic to use event data coded from partly changing sources for a very long period of time". In any case, despite the shorter time frame, the IRCC dataset includes more of certain types of events. Second, many water-related events, whether statements or actions, are directed. The TFDD does not code the direction of events, but the IRCC does. However, Kalbhenn and Bernauer (2012) suggest that "[d]isaggregating the data to monthly, weekly, or even daily events makes little sense in our context because most covariates commonly used in this area of research (e.g. economic indicators, political system data) are only available on a yearly basis". But while indeed GDP is only recorded annually, the Polity dataset offers a date-stamped record of changes to countries' level of democracy or autocracy. Moreover, if the events are date-stamped, then we can make more precise inference about the sequencing of events between different actors and of different types. I thus use the date-stamped IRCC event data.

The data used in this chapter are thus all the water events with date-stamps in the IRCC database. Figure 4.2 plots the distribution of events according to their IRCC score, which ranges between −6 (most conflictive, i.e. violent interstate dispute with declaration of war) and +6 (most cooperative, i.e. ratification of freshwater treaty) (see Kalbhenn and Bernauer 2012, for more details). In practice though, relatively few events were coded beyond 3 in absolute value. At the extremes are, for example, Israeli air raids that targeted an area being excavated as part of the Al-Asi Dam project on the Lebanese-Syrian border (coded −5), or India and Bangladesh signing an agreement to share the water of the Tista and six other rivers (coded 5).

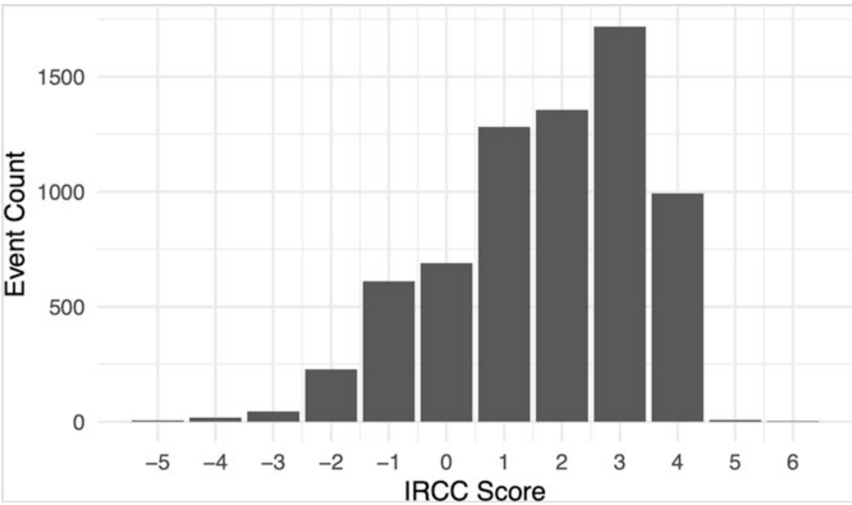

Fig. 4.2 IRCC water cooperation and conflict events

Figure 4.2 shows a left skewed distribution, corresponding to the observation that water cooperation is more common than conflict. Since the middle of the range is less distinctive (the difference between −1 and −2, for instance, is whether a statement is "mild" or "strong"), I follow previous work in binarizing this distribution into "conflict" and "cooperation" events, which also aids in relating results to this literature. All events with an IRCC score more than 0 were classified as cooperative, and all events with an IRCC score less than 0 were classified as conflictual. Given the rarity of "water wars", this category can perhaps better be categorized as political *disputes*, but regardless of label, these negatively signed events are worth examining separately from cooperation. As Zeitoun and Warner (2006, p. 437) state: "the absence of war does not mean the absence of conflict". Those events with an IRCC score of exactly 0 were coded as a third, neutral category and not modeled here. This resulted in a total of 908 conflictual events and 5360 cooperative events.

Here I define an event as a date-stamped action from a sender to a receiver. Agreements are defined as two directed actions, one each way. There is an important duality here though: these actions are instantaneous (within the continuous-time assumptions of the model) but also define the starting point of a tie through the residue such a tie creates.

This data comprises 104 states that sent or received at least one cooperative or conflictual water event in the period in question (1997–2007) as the nodes of the network. There are thus 1.0712×10^4 potential dyads in the data, though many of these are empty since water cooperation and conflict is largely spatially local. It is, however, not exclusively spatial and so tie opportunities were not constrained to contiguous dyads, despite the option being available in the most recent version of goldfish, the software used. This is later validated by the absence of strong contiguity effects.

One way to explore how dyadic relationships, defined as chains of interactions, have progressed is as a sequence (for a recent introduction to sequence analysis, see Cornwell 2015). Figure 4.3 plots the trajectories of IRCC scores in each directed-dyad relationship (that is, India-Pakistan and Pakistan-India each receive a line). Two chief observations can be drawn from this plot. First, the density of lines toward the left hand part of the plot signal that many relationships are relatively short, though the

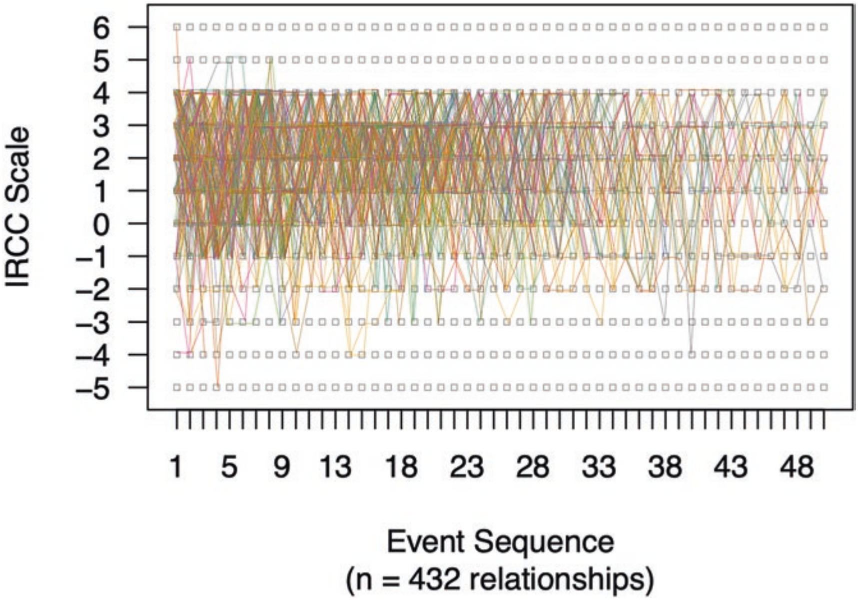

Fig. 4.3 Event sequences

thick lines extending half way across the plot also indicates that many relationships see a longer history of interactions. Indeed, while Fig. 4.3 only plots relationships up to 50 interactions to improve readability, several relationships had much longer chains of interactions. For example, in this period, Hungary sent 238 events (cooperative and conflictual) to Slovakia, and Slovakia reciprocated by sending 173 events. Similarly, Romania and Ukraine sent each other 215 and 165 events, respectively. In all, 21 directed dyads have chains of events during this period that are longer than 50 events.

Second, the line density in the middle of the graph between −1 and 4 accords with 1 and the finding that water wars are rather rare. But it also shows that most relationships over a number of events experience cooperative and, at some point, conflictual or neutral events. Cooperative relationships rarely stay cooperative; nor are conflictual relationships consigned to remain conflictual. Indeed, it is possible to see a common sequence early in the relationship as shown by where the lines are thickest. Relationships seem to often start cooperatively, then fall into some conflict by the third or fourth event, before returning to more cooperative relations. As De Stefano et al. (2010, p. 873) note, while a series of events may pass through several conflictive intensities over time, the process does not necessarily evolve linearly.

Such event data does have its caveats (see Schrodt 2012). First, many international events often go unreported, because they either are not deemed newsworthy or are kept hidden for strategic reasons. Second, popular media often presents a biased record of events, generally favoring the country in which they are based. Third, the data quantity that can be collected can introduce sensitivities relating to coding rules. It is therefore important that these are as transparent as possible. Overall though, event data can serve as an efficient trace of cooperative and conflictual relations between states, offering an improvement in granularity and the avoidance of some biases over other types of data often used.

Methods

The political science literature on international water cooperation and conflict has taken two main methodological approaches. Perhaps the most common approach remains the case study (e.g. Bréthaut 2016; Verweij 2017). Case studies can offer a rich account of specific interstate water relationships, but are said to struggle with generalization, despite a few comparative efforts (e.g. Knieper and Pahl-Wostl 2016). The principal alternative is the growing number of econometric studies of water event data (Furlong et al. 2006; Gleditsch et al. 2006; Hensel and Brochmann 2009). Yet, there have been remarkably few works that explicitly look at temporal dependencies in such data let alone structural dependencies.

Statistical network models offer various ways to not only account for but also explicitly explore structural dependencies (Lubell et al. 2012). Classic network models include exponential random graph models (ERGMs; Lusher et al. 2013) and stochastic actor-oriented models (SAOMs; Snijders et al. 2010). There are important differences relating to whether they are tie-based or actor-oriented and how they treat time (see Block et al. 2016, 2018), but neither are really equipped to fully leverage date-stamped tie data (events) because they explore dependencies among tie observations by simulating the most likely series of tie changes that lead to network structures and dispense with any information about the order of ties/events.

Two other statistical network models are better equipped, however: relational event models (REMs; Butts 2008) and dynamic network actor models (DyNAMs; Stadtfeld et al. 2017a). Both ultimately model the rate at which we expect to see ties in particular configurations (readers are referred to Stadtfeld et al. 2017b, for more details). The chief distinction between them is that, as an actor-oriented model similar to SAOMs, DyNAMs separate the overall tie rate into two functions as shown in equation 1: a Poisson process governing the rate at which actors make ties, and a multinomial choice model that, given a particular actor chosen to make a tie (i), governs which other node she chooses (j rather than any other node from among the set of A others). Each function can be specified with statistics (s or t) that capture salient, current features of the network, such as nodal attributes or structural configurations. How these are weighted by parameters θ (for the rate function) and β (for the choice function) determine actors' competing rates and competing attractiveness as a recipient for a tie, respectively.

$$\lambda_{ij}^{\text{DyNAM}}(x,\theta,\beta,s,t,A) = \underbrace{\exp(\theta^T s(x,i))}_{\text{Rate}} \underbrace{\frac{\exp(\beta^T t(x,i,j))}{\sum_{k\in A}\exp(\beta^T t(x,i,k))}}_{\text{Choice}}$$

This two component structure suggests a literal interpretation that an actor first becomes active and then decides to which other node to send a tie. However, this is not a necessary interpretation. Just as a choice function need not be interpreted literally as actors operating under strict and explicit utility maximization rules, but as capturing how a concatenation of different factors conjoin to make some ties more likely choices than others, so too can the separation be seen as largely artificial as a way to allow researchers more flexibility in specifying models and to allow them to interpret timing and choice separately.

DyNAMs have three main advantages: precision, performance, and properties. First, because they use information about the order and timing of events, they offer greater precision than SAOMs, and because they allow a flexible specification of rate and choice, they also offer greater precision than REMs. Second, because they model information about tie ordering directly, they can forego the simulation SAOMs and ERGMs rely on, and because they separate tie rates into actor rates and choice, they also involve a lower order of computational complexity than REMs. Details about the estimation are provided in Stadtfeld et al. (2017a, b) and Stadtfeld and Block (2017) illustrate the comparison with REMs in particular. Lastly, DyNAMs allow a plethora of new effects that leverage information contained in events' timing. This chapter demonstrates two of them: windowed effects that only count configurations within a specific temporal window, and weighted effects that depend on how many events have been sent.

This chapter also demonstrates how signed networks (discussed in Stadtfeld et al. 2017a) can be modeled as coevolving directed networks (introduced in Stadtfeld and Block 2017) to explore dependencies between positive and negative valence ties. As described in Stadtfeld et al. (2017a, pp. 17–18), signed networks can be modeled as dependent subprocesses, using effects that capture structural configurations relating to one network in the model specification for the other network to model dependencies between them. It also represents one of the first empirical studies that fully leverage the flexibility of the rate function for exploring variation in the rate of actors' activity.

The main effects have already been laid out in Fig. 4.1. In addition to activity, response, embeddedness, entrainment, reciprocity, and transitivity/balance are three further types of effects, ego (Fig. 4.1(g)), alter (Fig. 4.1(h)), and difference (Fig. 4.1(i)), that are used to map the effects of political geographic, economic, and institutional variables on actors' rate and choices in the dynamic network of cooperative and conflictual events. The ego effects capture the effect of water availability, a state's economic size, or its regime on cooperative or conflictual activity. The alter effects capture the effect these variables have on a state being selected as the recipient of a cooperative or conflictual event. And the difference effects help us investigate whether states are selected as recipients because they are dissimilar to the sender in these variables. Lastly, contiguity and water dependence are included as additional networks that are expected to entrain cooperation and conflict. The weighted versions and a one-year window were used for all structural effects to capture all recent events. The next section presents the results of fitting a DyNAM specified with these effects.

Analysis

Dynamic network actor-oriented models (DyNAMs), including both rate and choice model types, were fitted to conflict and cooperation events drawn from the IRCC dataset using the goldfish package version 1.4.0 "Bristol Shubunkins". All model results presented here converged with a maximum absolute score below 0.001. Diagnostics (see Hollway and Stadtfeld 2017, for more details) suggest little temporal heterogeneity in the models and few outliers. The final results are presented in Table 4.1. Robustness checks included the presence of neutral events, various combinations of weighted and windowed versions of the main structural effects, and some additional variables present in the IRCC dataset such as shared basins without affecting the chapter's main conclusions.

I begin by interpreting the rate models. First, note that we can interpret the intercept here as the unconditional waiting time for a country to send an event. On average, countries send a water-related cooperative event every 39 days and a conflictual event every 72 days, reflecting how much more common water-related cooperation is than conflict (Wolf 1998).

Of particular interest here is how a country's (recent) local network of cooperative and conflictual events affects the frequency of cooperation and conflict. Activity was statistically significant and positive across the board: the more countries have cooperated or been in conflict in the last year, the more likely they are to both cooperate and be in conflict again. Only one response effect was statistically significant: incoming conflict behavior makes states less likely to cooperate (with any other country). The embeddedness effects were all statistically significant, however rather

Table 4.1 Results

		Cooperation			Conflict	
Effect		Est.	S.E.		Est.	S.E.
Rate		*(N = 6540, LL −86117.11)*			*(N = 2360, LL −15835.18)*	
Intercept		−15.037	(0.093)***		−15.638	(0.244)***
Coop activity		0.011	(0.003)***		0.014	(0.004)**
Conf activity		0.010	(0.002)***		0.042	(0.003)***
Coop response		0.004	(0.003)		0.007	(0.005)
Conf response		−0.008	(0.002)**		−0.003	(0.005)
Coop embeddedness	*H5*	0.061	(0.001)***	*H6*	0.041	(0.003)***
Conf embeddedness	*H7*	−0.009	(0.003)**	*H8*	−0.216	(0.030)***
Ego's water		−0.049	(0.003)***		−0.132	(0.010)***
Ego's regime		0.012	(0.003)***		0.017	(0.007)**
Ego's economy		−0.139	(0.012)***		−0.212	(0.031)***
Choice		*(N = 5360, LL −15064.17)*			*(N = 908, LL −1881.1)*	
Coop entrainment		0.120	(0.008)***		0.106	(0.022)***
Conf entrainment		−0.057	(0.009)***		0.083	(0.021)***
Coop reciprocity		0.071	(0.008)***		0.097	(0.023)***
Conf reciprocity		−0.056	(0.009)***		−0.073	(0.021)***
Coop balance	*H1*	0.659	(0.012)***	*H2*	0.805	(0.038)***
Conf balance	*H3*	0.001	(0.029)	*H4*	−0.003	(0.165)
Institutional delegation		0.044	(0.175)		−0.037	(0.401)
Institutional allocation		0.718	(0.072)***		1.258	(0.199)***
Institutional enforcement		−0.710	(0.103)***		−0.993	(0.413)*
Institutional resolution		0.388	(0.049)***		0.074	(0.144)
Institutional flexibility		1.157	(0.173)***		1.451	(0.382)***
Alter's water		−0.020	(0.004)***		−0.026	(0.015)
Water differences		−0.116	(0.005)***		−0.207	(0.018)***
Alter's regime		−0.012	(0.003)***		−0.012	(0.008)
Regime differences		−0.017	(0.004)***		0.070	(0.010)***
Alter's economy		−0.070	(0.015)***		0.024	(0.046)
Economy differences		−0.384	(0.020)***		−0.496	(0.063)***
Contiguity		−0.142	(0.093)		−0.716	(0.311)*
Water dependence		0.183	(0.077)*		−0.026	(0.248)

*$p < 0.05$, **$p < 0.01$, ***$p < 0.001$

than being normative as expected in H1–H4, being embedded in a cooperative triangle supports both cooperative and conflictual behavior, whereas being embedded in a conflictual triangle suppresses both types of behavior. For example, a state that has cooperated with a partner that has cooperated with another of its partners in the last year will cooperate 2 days faster than the baseline and act conflictually 3 days faster than the baseline. But a state that has been in conflict with states that were themselves in conflict will cooperate 1 day slower than the baseline and act conflictually 17 days slower than the baseline. This suggests that being embedded in cooperative triads emboldens actors, and being embedded in conflictual triads makes actors more cautious. I propose to call this facilitative embeddedness rather than the normative embeddedness outlined by Granovetter.

Next, the ego effects are all statistically significant and go in the same direction for both conflict and cooperation. Consistent with Dellapenna and Gupta (2008), Hensel and Brochmann (2009), and Zawahri and Mitchell (2011), countries that suffer from water scarcity are more active in cooperation and conflict. Whereas a country that receives the minimum rainfall observed in the data will cooperate every 44 days and be in conflict every 95 days, a country that receives maximum rainfall will only cooperate every 140 days or be in conflict every 6.17 years. This supports the general finding in the literature that water availability affects cooperation and especially conflict. Other ego effects suggest that poorer, democratic countries are both more cooperative and conflictual. Fully democratic countries cooperate over water every 35 days and are in conflict every 60 days compared to 44 and 85 days for fully autocratic countries. Poor countries cooperate every 81 days and are in conflict every 216 days compared to 162 and 624 days for rich countries. This somewhat counterintuitive result is probably driven by major riparian countries such as India, who are democratic, often in conflict with their neighbors, and may also often appear in the online media sources used in the IRCC data.

Network effects also affect with whom countries cooperate or come into conflict (choice). Results for entrainment, reciprocity, and balance are complicated and best read together. Countries cooperate with those with whom they have cooperated and that have cooperated with them in the last year, and avoid cooperation with those with whom there was conflict in the last year. Conflict appears to be preceded not only by past conflict with that country, but also cooperation, suggesting that close cooperation can create friction too. And while countries seem to be attracted to the balanced configuration of cooperating with a partner's partner, they are also attracted to the imbalanced configuration of being in conflict with a cooperative partner's cooperative partner. This adds more mixed evidence for the structural balance theory (Harrigan and Yap 2017). To sum up these configurations with an example, country *a* is most likely to cooperate with country *b* if, in the last year, *a* has cooperated and not come into conflict with *b*, *b* has cooperated and not come into conflict with *a*, and *a* has cooperated with *c* who has also cooperated with *b*. Country *a* is most likely to come into conflict with *b* if, in the last year, *a* has cooperated or come into conflict with *b*, but *b* has only cooperated and not acted conflictually toward *a*, and *a* has also cooperated with *c* who has also cooperated with *b*. Overall, this suggests a complex embedding of riparian relationships that drive both cooperation and conflict, as illustrated in Fig. 4.3, and that again cooperative embedding can create frictions that result in conflicts.

Note that this deepening of the relationship is net of typical geographical controls, such as contiguity and water dependency. Contra recent literature (Furlong et al. 2006; Gleditsch et al. 2006), water dependency is statistically significant, but only for cooperation and not conflict. Like Brochmann and Gleditsch (2012), contiguity correlates with conflict, but is unexpectedly negative. However, this effect needs to be interpreted in light of the (weighted) conflict and cooperation ties above that would already capture any repeated interaction among neighboring states: a country is unlikely to come into conflict over water with a neighboring country that it had not already cooperated or fought with in the past. Countries cooperate and come into conflict with those who have similar levels of water availability, and especially cooperate with those who are suffering from water scarcity. They also cooperate with similar regimes (especially if they are authoritarian) and come into conflict with different regimes. Lastly, they cooperate and conflict with similarly sized economies, and especially cooperate with smaller economies. This tendency toward smaller and authoritarian states is likely due to the presence of various types of water-related support, such as infrastructure investment, in the dataset.

Finally, several institutional features are important here too. Strong allocation and flexibility provisions prompt both cooperation and conflict, whereas strong enforcement provisions suppress both cooperation and conflict. Strong resolution provisions also support cooperation but not conflict. Delegation did not appear significant here, but did in some of the robustness tests. Since institutional design features do multiple things, it is perhaps unsurprising that the results are ambiguous, suggesting more work is needed here (Biermann et al. 2020).

Conclusions

This chapter has demonstrated how network theory and statistical network modeling can be applied to international water-related cooperation and conflict event datasets. It also serves as first demonstrations of coevolving signed DyNAMs and a fully specified and emphasized rate function among actor-oriented network models.

The chapter has not only been demonstrative though. It has argued that countries' cooperation and conflict is structured by the residue of past events between them and with their network neighbors. Using dynamic network actor-oriented models (DyNAMs), and controlling for typical explanations in the literatures on water cooperation and conflict, I find that network configurations do affect when and with whom countries act cooperatively and conflictually. Most interesting is that countries that are embedded in cooperative relationships with two or more other states act quicker, both cooperatively and, it seems, conflictually, but that being embedded in conflictual relationships slows them down. I suggest that cooperative embedding is *facilitative* and emboldens activity, whereas actors that are embedded in conflictual relations exercise caution, but further research is necessary to examine the effect of embeddedness on rate in different settings.

A chief attraction of datasets like the IRCC for both scholars and practitioners is the promise of more generalizable findings (Bernauer and Böhmelt 2014). A well-specified and well-performing statistical model on carefully constructed and cleaned data that identifies average effects for various policy-relevant mechanisms can inform future policy about the likely effects of policy decisions. However, expectations must be managed for what can be predicted or forecasted when models (correctly) incorporate temporal and structural endogeneities and dependencies. Forecasting beyond the immediate future with models that include significant network effects faces the challenge that these effects capture dependencies and endogeneities that can fork the system into paths with quite different contexts for action (Block et al. 2018).

Yet network models can still provide practical policy advice. Structural effects highlight dependencies that make our inferences about other effects less biased, but can also suggest social points of leverage on relationships. For example, recent tensions over Ethiopia's Grand Ethiopian Renaissance Dam highlight the role that third parties, particularly Sudan, can play in mediating and mitigating the conflict, though these results caution that riparian relationships are neither simple nor straightforward. International water institutions therefore need to be designed and resourced so that they can manage the parties, not the water, or what Van Ast (1999) calls "interactive water management". This points to the need for further networks research in the area, in ways that fully leverage the increasingly detailed data available but take the networked structure of states' interactions seriously.

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