Network Theorizing

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ABSTRACT

Research on social networks has grown considerably in the last decade. However, there is a certain amount of confusion about network theory – what it is, what is distinctive about it, how to generate new theory. This article attempts to remedy the situation by clarifying the fundamental concepts of the field (such as the network) and characterizing how network reasoning works. We start by considering the definition of network, noting some confusion caused by two different perspectives, which we refer to as realist and nominalist. We then analyze two well-known network theories, Granovetter's (1973) strength of weak ties theory and Burt's (1992) structural holes theory, in order to identify characteristic elements of network theorizing. We argue that both theories share an underlying theoretical model, which we label the network flow model, from which we derive additional implications. We also discuss network phenomena that do not appear to fit the flow model, and discuss the possibility of a second fundamental model, which we call the bond model. We close with a discussion of the merits of model-based network theorizing for facilitating the generation of new theory, as well as a discussion of endogeneity in network theorizing.

Social network analysis (SNA) is currently popular. As shown in Figure 1, publications referencing "social networks" have been increasing exponentially over time. The interest in networks spans all of the social sciences, and is rising even faster in physics, epidemiology and biology. In management research, social networks have been used to understand job performance (Sparrowe, Liden, Wayne and Kraimer 2001), turnover (Kilduff and Krackhardt 1994; Krackhardt and Porter 1985, 1986), promotion (Burt 1992), innovation (Obstfeld 2005), creativity (Burt 2004), and unethical behavior (Brass, Butterfield, and Skaggs 1998). And in management consulting, network analyses are fast becoming standard diagnostic and prescriptive tools (e.g., Anklam 2007; Baker 2000; Bonabeau and Krebs 2002; Cross, Parker and Borgatti 2000).
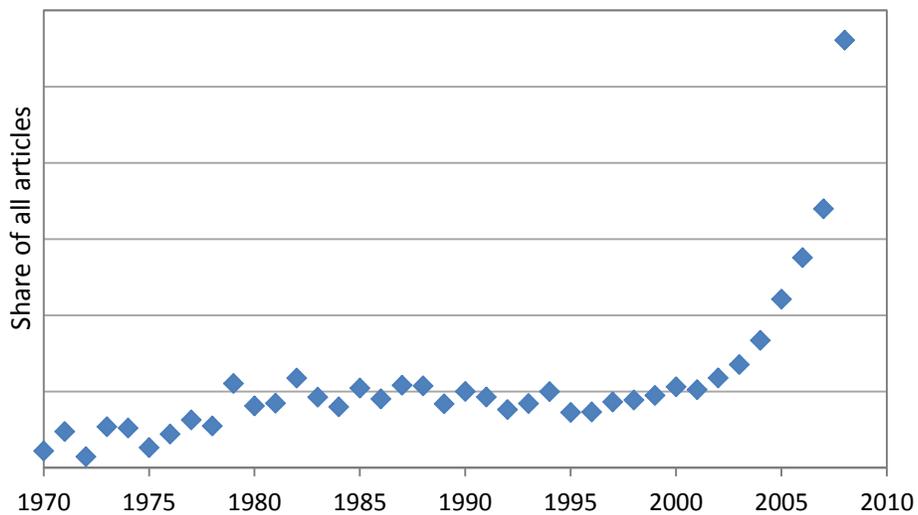
**Figure 1: Share of all articles indexed in Google Scholar
with "social network" in the title, by year.**

Despite this popularity (and, perhaps, in part because of it) there exists considerable confusion about network theorizing. Even though certain network theories are extremely well known – Granovetter's (1973) Strength of Weak Ties theory has been cited more than 14,000 times[1] – it is not unusual to read that network analysis contains no theory of its own (Salancik 1995). In this view, SNA is "just" a methodology, and what theory there is, "belongs to" other fields, such as social psychology.

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[1] Source: Google Scholar

Moreover, as the term "social network" gains caché, it is increasingly applied to everything from a trade association to a listserv to a social media website such as Facebook.

Our objective in this paper is to clarify the concept of social network, and to begin to identify the characteristic elements of social network theorizing. We have a particular interest in explicating the mechanisms used in network theory so as to facilitate the generation of new theory. In characterizing network theory, it is important to emphasize that our objective is not to define what should and should not be network theory. We do elaborate a view of what constitutes the heart of network theorizing, but it is worth remembering that the network analysis research program (in the sense of Lakatos 1980) is a social enterprise that includes all kinds of different researchers with different aims and backgrounds. There is a great deal of work that is part of the broader SNA research program that does not include the canonical elements we describe, or which includes additional elements that are not distinctive to the field.

It should also be noted that SNA theorizing encompasses two (analytically) distinct domains, which we refer to as "network theory" proper and "theory of networks". Network theory refers to the mechanisms and processes that interact with network structures to yield certain outcomes for individuals and groups. In the terminology of Brass (2002), network theory is about the consequences of network variables, such as having many ties or being centrally located. In contrast, theory of networks refers to the processes that determine why networks have the structures they do – the antecedents of network properties, in Brass's terms. This includes models of who forms what kind of tie with whom, who becomes central, and what characteristics (e.g., centralization or small-worldness) the network as a whole will have. In this paper, we focus on network theory proper, although we do find it useful in parts to make a few comments about theory of networks as well. In addition, we devote a section of this paper to assessing whether considering network theory without simultaneously treating theory of networks does harm to understanding of either.

What is a network?

A network consists of a set of actors or nodes along with a set of ties of specified type (such as friendship) that link them. The ties interconnect through shared endpoints to form paths that indirectly link nodes that are not directly tied. The pattern of ties in a network yields a particular structure, and nodes occupy positions within this structure. Much of the theoretical wealth of network analysis consists of characterizing network structures (e.g., small worldness) and node positions (e.g., centrality) and relating these to group and node outcomes.

It is important to realize that it is the researcher – by choosing a set of nodes and a type of tie – that defines a network. To appreciate the point, consider the boundary specification problem (Laumann, Marsden, and Prensky 1983), which refers to the question of how to select which nodes to study. The naïve concern is that we may select nodes "incorrectly", accidentally excluding nodes that should have been there and possibly including nodes that should not have been. In reality, however, the choice of nodes should not generally be regarded as an empirical question. Rather, it should be dictated by the research question and one's explanatory theory. For example, we may be interested in how centrality in an organizational communication network is related to work performance. Therefore, we study all communication ties among all members of the organization. In making this choice, no claim is made that only ties with other members of the organization exist or matter, but rather that position in the network defined by this kind of tie among this set of actors has a measureable effect on performance. A different researcher might be interested in how a person's communications outside the organization interact with the intra-organizational communication network to affect performance. Yet another researcher, perhaps a psychologist, might ignore the influence of others altogether (whether inside or outside the organization) and focus on how personality or life experiences affect a person's performance.

In our view, part of the angst involved in the boundary specification problem is due to confusing networks with groups. A fundamental part of the concept of group is the existence of boundaries. Even while we recognize that boundaries may be fuzzy or uncertain (e.g., there are part-time members, wannabees, conflicting views of what the group is, etc), the distinction between insiders and outsiders is

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an important part of the group concept. Therefore, when studying groups, we are justifiably concerned with establishing the boundaries of the group. For example, if we are studying gangs in Los Angeles, we would not want to approach the boundary specification problem in a wholly etic[2] way, such as defining gang members as all young males living in a given area.

In contrast to groups, networks do not have "natural" boundaries (although, of course, we are free to study natural groups, in which case the group boundaries determine our nodes).[3] Networks also don't have to be connected. A disconnected network is one in which some nodes cannot reach certain others by any path, meaning that the network is divided into fragments known as components (see Figure 2). For those confusing networks with groups, this may seem an odd conceptualization of networks. The advantage, however, is that it facilitates the study of network evolution. For example, suppose we study the freshman class at a university, focusing on friendships. Initially, it may be that none of the freshmen are friends with any other, defining a maximally disconnected network with as many components as nodes. Over time, friendships begin to develop and the number of components may reduce rapidly. Eventually, it is possible that all of the actors are connected in a single component in which every node can be reached from every other by at least one path (even if very long). Thus, by allowing the network to be disconnected, we can trace the evolution of connectivity within it. Thus, in this perspective, we do not ask "under what circumstances will networks emerge" (DTRA, 2006), as if they were groups. Rather, we ask how specific properties of the network, such as level of fragmentation or characteristic path length, change over time.

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[2] Etic versus emic is a distinction made in cognitive anthropology between organizing the world using researcher-driven criteria (etic) and organizing things the way natives do (emic). The terms come from the linguistic distinction between phonetic (how things sound) and phonemic (how things mean).
[3] It should be acknowledged, however, that there is a literature that labels organizational forms intermediate between hierarchies and markets as "networks". In this literature, a network refers to a group of organizations working closely together, almost as if they were one super-ordinate organization.
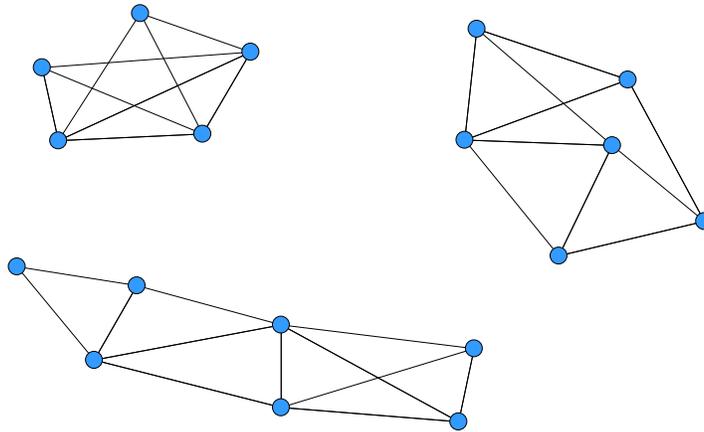
Figure 2: Network with three components

A closely related issue is what "counts" as a tie. A common beginner's question is 'which network questions should I ask in order to get at the network'. Implicit in the question is the idea – labeled the *realist* position by Laumann et al., (1983) – that there is a "true" network of relationships out there and our job as researchers is to discover it. Given that assumption, it is reasonable to ask which social network questions have proven effective at eliciting this network. However, a more sophisticated view of social networks – labeled the *nominalist* position by Laumann et al., (1983) -- holds that every network question (such as "who are you friends with?" or "who do seek advice from?") generates its own network, and which to use is determined by the research question. Thus, a given research question may lead us to examine the advice and friendship ties within an organization, while another research question may lead us to examine 'who likes whom' ties. No matter what kind of tie we are interested in, measuring that kind of tie among all pairs of nodes in the sample defines a network, and each network will have its own structure and its own implications for the nodes involved. For example, being central in a gossip network might be entertaining and beneficial, while being central in a who-dislikes-whom network might be painful and deleterious.

In practice, the kinds of ties that network theorists tend to focus on can be categorized into two basic types: states and events (see Table 1). States have continuity over time. This is not to say they are permanent but rather that they have an open-ended persistence. Examples of state-type ties include

kinship ties (e.g., parent of), other role-based relations (e.g., friend of; boss of), cognitive/perceptual

relations (e.g., recognizes; knows the skills of) and affective relations (e.g., likes; hates). State-type ties

can be dimensionalized in terms of strength, intensity, and duration.

In contrast, an event-type tie has a discrete and transitory nature and can be counted over periods

of time. Examples of event-type ties include email exchanges, phone conversations, and transactions such

as sales or treaties signed. Cumulated over time, event-type ties can be dimensionalized in terms of

frequency of occurrence (e.g., number of emails exchanged). It is these kinds of ties that researchers have

in mind when they define networks as "recurring patterns of ties" (e.g., Dubini and Aldrich 1991; Ebers

1997; Jaffee, McEvily, Tortoriello 2005).

Both state-type ties and event-type ties can be seen as roads or pipes that enable (and constrain)

some kind of flow between nodes.[4] Flows are what actually pass between nodes as they interact, such as

ideas or goods. Hence two friends (state-type social relation) may talk (event-type interaction) and, in so

doing, exchange some news (flow). As we discuss in the next section, one large swath of network theory

is about how position in a backcloth network determines the timing or quantity of flows to the actor

occupying that position.

Table 1: Types of Social Ties

State-Type Ties	Event-Type Ties
• Kinship ties (e.g., brother of) • Other role-based ties (e.g., boss of; friend of) • Cognitive (e.g., knows) • Affective (e.g., likes, dislikes)	• Interactions (e.g., giving advice to; sending email; signing treaty with; making a sale) • Transactions (e.g., signing treaty with; making a sale)

We might also note that, in empirical studies, researchers often make use of relational states and

events that are not, properly speaking, social ties. For example, a frequent proxy for social ties is group

co-membership, such as being on the same board of directors or belonging to the same club. Similarly,

co-participation in events, such as parties, is used as a proxy for unobserved social relationships. Other

dyadic variables of this type include geographic proximity (Allen 1977) and similarity of traits such as

behavior, beliefs and attitudes (McPherson and Smith-Lovin 1987; McPherson, Smith-Lovin and Cook

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[4] This is Atkin's (1972) "backcloth/traffic" distinction.

2001). From a theoretical point of view, co-memberships, co-participations, geographic proximities and trait similarities can all be seen either as dyadic factors contributing to the formation of ties (e.g., meeting the other members of your club), or as the visible outcomes of social ties (as when close friends join the same groups or spouses come to hold similar views).

Network Theorizing

To illustrate the nature and distinctive flavor of network theorizing, we start by describing in detail two well-known network theories, and then analyze them for their key characteristics. We begin with Granovetter's (1973) Strength of Weak Ties theory (SWT), and then move to Burt's (1992) Structural Holes theory.

The SWT theory is organized as a set of explicit premises and conclusions. The first premise of the theory is that the stronger[5] the tie between two people, the more likely their social worlds will overlap – that they will have ties with the same third parties. As a result, if A and B have a strong tie, and B and C have a strong tie, the claim is that A and C have an increased chance of having at least a weak tie (e.g., A and C are acquaintances). This is a kind of transitivity – one that some authors have called g-transitivity (Freeman 1979). The reason for this transitivity, Granovetter argues, is that the underlying causes of tie formation have this kind of transitivity built into them. For example, people tend to be *homophilous*, meaning that they tend to have stronger ties with people who are similar to themselves (Lazarsfeld and Merton 1954**;** McPherson et al., 2001). Homophily is weakly transitive because if A is similar to B, and B is similar to C, then A and C are likely to be somewhat (i.e., weakly) similar as well. To the extent that similarity causes ties, this will induce weak transitivity in the tie structure as well.

The second premise of SWT is that bridging ties are a potential source of novel ideas. A bridging tie is a tie that links a person to someone who is not connected to their other friends.[6] The idea is that, through a bridging tie, a person can hear things that are not already circulating among his close friends. In

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[5] While Granovetter (1973, p. 1361) provides a definition of strength of tie, it is useful to realize that any definition of tie strength which preserves the first premise can be used (Freeman, 1979).

[6] More technically, a bridge is a tie between A and B, which, if removed, would leave a very long path (if any at all) connecting A to B. A bridge, then, is a shortcut in the network.

Figure 3, A's tie with G is a bridging tie. Since A is the only person in her social group with a tie outside the group, A has the benefit of hearing things from G that the rest of A's group has not yet heard.
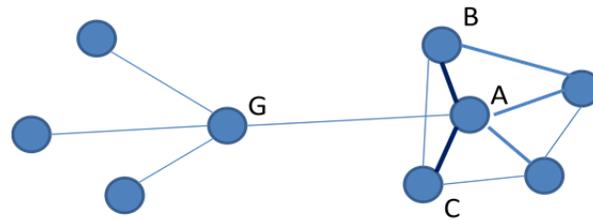

Figure 3. Bridging tie from A to G. Removing the tie disconnects the network.

Putting the two premises together, Granovetter reasoned that strong ties are unlikely to be the sources of novel information. The reason is as follows. First, bridging ties are unlikely to be strong. According to the first premise, if A and G have a strong tie, then G should have at least a weak tie to A's other strong friends, which would imply that the A-G tie was not a bridge, since there would be multiple short paths from A to G via their common acquaintances. Therefore, it is only weak ties that are likely to be bridges. Second, since bridges are the sources of novel information, and only weak ties are bridges, it is the weak ties that are the best potential sources of novel information.[7] Granovetter uses this theory to explain why people often get or at least hear about jobs through acquaintances rather than close friends. In this sense, the theory is one of individual social capital, where people with more weak ties (i.e., more social capital) are more successful. Granovetter also applies the theory at the group level, arguing that communities with many strong ties have pockets of strong local cohesion but weak global cohesion, while communities with many weak ties have weak local cohesion but strong global cohesion. Using the case study of Boston in which the city assimilated one adjacent community but failed to assimilate another he suggests that a community's diffuse, weak-tie structure constitutes group-level social capital that enables the group to work together to achieve goals, such as mobilizing resources and organizing community action to respond to an outside threat.

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[7] Note that there is no claim that all weak ties are sources of novel information – just the ones that happen to be bridges. Granovetter's point is simply that it is weak ties rather than strong ties that are more likely to be bridges.

Another well-known network theory is Burt's (1992) structural holes theory of social capital

(SH). The theory of SH is concerned with ego-networks – the cloud of nodes surrounding a given node,

along with all the ties among them. Burt argues that if we compare nodes A and B in Figure 3, the shape

of A's ego-network is likely to afford A more novel information than B's ego-network does for B, and as

a result A may perform better in a given setting, such as an employee in a firm. Both have the same

number of ties, and we can stipulate that their ties are of the same strength. But because B's contacts are

connected with each other, the information B gets from, say, X may well be the same information B gets

from Y. In contrast, A's ties connect to three different pools of information (represented by circles in

Figure 4). Burt argues that, as a result, A is likely to receive more non-redundant information at any given

time than B, which in turn can provide A with the capability of performing better or being perceived as

the source of new ideas.
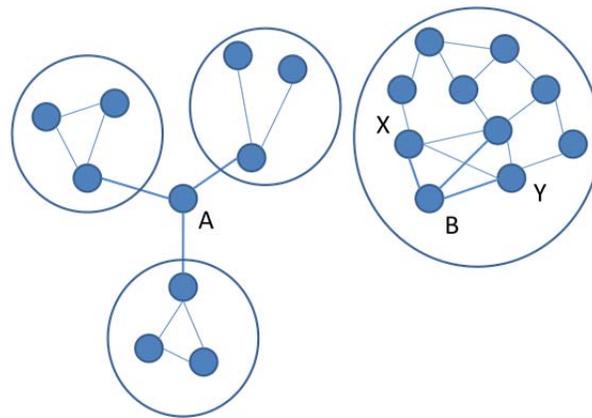
Figure 4. Node A's ego-network has more structural holes than B's.

Kilduff (2010) argues that Burt's portrayal of the social world differs significantly from that of

Granovetter along a variety of dimensions. For example, Kilduff sees Granovetter as embracing a

serendipitous world in which people form ties that only incidentally prove useful, while Burt embraces a

more strategic and instrumental view. However, at the level of the specific theories of SWT and SH, it

should be obvious that Burt's theory is closely related to Granovetter's. In Burt's language, A has more

structural holes than B, which means A has more non-redundant ties. In Granovetter's language, A has

more bridges than B. But whether we call them non-redundant ties or bridges, the concept is the same, and so are the consequences: more novel information. Where Granovetter and Burt differ is that Granovetter further argues that a tie's strength determines whether it will serve as a bridge. Burt does not disagree and even provides empirical evidence that bridging ties are weaker in that they are more subject to decay (Burt 1992, 2002). However, Burt sees tie strength as a mere "correlate" of the underlying principle, which is non-redundancy (1992, p. 27). Thus, the difference is between preferring the distal cause (strength of ties), as Granovetter does, and the proximal cause (bridging ties), as Burt does. The first yields an appealingly ironic and counterintuitive story line, while the second "captures the causal agent directly and thus provides a stronger foundation for theory" (Burt 1992, p. 28). In addition, Granovetter uses getting jobs as an outcome of having non-redundant information, while Burt uses getting promoted. In our view, these are small differences in ornamentation. Both theories are based on the same underlying model of how networks work.

Characterizing Network Theory

Examining SWT and SH from a meta-theoretical point of view, we can see two features of network theory that are highly characteristic. First, the twin notions of structure and position play a fundamental role. For example, in SWT, the reason why weak ties are useful is not because they are inherently so, but because it is the weak ties that tend to bridge between network clusters. It is their structural role that makes them advantageous. Similarly, in SH, it is the shape of the ego-network around a person that confers advantages to the person. Note that the theory ignores ego's own attributes (such as how creative they are) and also the attributes of ego's contacts (e.g., how smart they are, how gullible, how powerful) and only looks to see whether the alters are numerous and unconnected. This is not to say that ego and alter attributes are not important (they may well be much more important); it is just that the agenda of the theory – and the charter of network theory in general – is to explicate the connection between structure and outcome, and one aspect of this agenda is the study of the pure effects of structure. To be clear, the general agenda of examining the consequences of network structure includes the examination of how

structure and attributes interact to yield outcomes. But a piece of that investigation is the exploration of how structural differences alone have effects.[8]

Second, there is an implicit theory of network function; in the case of SWT and SH (but not all network theories), the network function is the flow or distribution of information. In effect, SWT and SH rely on an underlying model of a social system as a network of paths which act as conduits for information to flow. We refer to this as the *flow* or *pipes* model. The abstract flow model carries with it some basic assumptions, such as the longer a path, the longer it takes something to traverse it. From this general model we can readily derive a number of theoretical propositions that form the core of theories like SWT and SH. For instance, nodes that are far from all others will, on average, receive flows later than nodes that are more centrally positioned. Similarly, nodes that are embedded in locally dense parts of a network will often receive the same bits of flow from their various contacts, because the contacts are tied to each other as well. These flow outcomes (time until arrival; amount of non-redundant flow received) are then related to a variety of more general outcomes, such as creativity, likelihood of promotion, getting a job, etc. a

As an aside, by specifying additional features of the central process in the model, we can generate additional theoretical implications. For example, for the flow model, we can specify different variations for how flows move through the network (Borgatti 2005). For instance, a dollar bill moving through a network transfers from actor to actor in such a way that it is never in two places at the same time. In contrast, a virus or bit of news duplicates from actor to actor so that when A passes it to B, A retains a copy. Another dimension of how things can flow is what kinds of paths or trajectories they trace through the network. Some viruses, for instance, tend not to reinfect a node, either because the node has become immune, or because it is now isolated or dead. In network, theory, this kind of trajectory is known as a true path. In contrast, gossip can easily pass through a node multiple times, because transmitters do not necessarily know who has already received it. However, we might argue that gossip does not revisit ties. That is, once I have told you a story, I am unlikely to tell you the same story again (forgetfulness just adds

a bit of noise to the system). In network theory, this kind of traversal is known as a trail. A dollar bill illustrates yet another type of path, technically called a walk, which is unrestricted with respect to whether it reuses nodes or ties (e.g., on a given day a person might give the bill to a store, and the next day receive it back in change for another purchase. It could then be given by that person to that store yet again in a third transaction).

Given that things flow through the network according to certain rules, there are some obvious outcomes that can be predicted as consequences of the network structure. For instance, at the node level, we may be interested in the expected time until (first) arrival of whatever is flowing through the network. Certain (central) nodes are positioned in such a way that, on average, they receive the flow sooner than other nodes. We may also be interested in how often or with what level of certainty a node receives a given bit of flow. It should be noted that both of these flow outcomes are fully defined within the model but are not necessarily the empirical outcomes that we actually measure. What we do in network research is equate these model outcomes with other constructs such as the likelihood of getting a job (Granovetter 1973, 1974), being promoted (Brass 1984, 1985; Burt 1992), or being creative (Burt 2004; Perry-Smith 2006). Thus, hypotheses that are actually tested in empirical studies relate features of the observed network to outcomes such as performance in an organizational setting and network theory consists of elaborating how a given network structure interacts with a given process (such as information flow) to generate outcomes for the nodes or the network as a whole.

While the flow model is the most developed theoretical platform in network theory, it is not the only one. The field has clearly identified phenomena and developed theoretical explanations that cannot be reduced to the flow model. One such area is the study of power. Cook and Emerson (1978) pioneered the experimental study of the exercise of power in exchange networks. In their experiments, subjects occupied nodes in a network designed by the researcher. The subjects played a game in which, at each round, they had the option to negotiate a deal with someone they were connected to. At each round, each subject could only close on one deal. Across rounds, the subjects' objective was to make as many deals at the best possible terms as possible. For example, for the network in Figure 5, Cook and Emerson found

that the subject in position B was able to negotiate the best deals, even though subjects were not shown the structure of the network they were embedded in. From Cook and Emerson's point of view, the fundamental advantage that B enjoys is the dependency of others, which is a function of the (lack of) availability of alternatives on the part of B's potential partners. Node B has two alternatives available for making a deal, while A and C have no alternatives to B and are therefore wholly dependent on B. This positional advantage is very different from the concept of centrality, which largely emerges from the flow model. This can be seen in the experimental results for the network in Figure 6, in which B and D emerge as high power positions and A, C and E have very low power. This might seem surprising given that B, C and D all have two potential trading partners, but the difference is that C's partners B and D both have better alternatives to C, namely the wholly dependent A and E. Thus, whereas a basic principle in centrality phenomena is that being connected to well-connected others implies greater centrality, in power phenomena it can be the other way around: being connected to weak others makes one powerful and being connected to powerful others makes one weak (Bonacich 1987; Markovsky, Willer and Patton 1988; Marsden 1983).
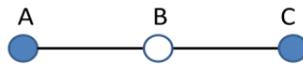
Figure 5. Experimental exchange network in which node B has the most power
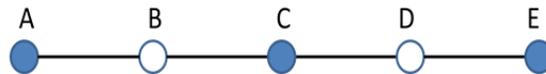
Figure 6. Experimental exchange network in which nodes B and D have the most power

What is especially interesting about network power is that network structure (and location within that structure) matters, and yet the basis for network power is not the accumulation or early reception of a resource that is flowing over well-positioned nodes, as it is in the flow model. This is especially clear in the experimental setting because the rules of the game explicitly prohibit the flow of resources. Nor is power itself flowing, since, if it were, nodes adjacent to a powerful node would be empowered.

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Another way to look at network power is in terms of coordination and virtual amalgamation. Consider a node E negotiating with a set of alters A1 through A4, as shown in Figure.7. Since there is only one E and several of the A, one might expect E to have a difficult time. But this would only be true if the A's worked together as a unit. One way this can happen is if the A's are bound together by ties of solidarity. In the extreme, this can be seen as converting the A's into a single node that can deal with E on an equal basis – i.e., a mechanism of virtual amalgamation as shown in Figure 8. This is the principle behind unionization.
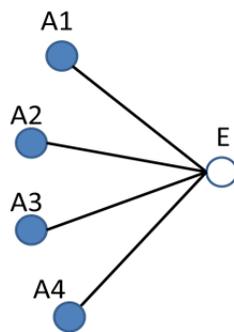
Figure 7. Negotiation network
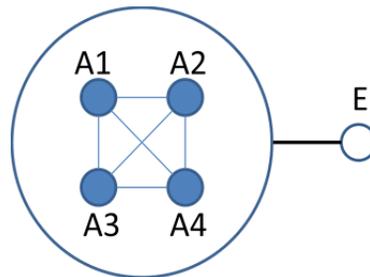
Figure 8. Negotiation network with the unionization of A's

A closer look at the unionization example suggests that two kinds of relationships among nodes are implicit. One is the potential exchange tie that exists between E and its alters. The other is the solidarity ties that may exist among the alters. A key point is that the alters in Figures 7 and 8 are essentially of a type, with the same interests (e.g., to exchange with E) and capabilities (making them interchangeable from E's point of view). This effectively allows E to induce competition (itself a kind of tie) between the A's (which can be mitigated by ties of solidarity, as in unionization). A different sort of

case is the so-called "network organization", in which a set of autonomous organizations coordinate closely, as if comprising a single, superordinate entity (Jones, Hesterly, and Borgatti 1997; Powell 1990). By working together they can accomplish more than they could alone. We can view this phenomenon as virtual capitalization, meaning that the bonds between the nodes enable them to act as if they were transferring the capabilities of the other nodes to each other, but without actually doing so. Supply chain networks have a similar character. Rather than vertically integrating and taking on the tasks and abilities of upstream suppliers (as in the simple capitalization process that occurs in the flow model), the firm has bonds with those suppliers that enable it to behave as if it had those capabilities. More generally, this is the same phenomenon studied by principal/agent theory, in which the agent acts in the interests of a principal without the principal having to do the work themselves.

In all of these examples – from exchange experiments to principals and agents – a common underlying theme is that the network tie serves as a bond that aligns and coordinates action, enabling groups of nodes to act as a single node, often with greater capabilities. The bonding function serves as the basis for what we call the bond or coordination model, and is the analogue of the flow function in the flow model.

An interesting question is whether the work on experimental exchange networks can be derived from the bond model. There is a point of commonality, which is that when a pair of nodes makes a deal in a given round, they become, momentarily, a unit that excludes those not part of the deal. From this perspective, a node's advantage derives from its inexcludability. For example, consider the positions of B and D in Figure 6, if C and D make a deal, B can make a deal with A. If D makes a deal with E, then B can make a deal with either A or C. There is no combination of outcomes in any round that does not give both B (and its twin, D) the option of making a deal.

Like the flow model, the bond model permits a number of derivations which in turn enable us to construct measures of power and predict power-based outcomes. For example, the logic of dependency and excludability dictates that the existence of node A on the other side of node B is detrimental for node C, who would rather B not have any alternatives to itself. Generalizing this a bit, paths of *even* length

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emanating from a node reduce its power, whereas paths of *odd* length increase its power. This theorem is the basis for several measures of network power, including GPI (Markovsky et al., 1988) and beta centrality (Bonacich 1987, 2007).

Another derivation from the bond model is that isomorphic nodes will have similar outcomes, even if they are not reachable from each other (as flow-based processes would require). For example, in Figure 9, nodes A and H are structurally isomorphic, and therefore must have the same structural advantages and disadvantages. Holding constant individual differences in the abilities of actors occupying network positions, we can expect that structurally isomorphic nodes will have similar outcomes.
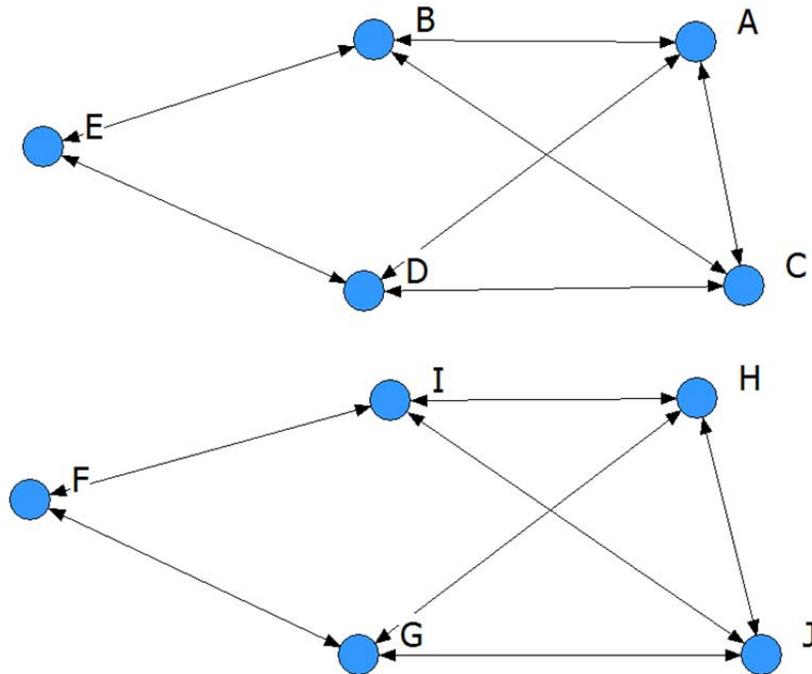
Figure 9: Nodes A and H are structurally isomorphic

The third thing to be noted about network theory is that the core concept of the field – the network – is not only a sociological construct, but also a mathematical object. As a result, it is sometimes possible to use the machinery of mathematics to generate new theory. For instance, Rapoport (1963) and others showed that transitivity tends to create highly clustered graphs that have many long paths or have

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disconnected components, which means that networks with high transitivity are slow or incomplete

diffusers. This, of course, is the basis for SWT and SH theory. More generally, the coincidence of

sociological networks and mathematical networks makes it easy to generate formal theory that is

expressed in mathematical form. This can be a blessing but also carries with it the danger that the non-

mathematically inclined will not see it as theory at all, but rather as some form of statistics. A good

example is the notion of betweenness centrality, which is defined by the formula shown in Equation 1. It

has been shown (Borgatti 2005) that the betweenness formula gives the expected values of the number of

times something reaches a node in a certain flow process (namely, one in which the things flow along

shortest paths, and when there are multiple equally short paths they choose one of them with equal

probability). Thus, what looks like methodology is in fact formal theory based on the flow model.

$$b_k = \sum_{i,j} \frac{g_{ikj}}{g_{ij}}$$

where b_k is the betweenness of node k, g_{ij} is the number of geodesic   *Equation 1*
paths from i to j, and g_{ikj} is the number of geodesic paths from i to j
that pass through k,

It is worth noting that even things as technical as the notions of structural equivalence (Lorrain

and White 1971) and regular equivalence (Everett and Borgatti 1994; White and Reitz 1983) were

explicitly developed in an effort to formalize the social role theory of Linton (1936), Nadel (1957),

Merton (1959) and others. Similarly, the notions of clique (Luce and Perry 1949), n-clique (Luce 1950),

k-plex (Seidman and Foster 1978) and other subgroups, which sound so methodological, were actually

attempts to state with mathematical precision the concept of group which Cooley (1909), Homans (1950)

and others had discussed at a more intuitive level.[9]

Goals of Network Theorizing

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[9] An explanation of these terms is beyond the scope of this article. For a review, consult Wasserman and Faust
(1994)

So far, we have focused on characterizing modes of explanation in network models. In this section we focus on characterizing the kinds of outcomes that these models are used to explain. As in much of social science, there are two generic types of outcomes that network research has sought to explain. The first can be broadly termed *choice* and includes behaviors, attitudes, beliefs and (in the case of collective actors like organizations) internal structural characteristics. Network research on choice has often been framed in terms of similarity of choice, as in explaining which pairs of nodes make similar choices. For this reason, work in this area is often referred to as the social homogeneity literature, as noted by Borgatti and Foster (2003). The second generic outcome is *success*, which includes performance and rewards, whether at the node or whole network level. Work in this area is known as the social capital literature. Combining these two generic outcomes with the two explanatory models we have outlined, we get a simple typology of network theorizing.

	Research Tradition	
	Social Capital	**Social Homogeneity**
Network Flow Model (ties as pipes)	Capitalization	Contagion
Network Coordination Model (ties as bonds)	Cooperation	Convergence

Table 2. Network functions (mechanisms) by model and research tradition.

As shown in Table 2, the top right quadrant, labeled *contagion*, consists of flow-based explanations of (similarity of) choice, which is a well-populated segment of the literature. The principal example of this kind of work is diffusion or adoption of innovation studies in which nodes are conceptualized as influencing each other to adopt their traits. For example, work in the organizational theory literature posits that one reason organizations have similar structures is diffusion (Davis, 1991; DiMaggio and Powell, 1983). Extending Dimaggio and Powell (1983) we can use locus of agency to distinguish four different types of diffusion. As shown in Table 3, DiMaggio and Powell discussed mimetic processes, in which the adopter actively seeks to copy a trait from a node in its environment, and coercive processes, in which the node is forced by a node in its environment to adopt a trait (such as a

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certain accounting system). In addition, we identify two other processes, the apprentice process, in which both the ego and its environment are actively trying to help ego get what the alter has, and the osmotic process, where neither party is actively expending energy to enable the transfer, but it happens anyway (as when ego learns a new term or concept simply by listening to alter).

| | | Alter – the social environment | |
		Active	Passive
Ego – the one adopting	Active	Apprentice processes	Mimetic processes
	Passive	Coercive processes	Osmotic processes

Table 3. Breakdown of diffusion processes by locus of agency

The bottom right quadrant of Table 2, labeled *convergence*, contains bond-based explanations of homogeneity. Work in this area includes research on structural equivalence (Lorrain and White, 1971; Burt, 1976) that posits that nodes adapt to their environments and as a result nodes with similar structural environments will demonstrate similarities (Erickson, 1988). For example, suppose two people in different parts of the world are highly central in the advice networks around them. i.e., everybody is constantly seeking their advice. As a result, both of them develop a dislike of the phone, because it so often brings work for them. Hence, sameness in terms of centrality level leads to similar attitudes. Work in this area can also be seen as a special case of coordination in which nodes behave similarly rather than simply in concert (as in the bottom left quadrant), similar to the sociological concept of *Gemeinschaft* (Tönnies 1887). Other work we would classify in this quadrant includes the networks-as-prisms concept of Podolny (2001), along with the empirical work of Kilduff and Krackhardt (1994) and identity-based network research of Podolny and Baron (1997) and Halgin (2009) which suggests that network ties provide informational clues to audiences regarding the quality and identity of an actor.

The top left quadrant of Table 2, labeled *capitalization*, contains flow-based explanations of achievement. The basic concept here is that social position in a network provides access to resources. Work in this area is exemplified by strength of weak ties theory (Granovetter, 1972), Lin's (1988) social resource theory, and the information benefits theory of structural holes (Burt, 1992).

Finally, the bottom left quadrant of Table 2, labeled *cooperation*, consists of bond-based explanations of achievement. Here, combinations of nodes act as a unit, excluding others and exploiting divisions among them.This is exemplified by the stream of research on experimental exchange networks (Bonacich 1987; Cook and Emerson 1978; Markovsky et al., 1988), as well as the control benefits theory of structural holes (Burt 1992). For a more detailed review of the work falling into each quadrant, see the review by Borgatti and Foster (2003).[10]

Discussion

In this section, we comment on the analysis presented in this article, organizing our comments into two sections, entitled model-based theorizing and endogeneity.

Model- based theorizing. In this paper, we have argued that at least some portions of network analysis can be described as *model-based theorizing*, and have outlined two fundamental models, the flow and bond models, that underlie extant network theorizing. According to Lave and March (1975), model-based theorizing is one of the strongest forms of theorizing. In model-based theorizing, we imagine an observed state of affairs as the outcome of an unseen process which is what is specified by the model. Given the model, you can derive testable implications, including the original observations that led you to postulate the model. Ideally, a model can also be expressed formally so that the machinery of mathematics and/or simulation can be used to derive additional implications that might be difficult to develop by simple intuition (e.g., Everett and Borgatti 1994; Lorrain and White 1971; Luce and Perry 1949; White and Reitz 1983). The implications are used to test the theory, as well as to apply the theory to new situations.

One feature of model-based theorizing is the separation between the abstract elements of the model, and the mapping of those elements to the real world. Hence, we should write network theory at the level of, say, the function of enabling something to flow from one node to another, not at the level of, say, who-likes-whom ties. For example, in SWT, Granovetter (1973, p 1361) specifies quite clearly what a

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[10] The terminology in Borgatti and Foster (2003) is somewhat different, but the underlying ideas are the same.

strong tie is (namely a combination of time, emotional intensity, intimacy, and reciprocal services). However, this definition is open to debate and is not appropriate in all settings, such as when the nodes are firms. However, a closer look at the theory shows that a specific definition is actually unnecessary: any type of tie that has the property of generating g-transitivity will do. The rest of the theory does not make use in any way of the fact that strong ties were defined in terms of emotional intensity and the rest. The only property of strong ties that is actually utilized is the property of g-transitivity.

There is an analogy here to object-oriented computer programming (OOP), in which real-world entities are modeled as classes of "objects" which consist of data along with procedures (called "methods") that operate on them. A key principle of OOP is that one should program to an interface rather than an implementation. What this means is that higher level code should not have to know the details of how lower level code works – the functions of the lower level code should be encapsulated so that higher level code deals only with the functions of the code, not the means by which they are accomplished. For example, if we are modeling interactions among animals, our main code should not have to know how, exactly, a cow sounds or a dog moves. Rather, it should be able to issue to the object representing a particular animal a general command such as "make sound" or "move" and have this interpreted appropriately by the object, which knows how to make its own sound and how to execute its own way of moving. In this way, any changes to how a specific kind of animal makes sounds or moves will not affect the main program, and new types of animals can easily be incorporated.

In network theory, the concept corresponding to OOP's object is the network, and what corresponds to OOP's methods is the set of processes or functions that we define on the network, such as flow of information. In our view, this analogy helps point the way toward dealing with issues of context and culture. For example, a theory built on a particular definition of tie (e.g., friendship) will run into problems when we try to apply it cross-culturally, since friendship has different implications in different cultures and settings. A better approach is to build theory at the level of abstract ties which have certain properties needed by the theory (e.g., ties create shared identity, or ties transfer resources). Then to apply

the theory in a given setting, we use our situated ethnographic knowledge to find an appropriate specific type of tie that, in that context, entails the functions needed by the theory.

The analogy also helps clarify the question of whether we can apply the same network theories to collective and/or non-human actors – such as firms – as we do to actors that are individual persons (Madhavan 2010). For example, if we wish to apply SWT theory to firms, we need only ensure that the kind of ties we study have the property of g-transitivity and serve as pipes through which resources flow. We needn't worry that ties among firms don't have "emotional intensity" or "intimacy" as long as there is a kind of inter-firm tie that has the two properties that Granovetter's model depends on – namely, transitivity and enabling the flow of information. Of course, it should be noted that different kinds of nodes have different capabilities, which needs to be taken account of in generating the auxiliary theorizing that links model outcomes to such outcome variables as, say, performance or creativity. For example, when an individual hears two bits of information he has a fighting chance of integrating them, but when a firm hears two bits of information it may be different parts of the organization that house them and the bits may never come together in the same space to be integrated.[11]

Endogeneity. In this paper, we have separated network theory from theory of networks in an attempt to trade breadth for depth. However, reviewers of this paper have raised some concerns about this separation. First, there is the question of whether the distinction is "merely" analytical since it might be expected that, in reality, the two kinds of processes occur together. Second, there is the concern that we cannot correctly predict outcomes of network structure if we haven't taken account of how the network got there – i.e., the trajectory matters. Third, there is the question of endogeneity. Endogeneity means different things in different contexts, but one sense of the term is that factors seen as causing the outcome are in some part dependent on the outcome. Finally, the issue of agency comes to mind. If actors deliberately shape the networks around them for their benefit, can it really be said that it was network structure that led to the benefit?

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[11] We are grateful to an anonymous reviewer for making this point.

To begin our discussion, let us make clear on a semantic level that network theory and theory of networks are not disjoint sets. Recall that we defined the domain of network theory to be the consequences of network processes and structures. In our examples, these consequences were things like performance or reward. However, it is obvious that the consequences of network processes can include other network phenomena, in which case network theory is simultaneously theory of networks, which is to say we have a *network theory of networks* (see Table 4). In a network theory of networks, both independent and dependent variables involve network properties. An example is the cascade of effects that can be produced by the formation of a positive or negative tie between two actors. For instance, suppose spouses Bill and Nancy develop a negative tie between them, culminating in an acrimonious divorce. According to balance theory, we can expect that a third person, Sally, with a strong positive tie to both parties will experience stress, and will be likely to weaken the tie with one of them -- i.e., choose sides. This in turn has a ripple effect on Sally's friends, who may also be forced to choose sides. Another example is the interaction between homophily and centrality (Ibarra, 1992). If actors have a marked tendency to be homophilous with respect to race, and one race has a clear numerical majority, we can expect that members of the majority race will be more central.

		Dependent Variable	
		Non-network variable as outcome	Network variable as outcome
Independent Variable	**Non-network variable as antecedent**	(Non-network theory)	Theory of Networks
	Network variable as antecedent	Network Theory	Network Theory of Networks

Table 4. Network theory and theory of networks

A more interesting question is whether, as Salancik (1995) seemed to feel, a network theory <u>must</u> include a theory of networks. In particular, are there any circumstances where we must take into account

how a network reached a given structure in order to understand the consequences of that structure? Common sense would suggest "yes". For example, consider two nodes who occupy identical positions in a network (both have many structural holes), and have similar motivations. However, node A reached that position through a long campaign of strategic relationship-building, while node B arrived at it serendipitously and in fact is unaware of the potentialities of its position. We can readily imagine that, in a population of nodes like A, the correlation between structural holes and power will be higher than in a population of nodes like B, who don't think to exploit their position. Thus, the causal link between holes and power varies depending on how the nodes got their holes. Or does it? The key difference between A and B is that A's journey to that position implies awareness of its value, allowing A to exploit it. But suppose there other ways of becoming aware of the value of one's structural holes. For example, suppose node B attends an executive education class on social network analysis. Given that B has the same position and same awareness as A, shouldn't the consequences for B be the same as the consequences for A, all else being equal?

Thus, on closer inspection, the answer to whether network theory must include theory of networks, would seem to be "no". If a model has been constructed that embodies the mechanisms which convert a given set of inputs at time T to an output at T+1, then given that input nothing else is needed to explain the outcome. In practice, however, it is a little more complicated. For one thing, knowing the input at T may involve a longitudinal analysis. As a very simplistic example, suppose an outcome is a function of whether a network is increasing in density, or decreasing (e.g., the nodes make certain choices when they perceive the density to be on the rise). A snapshot of the network at a single point in time doesn't tell us whether the density is waxing or waning. However, once we have determined, via longitudinal analysis, whether it is waxing or waning at time T, we can set the "momentum" variable at T to the observed value, and we now have all the information we need to understand what happens next.

As a more substantive example, consider the strength of weak ties theory. An appealing feature of the theory is that it spans both the theory of networks domain and the network theory domain. As discussed, a key premise of SWT is that networks form in such a way that they exhibit g-transitivity. It

can then be derived that bridging ties are unlikely to be strong ties. This is the 'theory of networks' portion of the theory. If we then combine another premise (that bridging ties are the most likely source of novel information), we can conclude that the structural property of having many weak ties is likely to be associated with access to more novel information, which in turn may be associated with performance gains. This is the' network theory' portion. The combination of the two portions is both satisfying and elegant. But do we need the first part to get the second part right? Strictly speaking, the answer is "no". In order to derive the hypothesis that weak ties will be associated with strong performance and that this is mediated by access to novel information we do not need to know why networks have g-transitivity, merely that they do.

On the other hand, there is also the matter of the satisfyingness of the theory. In any theory in which X leads to Y, we can wonder what leads to X. In some cases this feels like an urgent and necessary question. For example, if the explanation for 'why do people divorce' is 'because they want to', we are likely to demand an explanation of why they want to. In other cases, there is enough of a sense of process or mechanism in the theory that we are willing to back off of the chain of infinite regress. For example, among other arguments, Granovetter (1973) uses balance theory to explain g-transitivity. According to balance theory, a person seeks to be congruent with those she likes. When she is not, she feels dissonance, and seeks to reduce it. We could ask why, but most of us in the management field are willing to let that one go and let the psychologists deal with it. Ultimately, at what point we feel enough explanation has been given to be satisfying in a given context is a question for the sociology of science and not a question about a particular field, such as network theory.

It should be noted that the ability, in principle, to theorize about consequences of networks independently of antecedents does not absolve the field from resolving issues of endogeneity in a given empirical inquiry. For example, Lee (2010) finds that in a biotech setting, the cross-sectional correlation between structural holes and innovative performance disappears when controlling for inventors' past performance. Thus, in that particular case, it appears that it is performance that creates holes rather than the other way around, and whatever is responsible for performance is stable over time, so that past

performance predicts future performance. Thus it could be an individual characteristic such as skill or personality that causes both structural holes and performance. This is an important result, but should not be misread as saying something fundamental about network theorizing. In every field study we must be concerned about whether A causes B, or the other way around, or both are caused by an uncontrolled third variable.[12]

Finally, we take up the issue of agency as it relates to endogeneity. One of the legacies of the social capital approach in social network research is the notion that ties and position can be "good", i.e., associated with positive outcomes such as performance or reward. Inevitably, this leads to the following bit of reasoning: If occupying a certain position in the network is rewarding, we can expect actors to take steps to achieve that position. Thus, the network structure is not a given in the sense of an exogenous variable, but rather shaped by the actors specifically in order to achieve the very outcomes that we researchers associate with those structures. Therefore, any theory of social networks must take into account actors' agency in creating those networks. The problem with this, as we have pointed out, is that it is not the actors intentions and actions leading to occupying a certain position that creates the outcome but the actual occupation of the position. A rock dropped from the same place in the same way has the same outcomes regardless of whether it was dropped on purpose or by accident. Given the same conditions, the outcomes are the same.[13]

One thing this discussion highlights is the importance of node attributes and contextual factors in network research. Occupying a certain structural position carries certain potentialities, but the actual outcomes may depend on a number of additional factors, including how the actor plays it. How they play it may be a function of how they got there, and so knowing how they got there could give our predictive ability a boost. However, it is not the journey itself that is the theoretical variable, but rather the complex

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[12] Note that the possibility that A and B both cause each other should not concern us: if our theorizing suggests that A causes B, and we find that A and B cause each other, then our theory was supported. The fact that we have also learned something about the causes of A is a side benefit.

[13] It might be argued that this is not true in a court of law, where the consequences for the rock-dropper may differ depending on the court's perception of the dropper's intentions. But then the conditions are not the same. From the point of view of the law a rock dropped by accident versus with intent to kill are two different events.

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of conditions (e.g., state of mind, skills, motivations) at the end of the journey creates that is the causal agent. If we can measure that condition directly, there is no need to code the journey. In this sense, if we find that we cannot predict how X leads to Y without knowing how X came about, it is evidence that our theory of how X leads to Y is incomplete: we are missing a node attribute or other contextual factor that interacts with network position to bring about the outcome being modeled.

Conclusion

Our principal goal in this article has been to dissect and characterize network theorizing. In doing so, we have argued that much of network theory (and methodology) is based on the flow model, which is now well-elaborated and serves to unify large portions of network theory. We have also argued that another model, the bond model, is under development and can potentially unify several other areas of inquiry. More generally, we hope that our discussion of network concepts and model-based theorizing in network research will help clarify existing theory as well as facilitate the generation of new theory.

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