Self-Organizing Policy Networks: Risk, Partner Selection, and Cooperation in Estuaries

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Policy actors seek network contacts to improve individual payoffs in the institutional collective action dilemmas endemic to fragmented policy arenas. The risk hypothesis argues that actors seek bridging relationships (well-connected, popular partners that maximize their access to information) when cooperation involves low risks, but seek bonding relationships (transitive, reciprocal relationships that maximize credibility) when risks of defection increase. We test this hypothesis in newly developing policy arenas expected to favor relationships that resolve low-risk dilemmas. A stochastic actor-based model for network evolution estimated with survey data from 1999 and 2001 in 10 U.S. estuaries finds that actors do tend to select popular actors as partners, which presumably creates a centralized bridging structure capable of efficient information transmission for coordinating policies even without any government mandate. Actors also seek reciprocal bonding relationships supportive of small joint projects and quickly learn whether or not to trust their partners.

Two enduring traits of governance in the American federal system are the fragmentation of formal authority and the voluntary activities that emerge to mitigate the resultant institutional collective action problems (Feiock and Scholz 2010). A wide range of self-organizing mechanisms evolve to informally coordinate the actions of multiple policy actors, both governmental and nongovernmental, as has been observed in many different policy arenas (Bardach 1998; Scholz and Stiftel 2005). Yet the modes of analysis most prevalent in political science focus primarily on the individual or the authoritative institution as the unit of analysis, and are poorly equipped to understand the dynamic, self-organizing nature of voluntary institutions that fall somewhere between individuals and formal institutions and modify the behavior of both (cf. Granovetter 1985; Ostrom 1990).

The policy networks featured in this analysis provide a prominent example of such self-organizing mechanisms that arise to cope with institutional collective action dilemmas at central (Heclo 1978; Laumann and Knoke 1987) and local levels of governance (Bardach 1998; Laumann and Pappi 1976; Scholz and Wang 2006). Unlike stable, hierarchical authority structures designed by statute, self-organized policy networks are decentralized and dynamic. In any local ecology of policy games (Long 1958; Lubell, Henry, and McCoy 2010) involving governmental and nongovernmental actors from multiple levels of the federalist system, the overall network structure continuously evolves from the myriad of uncoordinated individual choices as actors constantly seek new contacts and drop old ones in order to cope with the most pressing problems of the day. Over time, the relationships most sought by actors shape the emergent structure of the network, which in turn influences individual and institutional behavior.

Recent developments in network analytic techniques provide a means of conceptualizing and empirically testing hypotheses about the changing shape and influence of policy networks. We utilize Snijders's (2001) stochastic actor-based model for network evolution to develop and empirically explore the *risk hypothesis* that preferences for partners reflect the nature of risk imposed by collective action problems in the local ecology of games: bridging social capital involving extensive weak ties and

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Research was partly funded by NSF grant SES-0519459. We thank Mark Schneider and Mark Lubell for use of data from NSF grant SBR97295905 and Tom Snijders and Christian Steglich for suggestions at several stages of the research. Replication materials are available at http://www.u.arizona.edu/∼berardo/Research.htm.

American Journal of Political Science, Vol. 54, No. 3, July 2010, Pp. 632–649

 ISSN 0092-5853

centralized brokers will be most valued when coordination and assurance problems predominate, while bonding capital involving intensive strong ties, reciprocity, and clustered transitive relationships will be preferred for more problematic cooperation problems involving higher risks of defection. This approach extends the efforts to provide precise definitions to the somewhat ambiguous concepts of bridging and bonding social capital (Burt 2005; Geys and Murdock 2008; Putnam 1993, 2000) that already play an important role in the study of civic engagement (Hill and Matsubayashi 2005; Putnam 1993).

The dynamics of partner selection are most observable in newly formed policy arenas exemplified by the 10 estuary water policy arenas we study, where policy actors actively seek new partners to mitigate the effects of emergent dilemmas (Schneider et al. 2003; Scholz and Stiftel 2005; Scholz and Wang 2006). We examine partner selection based on surveys of estuary policy actors in 1999 and 2001, using Snijders's model to analyze the factors that impact partnership selection as well as the impact of selected partners on an individual's level of generalized trust.

We first present a general model of network dynamics in collective action dilemmas. Then we develop testable implications of the risk hypothesis, apply the model to the estuary policy arena, and describe our research design and the unique threats to validity that affect the analysis of network dynamics. Finally, we present the results of our analysis and propose an agenda for the study of network dynamics.

Network Dynamics: Choosing Partners to Mitigate Dilemmas

What kind of partners would a policy actor choose in order to gain higher payoffs in the institutional collective action dilemmas imposed by fragmented authority? The risk hypothesis asserts that partner selection depends on the nature of the dilemma (Feiock and Scholz 2010).

Risk in the Local Ecology of Games

Consider an n-person game that can illustrate the partner selection problem for a broad range of risk conditions in dilemmas. Each player can choose to cooperate, C, or defect, D, and their payoffs are determined by the number of other players who choose C and D. If they choose C, they receive 1 for every other cooperator and $-b$ for every defector. If they choose D, they receive b for every cooperator and 0 for every other defector; thus everyone receives n-1 if all cooperate, or zero if all defect.

If $b > 1$, the payoff portrays the well-known prisoner's dilemma in which everyone is better off cooperating, but defection is the dominant choice or Nash equilibrium because it scores highest regardless of the choice of others. As b increases, both the temptation and sucker payoffs become increasingly unfavorable to cooperation, requiring a longer "shadow of the future" to sustain cooperation if the dilemma is repeated (Axelrod 1984). If $b < 1$, defection is no longer dominant, and the payoffs portray a coordination game. Coordination is easiest when $0 < b < .5$ because cooperation is risk-dominant in the sense that it provides the highest payoff as long as a majority of others choose C. Coordination is more problematic when $.5 > b > 1$ because defection is now risk-dominant; rational players would still choose C if they believed that others were likely to do so as well, because they would all get higher payoffs. But any doubts about the rationality of others would make defection the safer choice, particularly as b approaches 1.

In short, b reflects the riskiness of cooperation in the dilemma. Low values of b reflect low-risk coordination games in which no one stands to gain from defection if all others cooperate, but assurance is required that others understand the advantage of cooperation. As b increases beyond the value of 1, the temptation to defect and large sucker's penalty for cooperation create a greater risk, so building credible commitments becomes more important than supporting simple assurances that others understand the benefits of cooperation.

Risk and Partner Selection in Self-Organizing Policy Networks

The network component of the model assumes that players establish relationships with others in order to improve their payoffs in the *local ecology of games*, which is itself an environment in which interactions with others pose more or less serious risks. Lubell et al. (2010) recently revived Long's (1958) use of the ecology metaphor to represent the broad array of potential collective decision venues affecting policy actors involved in environmental policy arenas, where the high costs imposed by fragmented authority limit the opportunities for collaboration and partnerships. In settings like this, the nature of risk associated with collaborative opportunities will shape the relationships most sought by those facing the risks.

Our empirical study analyzes the structure of contacts that took place among policy actors in the local ecology of games defined by the water policy arena in 10 U.S.

estuaries. Snijders's stochastic actor-based model for network evolution (2001, 2005) is particularly well suited for developing and empirically testing hypotheses that relate the relative riskiness of dilemmas to observed network patterns formed in response to these dilemmas. In Snijders's model a randomly selected player, *ego,* evaluates her relationships at a randomly determined moment, based on the attributes and network position at that moment of all current and potential partners. Ego then selects a single utility-maximizing action based on the cost and expected benefits of creating or terminating links with any other actor, subject to error that reflects the difficulty in evaluating expected costs and benefits for each relationship. She may establish a link with a new *alter* if the expected benefits of the link exceed the cost of establishing and maintaining the link. Alternatively, she may drop an existing link if costs exceed benefits, or she may do nothing if her current links seem satisfactory. Over time, these myriad uncoordinated individual decisions shape the continuously evolving network; individual relationships are constantly changing because links are added or dropped as actors cope with the changing environment, but the type of relationships preferred by actors should remain stable as long as preferences remain unchanged. Thus the number of observed relationships of a given type provides a means of estimating the underlying preferences for relationships that appear more frequently than would be expected by chance for the number of actors and relationships in the network.

In order to specify empirically testable hypotheses about risk and the relevant types of relationships, the model adopts the following definitions and simplifying assumptions. A policy arena is defined by the local ecology of games and includes all N players who can influence outcomes and hence payoffs for other players in the ecology. In matrix notation, x_{ij}^{t} represents the presence (1) or absence (0) of a directed link at time t that provides player i with information from player j, defined for all N players in the policy arena. Links provide the initiator (i or *ego*) with information about the likely behavior of the selected partner (j or *alter*). Ego bears some cost that represents the effort required to initiate and maintain the relationship, and alter accepts the relationship by sharing information about alter's own behavior as well as about the behavior of others known to alter. The directed relationship may be reciprocated if both share information ($x_{ij} = x_{ji} = 1$), but this need not be true.

Partner selection will be affected by the individual attributes that make a partner more attractive, as is commonly assumed. For our purposes, however, the partner's network position in the full policy network, X^t, is equally important, since network positions differ in the information they can provide. We will consider how ego may value the positions occupied by alters according to the expected levels of risk that ego faces and discuss the role of individual attributes when applying the model to the estuary policy arena.

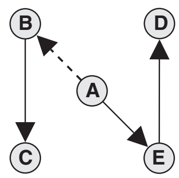
Figure 1 illustrates four network structures associated with bridging and bonding social capital (Burt 2005) that offer different levels of assurance and credibility of commitments to player A, who is evaluating potential partners. The circles represent a hypothetical set of players, and the solid arrows indicate the policy network in existence at the time of A's choice. The arrow points from *ego* to *alter,* and all relationships are known to all actors. The dotted arrow in each figure represents a potential directed link that A is evaluating; since all alters are assumed to share the same attributes in this illustration, the potential choice by ego reveals her preference for the network position of the selected alter. The formal representation of the revealed preference is provided below each figure; the superscript t is dropped for convenience. The risk hypothesis argues that A's preferences for network positions will differ according to the level of expected risks.

Bridging Structures Provide Assurance in Low-Risk Coordination Dilemmas

First consider the case of low-risk coordination dilemmas ($b < 1$) in which there is no incentive to lie or cheat on others. It is in these situations that actors would presumably seek bridging network structures that provide them with efficient methods of information exchange to assist in coordination, as illustrated in Figures 1A and 1B. Globally, these choices are associated with efficient transmission of information because they shorten the network's average path length—the number of links or intermediaries required for information about one actor to reach another in the policy arena.

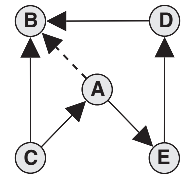
Open Two-Paths. From ego's perspective, one strategy to shorten path length is to seek alters who in turn have the greatest number of alters not already connected to ego; that is, ego selects alters that will maximize the number of actors reached by an open two-path, or $\#\{j \mid x_{ij} = 0, \max_h(x_{ih}\, x_{hj}) > 0\}$ (Snijders et al. 2008). Given the choice in Figure 1A, ego would prefer a link with B to the extent that B can provide information about C as well. In contrast to the open two-path created by a link with B, a link with D would close the existing two-path $A > E > D$; this closed two-path would be redundant and inefficient in the sense that the additional cost of the link will not result in information about a new actor not

FIGURE 1 Network Structures for Coordination and Cooperation



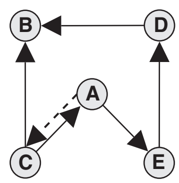
A. Coordination through Open Two-Paths

$$s_{i1}(x)=\#\{j \mid x_{ij}=0, \max_h(x_{ih}x_{hj})>0\}$$



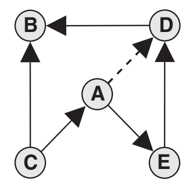
B. Coordination through Popular Alters

$$s_{i2}(x)=x_{ij}\sum_{..h}x_{hj}$$



C. Cooperation through Reciprocity

$$s_{i3}(x)=\sum_{j}x_{ij}x_{ji}$$



D. Cooperation through Transitive Triads

$$s_{i4}(x)=\sum_{j,h}x_{ij}x_{ih}x_{jh}$$

already available through the existing $A > E > D$ linkage. The redundancy induced by the $A > D$ link may improve reliability of information (Coleman 1988), but at the cost of an additional link.

Given a choice of alters with the same number of contacts, the alter with the greatest number of contacts not already directly linked to ego will maximize access to new sources of information. In the classic example, Granovetter (1973) finds that the most valuable information in job searches came from alters who had fewer overlapping relationships (weak ties) rather than from alters with strong, overlapping links (strong ties) to ego. Carpenter, Esterling, and Lazer (2004) note that lobbyists seeking access to information might be expected to avoid alters with redundant links, and Carpenter, Esterling, and Lazer (1998) found evidence that lobbyists actively seek nonredundant relationships.

Popular Alters. Since the seminal work of Bavelas and his colleagues in the Group Networks Laboratory at M.I.T. in the 1940s and 1950s, researchers have explored how central actors affect the functioning of networks (Bavelas 1950; Bavelas and Barret 1951). Organizational theorists have advanced and empirically tested the idea that more centralized organizational networks with one or a few nodes that occupy highly central positions facilitate coordination because the central actors can provide information efficiently to the rest of the group (Hagen, Killinger, and Streeter 1997; Turk 1977). Popular policy actors with a broad range of contacts appear to play crucial roles in coordinating activities of suitable partners around particular "issues" relevant to the policy community (Bardach 1998; Heclo 1978). In the estuaries we study, such central actors may be able to share information of value for other, less central actors, ranging from knowledge on local regulations for water use to the availability of alternative sources of funding for organizational activities.

This scenario is portrayed in Figure 1B, in which actor *B* provides a unique choice as a potential coordinator because both *C* and *D* are already linked to B; by creating a link to this central actor, *A* increases her chances of coordinating her behavior with *B*, *C*, and *D*. A popular central coordinator can provide assurances that those willing to maintain relationships with the coordinator will indeed follow the coordinator's example. From a network-wide perspective, a "star" structure with all peripheral actors connected only to one central coordinator provides the most efficient information distribution system in the sense that just a single link per actor can fully coordinate all actors. Unlike decentralized coordination through open two-path selection, however, centralized coordination is vulnerable to exploitation if some cooperative equilibria are more favorable to the coordinator, and vulnerable to loss, incompetence, and error if the coordinator fails or makes an inefficient choice.

In self-organizing network models, no actor can choose a single coordinator for everyone; instead, multiple coordinators emerge over time if actors independently seek relationships with the most popular alters. That is, ego seeks to maximize $x_{ij} \sum_{ih} x_{hj}$ by seeking alters with the most links directed toward them, or higher *indegree*.[1] The resultant network has many peripheral actors with low indegree and increasingly fewer actors with higher indegrees that act as coordinators (Barabási et al. 2000; Ravasz and Barabási 2003). Multiple intermediate coordinators increase the number of links required for full coordination in comparison with the star, but also decrease vulnerability to exploitation and incompetence.

Bonding Structures Provide Credible Commitment in High-Risk Cooperation Dilemmas

Now consider the case where risk of defection is higher. Although networks providing efficient information transmission may perform well in the short run for relatively simple problems, efficiency may also lead to lower long-term performance, particularly in more complex problem-solving situations (Lazer and Friedman 2007). Similarly, the credibility of information in the network may become more important than how efficiently the information is transmitted as the degree of risk and concern with defection increase. Redundant relationships thus become more worthwhile to the extent that redundancy can increase credibility, which in turn can support cooperative outcomes. Figures 1C and 1D present the two types of structures most closely associated with the redundancy of relationships that are more likely to solve high-risk dilemmas. Note that both scenarios include the same preexisting links as in Figure 1B, but evaluate a different potential link

Reciprocity. Putnam (1993) emphasized the importance of reciprocal ties of mutual cooperation in the development of social capital. Mutual exchanges help develop stronger relationships that make punishment of defection more likely and effective, which provides a mutual deterrence on which credible commitments can develop. In Figure 1C, for example, *A* could strengthen its relationship with *C* if it reciprocates the contact that *C* has already established. The resultant reciprocity not only enhances the "shadow of the future" (Axelrod 1984) through potential future punishment of current defections, but in actual relationships also provides broader access to information about the other's expected behavior and the development over time of shared attitudes and values. These in turn increase both the confidence of *A* in the credibility of *D*'s commitment to cooperate and the credibility of *A*'s commitment for *D*.

Transitivity. A similar argument can be extended to clusters of interconnected actors sharing redundant, overlapping links. Authors like Putnam (1993) and Coleman (1988) have argued that denser, overlapping networks reduce monitoring and sanctioning costs involved in resolving collective action problems; a group with links connecting all members to each other can prevent defection more effectively due to the rich information about each other's behavior and possibilities for combined punishment.

Carpenter, Esterling, and Lazer (2004) show that the transitive triad is the simplest network structure that represents the advantages of closed network structures. Consider the example in Figure 1D, where a direct relationship from *A* to *D* would provide redundant information to compare with information about *D* from the $A > E > D$ relationships.[2] This choice for *A* in this setting would maximize the number of transitive triads, $\sum_{j,h} x_{ij}\, x_{ih} x_{jh}$. A strong preference for transitive triads will produce the closed clusters associated with social capital in which most of ego's alters know each other, providing extensive redundancy and cross-checking of information within the closed group.

The social capital literature emphasizes a cognitive component, trust, which can emerge to support cooperation within the repeated interactions of closed groups. This suggests an alternative justification for the transitive triad; since *E* is already a trusted source of information for *A* and *D* is a trusted source for *E, E* is in a position to assure *A* of *D*'s trustworthiness. Furthermore, *D* is constrained from providing untimely or unreliable information to *A* because doing so may also affect *D*'s relationship with *E*. According to this vision, if actor *A* is most concerned with finding trustworthy policy contacts, then the link with *D*—the only possibility for forming a transitive triad—would be the preferred choice. The role of trust raises a

[1]In network terminology, the terms *indegree* and *outdegree* refer to incoming and outcoming ties. If an actor A identifies B as a contact, but B does not reciprocate, then A has an *outdegree* of 1 and an *indegree* of 0. Conversely, B has an *indegree* of 1 and an *outdegree* of 0.

[2]Note that the link with *D* will form a transitive triad from *A*'s perspective even if the link between *D* and *E* were reversed, with *D* seeking advice from *E*.

basic ambiguity in the social capital literature that will be discussed later: does ego seek alters with high trustworthiness, or does the trustworthiness of alters increase ego's trust?

We have discussed the preference for each of the illustrated network positions individually to clarify the role of risk in determining each position's value. In evaluating links, however, actors consider the value of all structures that would be changed by the link. A link to D in Figure 1D, for example, provides A not only with the added transitive triad that we illustrated, but also an open two-step ($A > D > B$) that might also be of value. If all expected dilemmas defining the policy arena were of a single type, the risk hypothesis suggests that only open two-step and popularity will matter for partner selection in low-risk policy arenas, and only reciprocity and transitivity will matter in high-risk policy arenas. But since the expected set of dilemmas will generally exhibit some variance in risk levels, the relative preference for relationships should reflect the variance in expected level of risk. Thus D in Figure 1D may be a particularly attractive partner in arenas with moderate levels of risk since D offers both an open two-step capable of providing assurances in low-risk situations and a transitive triad that provides credibility when risks are higher.

Network Dynamics in Newly Emerging Estuary Policy Arenas

We apply this model to network dynamics in newly emerging policy arenas that contain a diversity of actors, authorities, existing relationships, and expected policy dilemmas. We focus on estuary watersheds, the geographic areas where rivers meet oceans, because they provide a critical research site for the study of cooperation among multiple authorities and users of natural resources (Schneider et al. 2003; Scholz, Berardo, and Kile 2008). As in most policy arenas, the American federalist system has responded to new water policy challenges in the past by creating new specialized agencies with formal authority over different geographic areas and different aspects of water policies. When water use approaches threshold capacities of the natural system defined by the estuary, however, decisions by independent authorities impose growing positive and negative externalities on other authorities and their constituent stakeholders (Scholz and Stiftel 2005).

In this context, the challenge to traditionally independent authorities and their constituencies is to develop means of coordinating decisions in order to minimize negative externalities and take advantage of opportunities for positive externalities. For example, adopting common standards, regulations, and procedures to manage water quality would allow neighboring towns to exchange information, equipment, and personnel to their mutual advantage. Coordination reduces the policy search costs facing individual governing units while providing at least some relatively low-risk opportunities to pool resources and enhance the effectiveness of each town's individual actions. Similarly, coordinating plans for a single facility that could simultaneously provide wastewater treatment, stormwater retention, wetland mitigation, and habitat conservation can not only turn potential threats from single-purpose facilities into opportunities for cost sharing for the different lead agencies involved, but also imposes considerably greater risk if collaborating partners prove to be uncooperative. Hundreds of such threats and opportunities are documented in the Comprehensive Conservation and Management Plans developed for the 28 estuaries in the National Estuary Program (NEP; http://www.epa.gov/owow/estuaries/ccmp/index.html).

A panel of experts[3] we convened to discuss the role of network relationships in successful collaborative projects noted that organizations must engage in networking practices because they rarely have the technical, financial, political, and regulatory resources required to implement their desired policies. Partners are always necessary. Novel issues continuously emerge as organizations discover mutual dependencies imposed by the natural system in estuaries, and almost all organizations must reach out to others to find the resources to develop and implement collaborative efforts. Expanded network relationships can reduce the risks that traditionally make agencies reluctant to collaborate: bridging relationships can help locate and evaluate potentially collaborative partners, and bonding relationships can ease the difficult negotiations and reduce the need for costly enforcement mechanisms involved in ensuring the success of collaborative efforts.

Measuring Policy Networks

Our focus is on the general policy networks that can provide the basis for more formal collaborative relationships

[3]The panel met in February of 2006 and included experts from prominent organizations in Tampa Bay: the Executive Director of the Tampa Bay Estuary Program, a Senior Scientist at the Florida Fish & Wildlife Commission, the Director of the Pinellas County Department of Environmental Management, and the Director of the Resource Management Department as well as a former governing board member of the Southwest Florida Water Management District.

among partners in joint projects (Berardo 2010). Schneider et al. (2003) measured general network relationships in 22 estuaries in 1999 and again in 2001 using the following question: "*Please think about three people on whom you have relied most heavily in dealing with estuary issues during the past year. Consider the full range of stakeholders, including government agencies, interest groups, and local officials. Please write the name of the organization your contact works with in the space provided.*" This measures a directed relationship from the respondent's organization to the named organization, which may or may not be reciprocated by respondents in the other organization. By limiting responses to three organizations, only the strongest relationships are measured. By referring to the full range of stakeholders, the broadest range of potential relationships within the estuary should be suggested.

The data can be aggregated into two binary association matrices that represent the reported network relationships in 1999 and 2001. In each matrix a "1" in a cell represents a directed link from row actor *i* (the respondent's organization) to column actor *j* (the reported organization), and "0" represents the absence of a link. Since the relationships of interest are relevant only for dilemmas defined by each estuary's natural system, the full matrices include "structural zeroes (=10)" to indicate that relationships are not allowed between actors in different estuaries.

Figure 2 presents the resulting sociogram of the reported relationships in 1999 between the 194 organizations in 10 estuaries that will be analyzed later. Ellipses represent actors and arrows point from the actor reporting the contact (ego) toward the reported contact (alter). The estuary networks appear as 10 independent slices of a pie, since no links span estuary boundaries. The width of each ellipse reflects the actor's number of reported contacts or outdegree, the height reflects the actor's status centrality,[4] and solid colors represent government actors. Actors with the greatest status centrality are located closest to the center. Table A1 in the appendix identifies the central actors in each estuary in 1999 and 2001.

The most striking pattern evident in this initial inspection is that every estuary but one has one central actor and a small number of intermediary actors located between the central actor and the many peripheral actors. This pattern is associated with preferential attachment (Barabási et al. 2000; Ravasz and Barabási 2003) and suggests that partner selection in estuaries is driven by the search for popular alters that can act as central coordinators. But this visualization is limited in its ability to compare the frequency of other network structures of interest as well as to control for alternative explanations of the observed pattern of centrality. For this we turn to statistical analyses that can rule out alternative explanations of how networks form and evolve.

Research Design

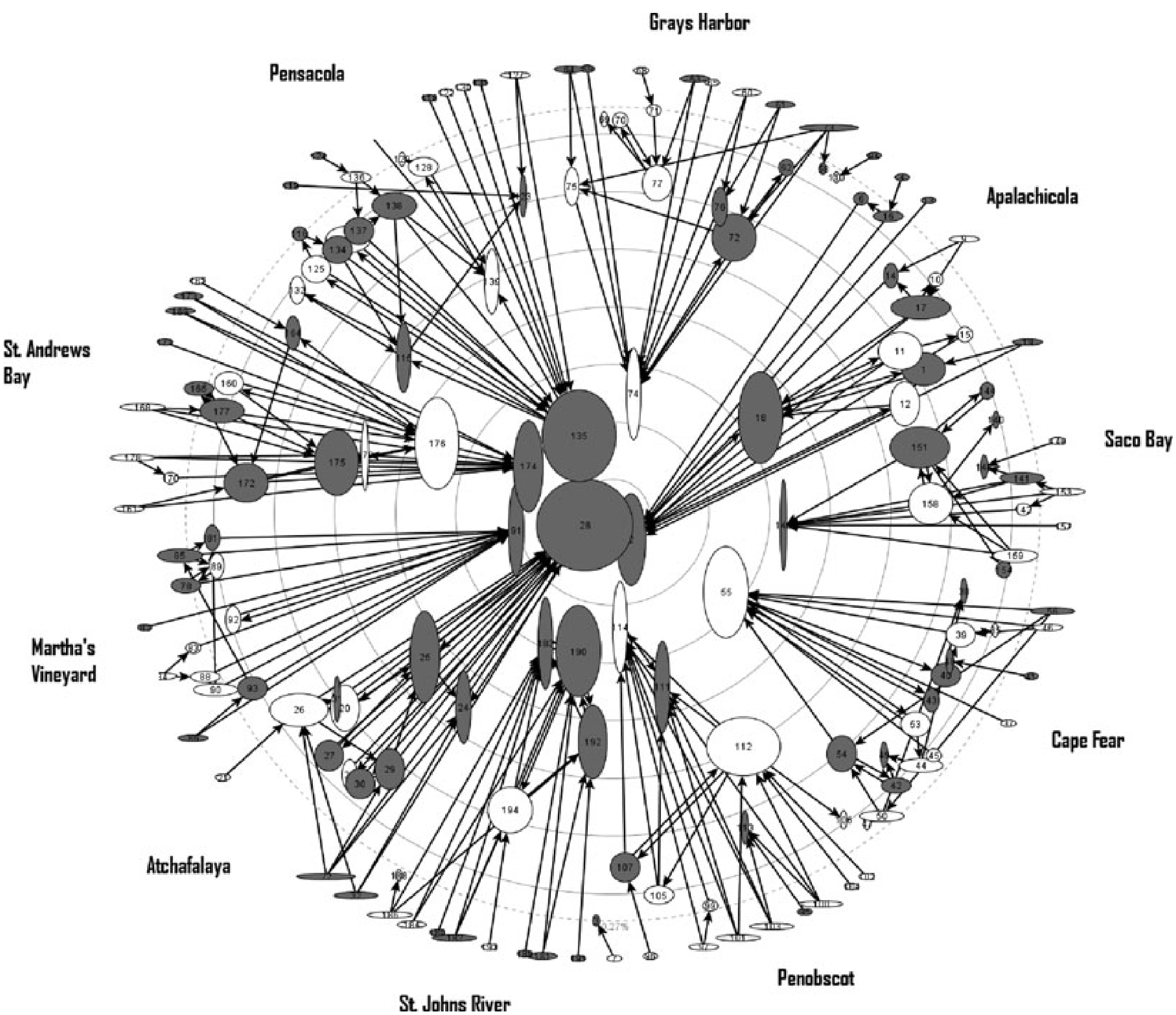
Our empirical study analyzes changes in network relationships between the 1999 and 2001 survey (described in Schneider et al. 2003) to determine which of the structures discussed above were most preferred. The time series also allows us to test whether trust affected partner selection or whether selected partners influenced ego's level of trust. Snijders's (2001) stochastic actor-based model for network evolution provides several advantages for the analyses of policy networks in comparison to cross-sectional Exponential Random Graph Model approaches (i.e., p^* models whose estimates are provided in Table A3 in the appendix).

First, the model conditions estimates on the observed structure in 1999 and analyzes only changes made between periods of observation. Differences in state laws and different histories of institutional development generally influence network patterns observed in the first period, so we cannot assume that all observed relationships are the result of voluntary partner selection. In addition, some of the 1999 relationships may be vestiges of choices of partners for previous political battles that no longer may be relevant to the needs of the organization. This can lead to misleading inferences from cross-sectional analyses.[5] By conditioning the estimates on the structures observed in 1999, the model minimizes bias from unmeasured fixed exogenous influences. It also rules out explanations of the observed dominance of central actors based on preexisting statutory requirements, since only changes in central tendencies are analyzed.

[4]Status centrality sums an actor's indegree (incoming contacts) weighted by the indegree of those who contact the actor (Brandes and Wagner 2004).

[5]For example, the cross-sectional p^* analyses of the 1999 and 2001, data in Table A3 of the appendix report significant coefficients of transitive triads that are not significant in the longitudinal analysis presented in Table 1, which are likely to reflect longstanding relationships that appear from the longitudinal analysis to be eroding. They also report a significant trust similarity impact on partner selection, whereas the simultaneous analysis in Table 1 indicates that the correlation actually reflects a significant impact of alter's trust on egos and an insignificant similarity impact on partner selection. Otherwise the effects are quite similar in magnitude, despite considerable differences in estimators. (In particular, p^* estimates are based on links rather than nodes and assume stability in structures around the invariant distribution of the MCMC process. See Snijders 2005.)

FIGURE 2 Sociograms for 10 Estuaries in 1999



Notes: Produced with Visone software (Brandes and Wagner 2004). Ellipses represent policy actors; the width reflects outdegree, the height reflects status centrality, and the solid color indicates governmental actors. Arrows point from the actor reporting a contact to the named contact. The distance from the center reflects centrality, with the most central actors placed toward the center of the diagram.

Second, the longitudinal model does not require an equilibrium assumption that every actor's relationship at the time of observation maximizes his utility within the constraints of existing relationships (e.g., see Jackson 2008). Cross-sectional p^* models implicitly require an equilibrium assumption to ensure that the observed distribution of preferred structures remains stable over time. This may be appropriate for longstanding organizational structures or stable political arenas, but appears less appropriate for studying policy network dynamics in newly emerging arenas; between 1999 and 2001, 89 links were maintained among the 125 organizations with observations in both periods, but 146 new links were formed and 108 links were dropped, revealing considerable change in the network (see Table A2 in the appendix for additional network-level information). Changes in relationships in the longitudinal model reflect ongoing individual micro-adjustments by the actors seeking to maximize their utility within the constantly evolving network pattern, and the estimated preference function provides coefficient values that maximize the likelihood that the second observed structure would emerge from the first.

Finally, as in other longitudinal methods, changes in relationships and in behavior can be modeled jointly to estimate simultaneously the impact of initial attributes or behavior on later choices of network partners (partner selection effect) and of initial network positions on subsequent behavior (network influence effect; see Snijders, van de Bunt, and Steglich 2010). Unfortunately, data limitations noted below prevent a more powerful retest of the Scholz, Berardo, and Kile (2008) finding that estuary political actors with high betweenness and degree centrality are most likely to collaborate in joint activities. We can, however, clarify the dual role of trust in social capital by testing whether trust grows out of interactions with one's alters and/or whether trust itself encourages more extensive relationships with trusting alters.

Network Relationships

The advantage of the stochastic actor-based model for network evolution comes at some cost in the form of more stringent data requirements. The model assumes that relationships for all actors are observed, although missing data and attrition in panel data are allowed (Snijders et al. 2008). Since the random sampling of network participants used in estuaries with NEP status would not produce appropriate data, we limit our analysis to the 10 non-NEP estuaries that were selected to match 12 randomly selected NEP estuaries in the original study (Schneider et al. 2003). They represent a broad range of the socioeconomic conditions found in the approximately 120 major estuaries in the continental United States, although their policy networks are clearly less developed and extensive in comparison with the NEP estuaries (Schneider et al. 2003). Snowball sampling from an extensive base of seed interviews in each non-NEP estuary continued to identify additional organizations to interview until no new organizations were mentioned. Given the multiple starting points, the 194 organizations identified in the snowball process should represent a reasonably complete listing of the major actors in each of the 10 policy arenas, thus approximating the model assumption that all actors within each independent network are included.[6]

The standard survey question noted previously that generated the data may underreport the number of relationships for two reasons. First, limiting responses to the three most important relationships provides a censored count in comparison to an open-ended response and produces fewer relationships than other name-generating techniques involving multiple prompts or a checklist of possible alters (Henry, Lubell, and McCoy 2009). Second, individual respondents may not know about organizational relationships that do not involve them. This generic problem is mitigated for the estuary data because the snowball technique identified multiple individuals from the larger organizations, and their responses were combined to provide the organization's full range of contacts. The implication of both limitations is that the analysis focuses on strong-tie relationships in the estuary, which if anything may bias results in favor of bonding rather than bridging relationships.[7]

Actor Attributes

Alternative explanations for the observed structure could be based on attributes of ego and alter that affect partner selection, so major differences in attributes need to be controlled to prevent spurious conclusions. Models of partner selection generally include three effects: *ego effects* reflecting attributes of ego that may increase or decrease the number of contacts sought by ego, *alter effects* reflecting attributes of alter that make them more or less attractive as contacts, and *similarity effects* reflecting similarities between ego and alter that may enhance the likelihood of a contact (homophily).

Our primary interest is in trust as an actor attribute, particularly because the model can clarify the mutually reinforcing roles of network relationships and trust often assumed to provide the basis of social capital (Putnam 1993). *Trust* is an 11-point scale recording the respondent's answer to the following question: "Thinking about the range of contacts you had with other stakeholders, how much do you completely trust these stakeholders to fulfill promises and obligations made in the context of current or developing estuary policies?" (0 = "complete distrust" and 10 = "complete trust.") Greater trust may encourage ego to establish more relationships, an ego effect, since trust reduces the costs of developing and

[6]In a few larger estuaries, the search for new leads stopped after the target of 30 was reached, so some actors might have been excluded from these estuaries. Schneider et al. (2003) report 1999 response rates in each estuary. Despite considerable effort, respondents from 64 of the initial 194 organizations could not be reached in 2001, which will require an appropriate method to handle composition change.

[7]Methods of measuring relationships have different strengths and weaknesses. Limiting responses to three produces a censored measure of strong relationships. An unlimited response format increases the variance across respondents in terms of effort to remember partners as well as in the strength of reported relationships. Responses from a list produce more comprehensive responses, but again include more variance in weak and strong relationships included by different respondents. More attention to the difficulties of measurement issues as associated with each type of analytic technique is required to provide a solid foundation for network analysis.

maintaining relationships. Furthermore, all actors are likely to seek trustworthy partners, so to the extent that trust is a proxy for the respondent's trustworthiness (Glaeser et al. 2000) and actors can judge other's trustworthiness, more trusting actors will have a higher indegree (alter effect). This effect is particularly important to include as an alternative explanation to the preference for more popular actors associated with low-risk coordination, since it may be trust rather than popularity that is being sought. Finally, the social capital argument suggests that trust may also introduce a similarity effect to the extent that trustworthy actors tend to seek each other and avoid untrustworthy actors, creating a clustered community of high-trust cooperators and an excluded, disconnected ghetto of low-trust defectors (Ahn and Scholz 2009).

Of course, similarity between ego's and alters' trust could also result if alters influenced the trustworthiness of ego. A respondent who by chance selects only trustworthy alters may plausibly become more trustworthy over time because of the experience with trustworthy alters. Longitudinal data allow the network dilemma model to simultaneously estimate both the *similarity effect* in the selection equation (in which trust similarity affects selection of contacts) and the *influence effect* (in which alters' trust affects ego's level of trust) in a simultaneously estimated influence equation for trust (Snijders et al. 2009). All effects related to trust should be most pronounced in the context of higher risk, where trust and credibility are particularly valued, and conversely should be less significant when lower risk coordination issues are more prevalent.

We include ego, alter, and similarity effects for two other attributes to control for factors unrelated to trust that are also likely to influence partner selection. *Government actor* is a dichotomous variable identifying governmental actors that make up a bit more than half of the total number of actors. They are expected to be in demand as suppliers of funding and regulations.

Prodevelopment is a 7-point scale measuring the respondent's self-reported policy orientation on a prodevelopment(7)/proenvironmental(1) scale. The main concern with policy orientation is the similarity effect referred to as homophily in network analysis, in which relationships are more likely among like-minded actors. Similarity in ideology is more likely to produce better information at lower maintenance costs and hence is likely to be preferred over relationships with actors that have different policy-related positions (cf. Sabatier and Jenkins-Smith 1993). If respondents tend to select like-minded contacts, creating overlapping coalitional clusters of actors at each end of the policy spectrum, then the omission of the similarity effect may result in an overestimation of the importance of reciprocity and transitivity. Descriptive statistics for all variables are presented in Table A2.

The Model

In order to test the risk hypothesis, we need to estimate the impact of the four network structures contained in Figure 1 on the probability that an actor will create or maintain a link with a given alter, controlling for alter, ego, and similarity effects. The *partner selection function* we estimate is

$$f^{net}(x_{ij}) = \sum_k \beta_k^{net} s_{ijk}^{net}(x_{ij}) + \beta_k e_{ik}(x_i) + \beta_k a_{jk}(x_j) + \beta_k d_{ijk}(x_{ij}) + \varepsilon^{net}, \quad (1)$$

where k is a shorthand method to represent the number of parameters β_k to be estimated, s_{ijk}^{net} represents network structural characteristics, e_{ik} represents the three ego effects associated with attributes of actor i, a_{jk} represents the three alter effects associated the attributes of actor j, d_{ijk} represents the three similarity effects associated with the similarity of attributes in the dyad of i and j, and ε^{net} is a stochastic error term that represents in part the bounded rationality assumption about limited knowledge of the attributes and network positions of all other actors in the network. This model provides an estimator that predicts the log odds of any link x_{ij} in any realized network X drawn from the underlying process represented by the following function:

$$\frac{\Pr(x_{ij}=1)}{\Pr(x_{ij}=0)} = e^{f^{net}(x_{ij})}. \quad (2)$$

In addition to the network structural characteristics introduced earlier, the equation includes an "outdegree" effect to account for the density of the graph. A negative outdegree coefficient would reflect the low expected odds of a link for a dyad with no significant structures or attributes, and positive coefficients for other structures or attributes represent benefits that increase the odds of a link for dyads when those structures are present.

The influence effect on trust is estimated with the *behavioral evaluation function* (Snijders et al. 2008):

$$f^{beh}(x) = \sum_k \beta_k e_{ik}(x_i) + \beta_k a_{jk}(x_j) + \varepsilon^{beh}, \quad (3)$$

where again β_k represents parameters to be estimated, e_{ik} the attributes of ego, and a_{jk} the attributes of alters, and ε^{beh}represents the stochastic error term for behavior. In this case, the function predicts a given level of trust in the 2001 observation period based on ego's previous levels of the trust, government, and proenvironment variables, as well as on alters' levels of trust in the 1999 observation period. The model simultaneously estimates the network and behavioral evaluation function that best explains the observed changes in both network linkages and trust between the first and second observations.[8]

Estimation Procedure

A pseudo-likelihood estimator of equation (1) could predict the presence of link y_{ij} in terms of the change in the number of each network structure that would occur if y_{ij} changed from zero to one. For example, if i initially has links to three nodes that are linked with j, then establishing a link where none existed between i and j would increase the number of transitive triads by three—the presence of the link would therefore indicate a strong preference for transitivity. By calculating the changes in each structural variable for each dyad and using the counts to predict whether or not the dyadic link exists, a logistic regression could produce estimates of structural coefficients for the partner selection equation. However, significant coefficients would generally indicate that any dyadic observation was dependent on other dyads, which would further indicate biased estimates because the dyadic observations would not meet the assumption of independence.

To avoid the inevitable problem of interdependence of dyadic observations in network analysis, the Markov Chain Monte Carlo (MCMC) estimator used in Snijders's stochastic actor-based model for network evolution does not use the ties observed in period one to predict ties in period two, but rather treats the two observations as snapshots of an underlying process. The process is defined by the partner selection (1) and influence (2) equations: as noted earlier, the continuous time model randomly selects one actor at a randomly determined moment. The actor changes at most one link or one level of trust to enhance utility, as reflected in the equations and based on the current network configuration, and the same step is repeated for another randomly determined actor. The estimation procedure uses MCMC simulations of this process to determine the set of coefficients that best reproduce the observed changes in the relevant structures between the first and second periods. The model also estimates a rate parameter that determines the average number of discrete choices an actor makes in order to account for the observed changes in links between periods. Additional simulations using the estimated coefficients provide the expected frequencies of each structure (e.g., transitive triads) associated with those coefficients, which are compared with the observed number in the final period to calculate the standard error for each coefficient. See Snijders (2001, 2005) for technical details and Snijders, van de Bunt, and Steglich (2010) for an intuitive presentation of the estimation procedure and guideline for analysis.

Table 1 reports the results estimated with SIENA[9] for pooled data across all 10 estuaries, following the procedure recommended in Snijders, van de Bunt, and Steglich (2010): estimate the basic selection model, use simulations to test for important alternative structures that improve goodness of fit, then simultaneously estimate the influence model using the resultant selection model, and again check goodness of fit. Model convergence is satisfactory for all parameters in the final model, as indicated by a low ($t < .1$) t-statistic. The rate parameters indicate a plausible average number of 4.85 link choices and 7 step changes in trust per organization during the two-year period. Furthermore, the coefficient for outdegree indicates that the probability of a link between i and any randomly selected j for which all other variables equal zero is $p = 0.1$, which is slightly below the frequency of observed links in the network, as expected. More generally, negative coefficients indicate that an increase in the associated variable decreases the probability of a link while positive coefficients increase the probability. Alters associated with higher values of structural variables with positive coefficients are therefore more likely to be selected or maintained as partners.

Estimation Results

The estimates for the selection model in the top half of Table 1 portray a network process that involves both bridging and bonding social capital. The significance of popular alters indicates the value of bridging capital, while

[8]In the simulated Markov Chain, all exogenous variables are fixed at their observed 1999 value, but trust, the endogenous variable, is continuously updated at random intervals in a separate process integrated with the partner selection. To be consistent with Markov assumptions, only one randomly selected individual "evaluates" the trust function at a given instant, based on the links and values of trust for all actors at that time, and increases or decreases trust by one unit or leaves it unchanged, as determined by the function.

[9]SIENA is distributed free at http://stat.gamma.rug.nl/snijders/siena.html. Our estimation used the standard actor-oriented model (type 1) and unconditional moment estimation of SIENA version 3.17p (Snijders et al. 2008). The default procedure used to account for composition change includes second-period dropouts in simulations, but the structures and attributes associated with them are ignored in the coefficient updating process.

Table 1 Analysis of Network Dynamics in 10 Estuaries, 1999–2001

Variables	Longitudinal Model (Coefficients)
PARTNER SELECTION	
Average Choices per Actor	4.85**
	(0.51)
Network Structures	
Outdegree	−2.20**
	(0.12)
Low-Risk Coordination	
Popularity of Alter	0.21**
	(0.02)
High-Risk Cooperation	
Reciprocity	0.66**
	(0.24)
Transitive Triplets	0.12
	(0.07)
Ego's Attributes	
Generalized Trust	−0.05
	(0.06)
Prodevelopment Beliefs	0.21
	(0.44)
Government Actor	0.03
	(0.13)
Alter's Attributes	
Generalized Trust	0.03
	(0.04)
Prodevelopment Beliefs	0.29
	(0.31)
Government Actor	0.21
	(0.12)
Dyadic Similarity	
Generalized Trust	0.13
	(0.80)
Prodevelopment Beliefs	0.43
	(0.56)
Government Actor	0.19
	(0.13)
INFLUENCE EFFECT ON TRUST	
Average Choices per Actor	7.05**
	(1.80)
Ego's Effects	
Trust Tendency	0.01
	(0.05)
Effect of Trust Measured in 1999	−0.00
	(0.02)
Effect of Government Type	0.11
	(0.10)
Effect of Prodevelopment Beliefs Measured in 1999	−0.27
	(0.33)
Alters' Effects	
Influence of Alters' Trust	4.78**
	(1.62)

** $p < .01$ (two-tailed). Coefficients from longitudinal SIENA analysis of directed network.

the significance of reciprocity and of similarity on trust in the trusting equation indicates the value for bonding capital.

Bridging Social Capital

The significant coefficient for popular alters confirms the importance of central coordinators as a source of bridging capital suggested in Figure 1. The coefficient of 0.21 shows that each additional incoming link increases the odds to choose that partner by a factor of $e^{0.21} = 1.23$. In other words, a potential partner with an indegree of one would increase the baseline probability of observing the link from 0.10 to 0.12, while an indegree of eight (the mean for the most central actors in the 10 estuaries) increases the probability of selecting or maintaining the link with that popular alter to 0.37. Thus a de facto central coordinator who has already been selected by many other actors is much more likely to be selected by new partners who have not already done so.

Although any actor with a higher indegree will be preferred over the remaining actors, the stochastic element in the model limits the trend toward centrality. Note that a 0.37 probability of maintaining the link also represents a $1 - 0.37 = 0.63$ probability that the link will not be maintained by those already linked to the central actor. This ever-changing pattern of relationships accounts for the emergence of new central actors for some estuaries (see Table A1 in the appendix) and the existence of intermediate actors between the most central and peripheral actors noted in the discussion of Figure 2. In general, significant positive coefficients indicate that the related structures will appear more frequently than would be expected by chance in a pure random graph with the same number of nodes and links, and the size of the coefficient reflects the extent of change of the related structure as well as its expected distribution in long-term equilibrium. The long-term impacts of the estimated model on the indegree of the most central actors can be estimated through simulations, but cannot be calculated directly from the coefficients. The maximum indegree reported in Table A1 appears to be relatively stable between the first and second observations, increasing in some but decreasing in other estuaries—note that the panel dropouts were not replaced in the 2001 survey, which renders direct comparisons difficult without the composition adjustment procedure used in the longitudinal analysis. The lack of clear trends suggests that the equilibrium condition for central coordination may have been reached in this sample.

There is no supporting evidence for significant impacts of the alternative two-step path coordination structure associated with a preference for ties providing the most extensive indirect contacts. The variable is not included in Table 1 because the appropriate goodness-of-fit test (Schweinberger 2009) does not support its inclusion, and because it causes multicollinearity problems due to its highly negative correlation with transitive triads.[10] The nonsignificance of two-step paths suggests a relatively low concern with exploitation by centralized coordinators, since this alternative means of coordination could offer protection against exploitation by central leaders, albeit at the cost of requiring many more links to achieve the same level of coordination.

Bonding Social Capital

The significant coefficient for reciprocity but marginally insignificant coefficient for transitivity suggests that the importance of bonding social capital is primarily at the dyadic two-partner level. The existence of the incoming tie from alter to ego almost doubles the likelihood that ego will establish or maintain a tie to alter, increasing the probability from the baseline value of 0.10 to 0.18.

Reciprocity in consultation on estuary matters can support credible commitments in two-party collaborative projects, whereas transitive relationships are more critical for credible commitments in larger projects. The positive coefficient for transitivity provides some evidence that it plays a role in partner selection, while its marginal insignificance may suggest that multiparty projects are not sufficiently widespread at this point to motivate the investment of network resources required to maintain redundant transitive relationships. Alternatively, contact relationships may not play the expected role in establishing credibility required for resolving the *n*-person games that are part of the local ecology of games.

Perhaps equally surprising from the bonding capital perspective, there is little evidence that shared trust, organizational type, or ideology play much of a role in partner selection. None of the similarity measures have significant coefficients, so the general tendency of actors to associate with similar counterparts (homophily) is not evident in the data. None of the included attributes of ego or alter have significant coefficients either, indicating that they do not affect the motivation for egos to create and maintain relationships with alters. In particular, trust does not increase an actor's willingness to form ties (perhaps because censored outdegree data did not reflect the true variance across actors) or preference for high-trust alters.

The lack of significant effects of the variables "governmental actor" and "prodevelopment beliefs" on the selection of partners suggests a surprisingly homogeneous consultation pattern among all actors in the estuaries, at least on the dimensions available to the analysis. This stands in contrast to the persistent partition of actors in well-established policy arenas into ideologically opposed advocacy coalitions (e.g., Weible 2010). Schneider et al. (2003) have argued that the relative newness of many of the estuary-based policy arenas may account for the observed lack of clear partitions, although the extent to which the techniques in Weible (2010) provide answers consistent with the stochastic actor-oriented model that we present here also needs investigation.

Bonding social capital appears to play its greatest role in terms of the influence of network relationships on trust. The level of trust of ego's partners significantly changes ego's reported level of general trust toward others in the second period, controlling for trust, organizational type, and ideology in the first period as well as for partner selection effects. In fact, first-period observations of trust, organizational type, and ideology have no direct impact on trust in the second period, suggesting that the social bonds with alters play the most critical role in determining trust. More trusting partners presumably behave in a more trustworthy manner (Glaeser et al. 2000), thereby providing ego with greater evidence that others could be trusted. Conversely, experience with lower-trust partners reduces ego's level of trust. The puzzle from the bonding capital perspective is why added trust does not subsequently encourage ego to expand relationships and seek out more trusting individuals, which would be indicated respectively by a positive coefficient for ego's trust and alter's trust in the selection equation.

Implications for Self-Organizing Policy Networks in New Policy Arenas

The results suggest an image of network dynamics in which actors in newly recognized policy arenas initially seek popular partners that expand their bridging capital in order to discover collaborative possibilities and resolve relatively simple, low-risk dilemmas. They also seek reciprocal relationships to provide credibility for smaller

[10]The censored relationship measure used here suppresses variation in outdegree and might tend to underestimate the importance of two-path, but the consistent negative coefficients across various models strongly support the lack of effect.

projects and quickly learn to trust or distrust those they rely on.

This image complements Scholz, Berardo, and Kile's finding that bridging (betweenness centrality) rather than bonding (egonet density) relationships increase the likelihood that a given estuary policy actor will participate in collaborative activities. They conclude that "collaborative solutions to fragmentation problems in estuaries require enhanced search capacities more than enhanced credibility. Information about potential partners appears to pose the greatest constraint to the expansion of joint programs, at least at this stage in the development of the estuary policy arena" (2008, 205).

We find that central coordination emerges in this context through the uncoordinated selection of popular partners by individual actors seeking better payoffs. Whether coordinators are initially selected by blind chance or by leadership attributes, central positions presumably will last only for those who develop a capacity to coordinate. Central coordination can readily outperform decentralized information diffusion for simple, low-risk coordination dilemmas, as when many equally valued equilibria exist and the problem is simply to know what everyone else is choosing. A similar distribution of central coordinators has been found in many naturally occurring networks that develop from preferential association and is associated with reliable information transmission efficiency that rivals the most efficient but less reliable single coordinator network (Barabási et al. 2000).

Although low-risk coordination issues appear to dominate the partner selection process in new policy arenas, credibility issues associated with higher-risk dilemmas may become increasingly dominant as more easily resolved coordination problems are mitigated and the riskier, more complex problems remain to be resolved. The advantage of central coordination declines with the complexity and need for consultation involved in crafting solutions (cf. Lazer and Friedman 2007). In addition, central coordinators can exploit their brokerage positions for their own advantage (Burt 2005), particularly as the constraints imposed by rapidly changing relationships observed in the estuaries studied here decline with the maturing of the policy arena.

In short, we suspect that the value of bridging capital in this early phase of network dynamics gradually diminishes in favor of bonding capital as the policy arena matures. The early resolution of low-risk dilemmas builds trust and a willingness to invest in stronger, more redundant relationships with expanded commitments capable of tackling higher-risk cooperation problems (Berardo 2010). These more-developed policy networks in turn provide a foundation for the development of area-wide partnerships (Lubell et al. 2002), specialized institutions (Ostrom 1990) like the NEP, and an array of other mitigating mechanisms for resolving ever-larger, more complex, and riskier dilemmas (Feiock and Scholz 2010). Of course, the inevitable tension between authority and cooperation can readily disrupt this progression (Fukuyama 1999); actors then may seek coalitional relationships to defend their interests in zero-sum games imposed by more authoritarian settings (Jones 2010), where bonding capital tends to reinforce cleavages (Hill and Matsubayashi 2005) rather than dissolve them.

Conclusion: An Agenda for the Study of Network Dynamics

Relationships have again become a central issue in political science, but the theories and empirical methods to study relationships remain underdeveloped in comparison to those for studying individual behavior. We have demonstrated how the stochastic actor-based model for network evolution (Snijders 2001) can provide a useful tool for understanding self-organizing policy networks and other similar political relationships. The model provides conceptual tools for translating general propositions about bridging and bonding capital into empirically testable hypotheses and includes related estimation procedures well suited for testing these and other hypotheses about policy networks.

A mature theory of network dynamics will need to extend the simple hypotheses of self-organizing bridging and bonding capital developed here to cover the more complex relationships noted in the previous section, particularly in settings where relationships must simultaneously cope with both cooperation and conflict. In addition, network models need to explore multiplex relationships involving simultaneous or coordinated partnership selection typical of coalitional developments of interest groups. The properties and robustness of estimators need further exploration when confronting common measurement and data-gathering problems of network analysis, particularly including problems related to censored and underreported relationships as well as ambiguity about the network boundaries and the critical relationships to be measured. Despite these shortcomings in the current study, our exploration of the risk hypothesis will hopefully encourage the theoretical and empirical developments of network analysis capable of removing these caveats from future studies.

Appendix

TABLE A1 Most Popular Actor per Estuary (1999 and 2001)

	1999				2001			
Estuary	Most Central Actor	Type of Organization	Popularity (Indegree)	% of Mentions	Most Central Actor	Type of Organization	Popularity (Indegree)	% of Mentions
Apalachicola, FL	National Estuarine Research Reserve (ANERR)	Federal/State Partnership	10	53	Same as 1999	Federal/State Partnership	6	67
Atchafalaya, LA	U.S. Army Corps of Engineers	Federal Agency	10	77	Same as 1999	Federal Agency	6	60
Cape Fear, NC	UNC-Wilmington	Research Organization	8	33	NC Dept. of Environment and Nat. Resources	State Agency	6	32
					Lower Cape Fear River Program	Public/private partnership	6	32
Grays Harbor, WA	GH's Regional Planning Commission	Regional Agency	9	43	Washington State Dept. of Ecology	State Agency	7	78
Martha's Vineyard, MA	MV's Land and Water Commission	Regional Agency	10	62.5	1. MV's Land and Water Commission	Regional Agency	2	25
					2. Massachusetts Coastal Zone Management	State Agency	2	25
					3. Martha's Vineyard Shellfish Group	Private Company	2	25
					4. The Wapanoag Tribe	Tribe	2	25
Penobscot, ME	Island Institute	Research Organization	8	52	U. of Maine Coop. Extension	Research Organization	5	42
Pensacola, FL	Florida Dept. of Env. Protection	State Agency	10	40	Same as 1999	State Agency	13	72
Saco, ME	Maine Geological Survey	State Agency	7	35	Southern Maine Regional Planning Commission	Regional Agency	6	60
St. Andrews, FL	U.S. Fish and Wildlife Service	Federal Agency	9	45	Same as 1999	Federal Agency	12	86
Lower St. Johns River, FL	City of Jacksonville	Local Government	7	47	St. Johns River Water Management District	Regional Agency	9	82
	St. Johns River Water Management District	Regional Agency	7	47				

TABLE A2 Descriptive Statistics

Actor-Level Variables	Mean	Standard Dev.	Min	Max
Generalized trust t_1	5.84	2.00	0	10
Generalized trust t_2	6.04	2.01	0	10
Prodevelopment beliefs	5.44	1.17	1	7
Government actor	0.49	0.50	0	1

Network-Level Statistics	1999 (t_1)	2001 (t_2)
Number of nodes	194	125
Number of networks	10	10
Average degree by node	1.43	1.26
Number of total ties	277	235
Number of mutual dyads	30	25
Number of asymmetric dyads	217	146
Number of transitive triplets	123	121
Number of out 2-stars	205	171
Number of in 2-stars	533	409
Number of 2-path	505	376
Missing data fraction	0.00	0.33

Note: 2001 statistics are not directly comparable to 1999 because of the dropouts. No replacement sampling was used to compensate for panel attrition.

Change in Links	1999 (t_1) to 2001 (t_2)					
0 => 0	0 => 1	1 => 0	1 => 1	Distance	Jaccard	Missing t_1 = => t_2
35700	146	108	89	254	0.259	1399 (4%)

Note: Category 0 => 0 includes structural zeroes.

Change in Trust	1999 (t_1) to 2001 (t_2)			
Actor Changes	down	up	constant	missing
	41	47	37	69
Total Step Changes	down	up	total t_1 = > t_2	
	88	87	177	

TABLE A3 Cross-sectional P^* Analyses of Partner Selection for 1999 and 2001 Data

Variables	1999 Model Coefficients	Standard Error	2001 Model Coefficients	Standard Error
Network Structures				
Out-2-star	−.02	0.10	0.05	0.10
Low-Risk Coordination				
Popularity of Alter (in-2-star)	0.23**	0.02	0.29**	0.02
Two-Paths	0.02	0.03	0.00	0.04
High-Risk Cooperation				
Reciprocity	0.96**	0.28	0.84**	0.33
Transitive Triplets	0.27**	0.07	0.46**	0.06
Ego's Attributes				
Generalized Trust	0.06	0.03	0.01	0.02
Prodevelopment Beliefs	0.22	0.37	0.23	0.39
Government Actor	0.03	0.14	0.33**	0.16

continued

Table A3 Continued

Variables	1999 Model Coefficients	Standard Error	2001 Model Coefficients	Standard Error
Alter's Attributes				
Generalized Trust	−0.03	0.03	0.01	0.02
Prodevelopment Beliefs	0.00	0.26	0.33	0.30
Government Actor	0.18	0.09	0.17	0.10
Dyadic Similarity				
Generalized Trust	0.84**	0.38	0.84	1.56
Prodevelopment Beliefs	0.89	0.52	1.40**	0.56
Government Actor	0.04	0.13	0.22	0.14

Notes: **$p < .01$ (two-tailed).
Coefficients for 1999 from SIENA 3.1 p* with default (M.H. for single ties, A, continuous, code 14, A) analysis of directed network. Coefficients for 2001 from SIENA 3.17p with Gibbs option 1 (Gibbs steps for single tie variables, continuous chain).
2001 estimates are unreliable because there is no procedure in cross-sectional analysis to account for composition changes between observations, so dropouts are by default assumed to be present but with no links. The actors observed in both periods are presumably more longstanding ones with more longstanding relationships, which may account for the differences between periods, including the significance of government actors, the similarity of prodevelopment beliefs, and the increase in transitive triplets coefficients in the 2001 estimation.

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