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Network Perspectives in Innovation Research: Looking Back and Moving Forward*

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Abstract

Purpose: This article aims to provide a balanced understanding of the structural conditions and social processes involved in the creation and diffusion of innovation. **Research design, data and methodology:** Drawing on organizational and economic sociology and strategic management literature, this article offers a conceptual framework that highlights the two dimensions of network structures: the vertical dimension focusing on power and legitimacy vs. the horizontal dimension highlighting information value. By organizing the literature on the functions and consequences of network, this paper advances a theoretical perspective in understanding the vast array of empirical studies on innovation involving network analysis. **Results:** Using the proposed framework, this article explains how the mechanisms of power, legitimacy, and information value work together with social structural factors, thus enriching our understanding of innovation. This study reveals that the information mechanism (horizontal dimension) has been most important in innovation creation and diffusion, and that trust, credibility, and legitimacy are operative in innovation diffusion. **Conclusions:** This paper contributes to the literature by responding to calls to extend existing frameworks to better account for the dynamics between innovation and network. In addition, this article highlights how conceptualizing innovation within the horizontal-vertical dimensions of network structures, creates new opportunities for future research.

Keywords: Network, Innovation, Power, Legitimacy, Information

JEL Classification Code: D21, D85, L14

1. Introduction

This paper is motivated by the observed distinction between two dimensions of network structures: the vertical and horizontal. Scholars who are interested in looking at the vertical dimension tend to emphasize advantages accrued to the occupant of a particular network position (e.g., Bothner, 2003; Burt, 1992; Podolny, 1993). This view figures more prominently in empirical research involving exchange or transactional situations, where relations tend to be governed by the logic of competition. By contrast, social scientists who are more concerned with the flow of information among actors examine network structures along the horizontal dimension. This view is most often researched in the interactional or communication contexts (e.g., Burt, 1992, 2005; Granovetter, 1973). Note that this horizontal-vertical distinction also echoes Podolny's (2001) metaphorical distinction of "network as pipes and prisms". The analytic distinction along the two dimensions suggested herein, and the now widely accepted Podolny's

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pictorial metaphors, together, even more vividly convey central ideas behind network analysis research.

In what follows, this article aims to demonstrate which network-analytic construct(s) along the above two dimensions are most likely to provide strong purchase on uncovering social processes involved in innovation. More generally, this article attempts to show one of the ways in which structural sociology can contribute to the scholarship on innovation. This study also seeks to establish the basis for the utility of the horizontal-vertical dimensions of network structures in organizing the vast array of empirical literatures on innovation and related topics involving network analysis.

To achieve these goals, this article is organized as follows: First, the relation between network analysis and the two fields of organizational studies and economic sociology is discussed. Next, two major theoretical roots that underlie network conceptions of social structure are revisited. In particular, this review focuses on most common mechanisms invoked by network analysts in their linking network structures to behavioral or performance outcomes. Drawing on the existing studies on innovation, then, this article addresses the question of to what extent each of these mechanisms should matter in making sense of structural antecedents of innovation process. Finally, we evaluate the question of how useful the concepts that transcend the horizontal-vertical distinction may be in connecting current scholarship on innovation. As an exemplary concept that transcends the distinction, we cite "a family of redundancy trade-offs", introduced by Reagans and Zuckerman (2008). Understanding this set of trade-offs (brokerage vs. closure, exploitation vs. exploration, generalism vs. specialism, focused identity vs. multi-vocality) helps to not only see the connection between the network perspective and other theoretical perspectives existing in organization studies and economic sociology, but also guide network practitioners better design research and interpret findings.

2. Network Analysis in the Sociology of Organizations and Markets

The concept of social structure is at the core of most sociological analysis of organizations and markets (O&M). Both organizational sociology and economic sociology began its own intellectual history with the fundamental question of how social structures shape the behavior and outcomes of organizational actors and market participants. The vision central to the article, "Social Structure and Organizations" by Stinchcombe (1965) laid the foundation for much sociological work on organizations (Lounsbury & Ventresca, 2002). Further, economic sociologists widely cite Granovetter's (1985) "Economic Action and Social Structure: The Problem of Embeddedness" as the pioneering paper that launched their subfield (i.e., Fligstein & Dauter, 2007). The inclusion of the term, "social structure" in both of these seminal pieces indicates the founding theme of both fields.

Yet, it is with the accelerating adoption of network approaches to the study of O&M among structurally-oriented researchers that both fields have made a significant progress in unveiling structural basis of many phenomena of substantive interest. Research topics range from managerial behavior (Mizruchi, 1990), market entry (i.e., Jensen, 2003), venture capital investment patterns (i.e., Podolny, 2001; Sorenson & Stuart, 2001), and entrepreneurship (i.e., Stuart & Soreson, 2005) to collaborative tie formation (i.e., Gulati, 1995; Stuart, 1998), knowledge transfer (i.e., Hansen, 1999; Reagan & McEvily, 2003), and creation and diffusion of various innovations (i.e., Davis, 1991 on corporate governance innovation; Fleming, 2002 on technological innovation; Padgett & McLean, 2006 on organizational innovation; Stark, 1996 on economic innovation; Uzzi & Spiro, 2005 on artistic innovation; and Westphal, Gulati, & Shortell, 1997 on managerial innovation). The appreciation of network analysis as a powerful research approach is also apparent in our adjacent subfields of historical sociology and political sociology: a wide range of collective behavior and collective action outcomes such as social movement participation (i.e., Fernandez & McAdam, 1988) and adoption and diffusion of law and policy (i.e., Ingram & Rao, 2004; Strang & Macy, 2001) have been studied with network analysis.

More importantly, social scientists have become increasingly attracted to network analysis technique primarily because it allows them to depict and analyze macro-structural properties emerged from patterns of relationships among a set of entities. Indeed, Granovetter, the founding father of economic sociology who is also closely associated with the term "social network analysis", explicitly states in the opening statement of his classic paper, "The Strength of Weak Ties", that "analysis of social networks is suggested as a tool for linking micro and macro levels of sociological theory." In this article, Granovetter draws out the macro implications from one aspect of micro interaction: the strength of dyadic ties. Since then, equipped with more sophisticated computing techniques, network analysis researchers have elaborated large-scale implications emerged out of the very simple data of small-scale interaction patterns (e.g., Centola & Macy, 2007).

The strength of weak ties theory has been subject to subsequent validation/refutation, among which Burt's structural holes theory (1982) is most path-breaking. The core theorem of the structural holes theory is based on the

logic of non-redundancy, rather than tie strength. Further, both of these theories have been very influential within and beyond the subfields of O&M and have motivated many subsequent network analysis studies. Inspired by the basic ideas of these theories, a new research line, often grouped as "small world problem", started out to investigate network topological and network dynamic implications arising from micro-relations (i.e., Kogut & Walker, 2001; Smith-Doerr & Powell, 2005; Uzzi & Spiro, 2005; Wattz, 2004). As implied above, the level of analysis in network research varies from ego-centric through dyadic to field-level, depending on the specific research question raised (cf., Mizruchi & Marquis, 2006).

Considering the wide applicability and promising potentials of network analysis as a research tool, it is not surprising to hear the pronouncement that network analysis is one of the most influential contributions of sociology to scholarship across many disciplines. Academic collaborations that span the traditional disciplinary boundaries are increasing accordingly. Watts (2004), who works across the boundary of social science and physical science, describes what he terms "new science of networks" in Annual Review of Sociology. To a lesser degree, neo-classical economists has accepted the idea that network matters as a determinant of market behavior (cf., Rauch & Cassella, 2001).

However, the rapid diffusion of a research practice beyond its traditional domain also poses its own problems. As Zuckerman (2003) reminds us, researchers sometimes could lose sight of the limits of network analysis in their causal assessment of the substantive topic in question. Indeed, more rigorous work that examines the influence of network structures carefully considers from such basic definitional issues on what constitutes nodes and ties, through design issue of the network boundary problem, to more demanding causality issue of the network endogeneity problem (e.g., Krackhardt, 1990; Laumann, Knoke, & Kim, 1985; Marsden, 1990). At the same time, it is worth mentioning that most network practitioners are working under the conditions wherein the trade-off between the pay-offs from high quality research and its costs exists.

3. Revisiting Theoretical Foundations

Having sketched the current status of network research, this section revisits two most influential theoretical foundations that underlie contemporary conceptions of network structures. The rationale behind this digression is that empirical research uncovers structural antecedents of observed behavior or outcomes when its main conceptual and operational constructs are more solidly grounded in theoretical anchors. This will also take us to the position where a careful consideration of both promises and perils of network analysis can be delivered (cf., Emirbayer & Goodwin, 1994). Rather than offering a comprehensive review of intellectual heritages of network analysis, this article focuses on two distinctive but related theoretical influences on contemporary theorizing of networks: namely, the structural social-psychological tradition and the structural/formal sociological tradition. Although it is widely acknowledged that network analysis has been less theoretically and more empirically driven (Emirbayer & Goodwin, 1994; Wellman, 1983), this article observes that many contemporary network analysts sometimes attribute explanatory power to network structures by bringing in causal mechanisms suggested by the structural social-psychological tradition and the structural-formal sociological tradition. Of course, each of these research traditions has its own long intellectual genealogy including balance theory (Festinger, 1957) and sociometry (Moreno, 1934). However, this article focuses here on the more immediate precursors of what is generally grouped together as "social network analysis".

Exchange network theory by Richard Emerson, a structural-social psychologist, has been a major influence on network conception of structures (e.g., Cook & Emerson, 1978; Emerson, 1972a, 1972b). Emerson's theoretical formulation incorporates psychological basis of behavioral principles (i.e., interests, inducements/ punishment) found in the work of the mid-century social exchange theorist, George Homans (1961). However, it also seeks to address the larger theoretical concern of the micro-macro linkage raised by another social exchange theorist, Peter Blau (1964). Recall that this intellectual goal also motivated Granovetter's 1973 piece, "The Strength of Weak Ties". Perhaps more importantly, Emerson embedded his general power-dependence principle (1962, 1964) in this theoretical framework. Further, the primary focus of exchange network theory is on exchange relations of "valued" resources. Thus, various power/dependence implications can be deduced out of observed exchange patterns.

From rudiment sets of exchange relations ("relational" in exchange terms; "dyadic" in social network terms), Emerson develops more complex social structures, namely, exchange networks ("structural" in exchange terms, "population-level" or "topological" in social network terms). Note the resemblance between original exchange network theory and social network analysis, albeit with the existence of technical difference in operationalizing these ideas. Different prototypes of network structures (i.e., monopoly, stratified, circles, and chains) and various principles governing exchange in these structures have been subsequently pursued by Emerson's colleagues and other structural social psychologists (e.g., Cook & Emerson, 1978; Emerson, 1981; Molm, 1989), and structural change

is viewed as a consequence of various social processes (i.e., coalition formation) in exchange networks largely because of a power imbalance within the exchange network structure.

While the structural social-psychological foundation of network conception of structure mainly revolves around Emerson's exchange network theory, the structural - formal theoretical foundation that led to social network analysis as a research program comes from much more diverse sources, ranging from structural anthropology (cf., Nadel, 1957), sociometry (cf., Moreno, 1934), and mathematical graph theory (cf., Bronfenbrenner, 1943). Rather than going over the influences from each line, this study focuses instead on the common impact that these lines had in bringing social network analysis together as a research program. The most obvious one is the view of social structures as networks. This comes from the agreement that social structures are "patterns" of particular relations between actors and these observed patterns, "of themselves", are meaningful and consequential. Yet, within the broad tradition of structural-formal theory, there is disagreement over the importance of the effect of social structures (cf., Martin, 2009) and the conceptions of actor, relation, or structure. This disagreement continues into the contemporary scholarship on network structures (Zuckerman, 2003). However, considering the long-standing debate in social theory - on such issues as theory of action, agency, and social structure, this divergence seems inevitable.

Although social network analysis that comes out of this tradition is not so distant from structural psychological tradition of studying social structure in terms of mode of enquiry, the two traditions diverge. The structural social psychological perspective is more deductively driven and relies on experimental data. In contrast, social network analysis group uses survey or archival data and relies on a mixture of deductive and inductive reasoning. On the more theoretical level, exchange network theorists tend to develop theory from narrow definitions of network elements, and they are more geared toward reaching a tighter, more coherent theoretical body (i.e., Cook & Whitmeyer, 1992). In comparison, social network analysis tends to be more permissive in its definitions of what constitutes as actors (i.e., are such entities as organizations or non-human objects legitimate actor with consistent, purposive action capacity?) and what constitutes as ties (i.e. communication and/or transactional relations) (e.g., Zuckerman, 2003). The studies using social network analysis are sometimes criticized for less precision on these grounds. However, given the nature of research interests by social network analysts and the cost involved in creating relational dataset to examine these kinds of topics, some of the criticisms levied against social network analysis can be read less acutely.

4. Mechanisms Explaining Structural Advantages

Albeit with some divergence in analytical styles and level of sophistication in the use of network analysis technique, the most notable fact to remember is that all social network analysts are concerned with how social structures, concretized as network patterns, work in their own research settings. Is there a unique influence of structural positions and their formal patterns, independent of idiosyncratic characteristics of positional occupants? Are structural factors complementary to more traditional-variables such as demographic attributes? Or are structural factors merely spurious? Indeed, structurally-oriented social scientists view that social network analysis allows them to capture what are once vaguely known as social structures and, thus, enables them to move toward disentangling complex causal paths that often embodies social reality (Marsden, 1990; Martin, 2009; Wellman, 1993). With the understanding of theoretical roots of network conceptions of social structures, we now distinguish key network-analytic concepts along the two dimensions: the vertical vs. the horizontal. This section focuses on each of mechanisms involved in linking social structure characterized by a particular network concept to behavioral or performance outcome.

4.1. Along the Vertical Dimension: Power and Legitimacy

The core rationale behind the vertical dimension is the imperative of competition. Competition centers around acquiring "valued" resources (i.e., not only material resources such as money and talents, but also intangible resources as knowledge, deference, or endorsement) in exchange situations. As mentioned in the previous section, this is the thrust of Emerson's exchange network theory (1972a, 1972b). Exchange theory indicates that power/dependence dynamics occur as exchange network patterns change. At any given moment of time, actors who are most advantageously placed in the given exchange network are those with many alternative exchange partners, each of whom hold the equally valuable resource desired, hence, with easy access to many substitute resources. Therefore, the competitive implication is to occupy the most advantageous position in terms of resource acquisition that does not trigger balancing operation by other exchange partners. Reagans and Zuckerman's (2008) reevaluation of the structural holes theory in terms of the power advantage of broker closely resembles the exchange theorists' logic of power/dependence. They show that how redundancy-strategy, not non-redundancy-strategy suggested in structural holes theory, is a surer way to occupy a more

powerful position, the position where larger surplus is obtained through exchange relations.

Some of the theoretical ideas suggested by exchange network theorists (or also known as the power/dependency perspective) have been borrowed by organizational scholars in their investigation of inter-organizational relations (cf., Pfeffer & Salancik, 1978). The so-called resource-dependency school has received renewed attention (Davis, 2005) and has been refined as a more powerful explanatory framework that sheds light on many prevalent inter-organizational phenomenon, such as M&As and sourcing of input materials (e.g., Casciaro & Piskorski, 2005; Gulati & Sytch, 2007). The logic of reducing dependency is the key structural imperative in this research stream (e.g., Porter, 1985). However, a lot of this work takes what is broadly known as the contingency perspective on (inter) organizational structures. The contingency perspective emphasizes that the need for valuable resources and (inter) organizational structures codetermine each other. This view departs from a more structural perspective on the empirical phenomenon that privileges structures over function (i.e., the need for resources) in general. Rather than claiming to be a "general" structural theory of competitive advantage, the resource-dependence perspective proposes that the advantage of a structural position is contingent on the value of resources that the actor desires to acquire.

In parallel, network-grounded models of competition have been proposed (cf., Bothner, 2003; Burt, 1992; Podolny, 1993). Inspired by Lorrain and White's (1971) original conception of similarity as structural equivalence, Burt (1982) formulated a structural model of competition based on the network-analytic concept of structural equivalence as similarity. At the organizational level, Mizruchi (1990) suggests that the failure to follow a proximate rival firm's pattern of campaign contributions might result in the loss of political power. The advantage of this approach to competition, suggests Bothner (2003), is that it helps broaden the scope of competition by allowing us to capture spatially and temporally varying levels of substitutability. That is, network conceptualization captures competitive dynamics that occur when producers engage with each other over time on multiple domain as well as other market participants. It is notable that the network analytic-concept of rivalry based on similarity is consistent with the idea of actors' move toward dependence symmetry as suggested by exchange theorists as a factor that drives structural change.

Furthermore, White (1981) pioneered a sociological conception of "market as role structures among producers". White depicts the market by structuring producers along the price-quality schedule, thus realizing the very initial idea of network analysis. Yet, the idea of roles as structurally-equivalent positions is quite static. Podolny (1993) advanced White's initial ideas of "market as role structures" by formulating a status-based theory of market competition. To validate his theoretical proposition, Podolny demonstrates how status-based competition plays out in the bond-offering market. Status, conceptualized as deference network structure and operationalized as Bonacichi (1982) measure, is perhaps the most salient network-theoretic concept grounded in the competition logic (e.g., Bothner, 2003). The main rationale behind the status-based competition theory lies with the "signaling value". That is, status conveys across the market interface and works as a signal especially when the uncertainty surrounding product quality is high (Podolny, 2001). Hence, we can expect status-seeking behavior among producers. However, due to the Mathew effect (i.e., the principle of accumulated advantage), this tendency produces a quite stable market order (i.e., a stable status hierarchy among producers), not an anarchy. Note that the concept of the "signaling value" can actually incorporate both the economic notion of "signal as information" and the sociological notion of "legitimacy". To put it differently, status matters as it signals the information that the market believes as useful in discerning the quality of the product, quite independently of the actual quality of that product. In sociology, this is exactly what legitimacy does: legitimacy is what the audience confers on the focal actor based on her prevailing belief, prior to assessing the technical performance of the focal actor (Zuckerman et al., 2003).

At first, the status-based competition model seems to depart quite significantly from the concerns of exchange theorists, who engage more with the "exchange" aspect of network; that is, the actual acquisition of valuable resources. However, these two perspectives are not necessarily incompatible. Status can be conceptualized as both "valuable resource" that leaks via affiliation network and "structural position" that rank-orders actors (Bothner, Gadart, & Lee, 2009). In this light, the occupancy of a high-status position is a result of the accumulation of status resource. The intrinsic advantage accrued to this occupancy of position comes from the signaling value. At the same time, the occupation of this structural position allows the focal actor to accumulate more status (i.e., Baker & Faulkner, 1991). As the actor is more likely to be sought by others as viable sources of status, the likelihood that this actor will remain in this high-status position increases. As a result, the occupancy of the high-status position also increases the dependency of others on the focal actor. Hence, the power logic is also implicitly embedded in the status-based model of competition. It is worth noting that the social comparison-based (similarity) competition model considers different logic of competition than status-based model of competition as the main operative mechanism. In a more social psychologically-based network model of

resource comparison, Burt suggests that an individual in a social structure experiences "feelings of deprivation" insofar as she perceives her resources to be less than those received by others, and those others' network positions are structurally equivalent to her own. Bothner (2003) suggests that the theoretical account that encompasses these two approaches to competition can offer a broader understanding of when position in a hierarchical ordering induces the social-comparison pressure.

4.2. Along the Horizontal Dimension: Information Value

As opposed to the logic of competition that dominates the vertical dimension of network structures described above, the core rationale behind the horizontal dimension is the imperative of communication. This rationale indicates that network structure that best facilitates communication reigns. More specifically, it suggests that the access to distant, non-redundant information is key to structural advantage at the ego-centric level, and the optimal macro-structure is one that most increases the flow of non-redundant information. The central mechanism explaining structural advantage in communication contexts is "information value". The weak-tie theory initiated by Granovetter (1973) suggests that weak ties (distant and infrequent relationships) are efficient for information sharing because they provide access to novel information by bridging otherwise disconnected clusters (bridging ties in Robert Putnam's words). Strong ties (or bonding ties), in contrast, are likely to lead to redundant information because they tend to occur among cohesive groups where everyone knows what the others know. By definition, this idea is most relevant in communication network contexts. Since the value of information does not tend to deplete with more usage, as do other resources, exchange network would be too restricted a context. However, not only more access to non-redundant information would matter, but the time to access also would matter.

In his structural holes theory, Burt (1992) suggests that strong ties can also be nonredundant contacts: he also acknowledges that even though weak ties are more likely to provide non-redundancy as initially non-redundant, strong ties tend to become redundant over time. Burt (1992) argues, in general, that "tie weakness" is a correlate, not a cause, of non-redundancy. The "absence" of ties among contacts in a focal actor's network, he continues, is a more direct indicator of non-redundancy. In both of these theories, the main mechanism that drives the effect of weak ties and structural holes on performance outcome is "information benefit", which is the access to a wide range of distant information, resulting in less redundancy and more diversity in information portfolio. However, the competition imperative that governs the vertical dimension of network and the communication imperative described herein might not be incompatible under some conditions. This is because the logic of power can also be applied to communication situations since controlling information can be a significant source of power (i.e., divide and conquer situation). Burt's (1992) theory of competitive advantage of brokerages elucidates this possibility.

Since its inception, the weak-tie theory has been tested in several different study contexts. Weak ties connecting actors who are otherwise socially distant were shown to accelerate the adoption of innovation (Rogers, 1962), enhance search (Hansen, 1999), and help coordinate collective action (Macy, 1990). Extensions of the weak-tie theory to the "small world problem" by physicists and mathematicians (Newman, 2000; Watts & Strogatz, 1998) led to productive interdisciplinary collaboration. This small world model has been also applied to the diffusion literature. Study contexts include political organizing (Hedstrom, Sandell, & Stern, 2000) and financial market and economy (Davis, Yoo, & Baker, 2003; Stark & Verdes, 2006), as well as creative collaboration (Burt 2004; Uzzi & Spiro, 2005). In most of these cases, weak ties have been shown to be advantageous because of their "information value". As the original theory of weak-ties has been put to increasing empirical tests, network analysts began to gain much finer understanding on the boundary conditions of the initial theorem. This article will consider more of these conditions in the following section when we discuss the structural conditions of innovation process.

5. Structural Conditions of the Creation and Diffusion of Innovation

The previous sections have been motivated by the idea that one way to see what important links are missing in the resolution of one's own empirical puzzle is to pay attention to the historical development of the key theoretical perspectives that we believe to be most useful to resolve the given puzzle. When reviewing some of the main theoretical ideas that dominate network analysis, the last section focuses particular mechanisms that figures most prevalently in empirical research, in general, and the current section aims to shed light on the structural antecedents of innovation, in particular. We intend this objective to be achieved by organizing the extant empirical research on innovation around the mechanisms of "power", "legitimacy", and "information". Each innovation occurs in different cultural and technical contexts. However, understanding how these different contingencies work together with social structural factors helps us to make sense of innovation process in general. It helps us to detect

an intellectual gap arisen in the current scholarship. As a result of this framing, this paper can also address the question of how useful the concepts that are most likely to transcend the horizontal-vertical distinction may be in filling in the intellectual gap.

A broad review of the literature on innovation reveals that the extant empirical research can be divided by the three criteria: what type of innovation is on interest? Does it focus on innovation at the individual level or organizational level? Does it focus on creation or diffusion of innovation? The second question can be translated, in network terms, as whether an individual or an organization (or sometimes a technological entity in the case of patent) constitutes the node. In innovation research, a tie is usually defined in terms of the incidence of collaboration (i.e., a membership to a collaborative team or other forms of groups such as corporate board at the individual level, a membership to strategic alliances, or other forms of collaborations, such as professional organization at the organizational level, and citation linkage in the case of patent). Most research in the field of strategic management focuses on the creation of technological innovation (in terms of output), such as new product development and patent output at the intra- or inter-organizational level.

In sociological literature, where social contagion process is of more interest, empirical research predominantly focuses around the diffusion process of various kinds of innovation. Research topics range from the diffusion of innovative managerial practices (i.e., poison pill provision, performance-based CEO compensation policy) via inter-corporate board network to medical innovation diffusion via physician network. In these studies, such individuals (i.e., corporate executives, scientists, physicians) constitute the node, and a membership to various kinds of group (i.e., corporate board or professional organizations) constitutes the tie. In a case where survey data is collected, informal advice network is constituted based on ego-centric network data.

In the research stream where the predominant interest is how firms innovate, network analysis has been adopted to examine some of the organizational structures where technological innovation occurs. Researchers have provided evidence that shows the increasing number of technological innovation across firm boundaries, especially in biotechnology industry (Powell, Koput, & Smith-Doerr, 1996; Shan, Walker, & Kogut, 1994). For example, Shan et al. (1994) finds that the number of collaborative relationships the focal firm formed (the most simple network measure, the number of direct ties) is positively related to its innovation output. Powell et al. (1996) finds that centrality in inter-organizational research networks predicts faster growth for the start-ups. In most of the early papers on technological innovation, the focus is less on the exact structural configurations of innovation creation and more on how network form of governance is one of way of overcoming the problem of "liability of smallness" for small firms and the problem of "competency trap" for large firms in terms of innovation creation. Ahuja (2000) advances this stream by introducing more network concepts and measures (i.e., direct ties, indirect ties, and structural holes) to predict innovation creation in chemical industry.

One rare exception that studies technological diffusion from the network perspective is Podolny and Stuart's (1995) paper on technological evolution in semi-conductor industry. This study addresses the question of whether an innovation becomes a technological dead-end or serves as the basis for subsequent innovations. In this work, the possibility for innovation diffusion was predicted by the pattern of ties in the technological niche of the innovation, the quality of the innovation, and the status of the innovator. Although it is difficult to parse out only structural mechanisms implied in this work due to too many considerations involved, this line of research considers inter-organizational network structures predominantly in terms of "pipes", where valuable resources circulate. In the case of Podolny and Stuart (1995), status – the "prisms" aspect of the network – has been examined, albeit indirectly.

The more recent innovation research using network analysis revolves around two major themes. The first research theme is the impact on innovation of the interaction between industry-based network and geographic network - or between social space and physical space (e.g., Whittington, Owen-Smith, & Powell, 2009). This question tends to be motivated by the contradictory observation of regional innovation clusters and collaborations that span geographic boundaries. The second research theme emerged is on the trade-off between brokerage vs. closure/cohesion at the various stages of innovation process. The innovation process is analytically disaggregated into information search stage, knowledge transfer stage, exploitative learning stage, and recombination stage. In this process-based view of innovation creation, researchers emphasize the learning aspect of innovation from the tradition of organizational learning school, also known as the Carnegie-Mellon school (Levitt & March, 1988). Hence, they tend to focus on the question of what actually flows through network.

The focus on the knowledge content of the tie requires an additional mechanism, "trust", where the literature on social cohesion usually has a lot to add. Building on Coleman's (1988) conception of social capital, proponents of cohesion argue that closed social structures engender greater trust, which is better for transferring complex knowledge. Cohesion occurs when individuals have dense and overlapping ties with each other. Depending on the characteristics of knowledge (codified vs. tacit; simple vs.

complex), the relative benefits of brokerage vs. closure or strong ties vs. weak ties are adjudicated. The implication from this research in light of the theoretical anchors suggested in the previous sections is that when the final stages of innovation, recombination process, requires vision and diverse information, brokerage position prevails. When recombination involves transferring tacit learning process that requires additional social support, cohesion is more important. Research studying team-level innovation processes find that the optimal structure for innovation is the internally cohesive network connected by diverse sets of outside network (Fleming, Mingo, & Chen 2007; Hansen, 1999; Reagans & McEvily, 2003; Uzzi & Spiro, 2005). The literature reviewed above mostly explains structural antecedents of innovation creation in terms of "information" and "trust". That is, depending on the content and stage of innovation, different network structures have varying power predicting the network-innovation nexus.

Sociologists have long explained diffusion process in terms of social influence or social contagion (Coleman, Katz, & Menzel, 1966; Katz & Lazarfeld, 1955). The basic idea is that the focal actors' adoption is a function of her exposure to previous adopters' knowledge, attitude, or behavior concerning the innovation. Thus, contemporary research on social processes of innovation diffusion is often studied from the perspective of social influence (micro-level) or social contagion (macro-level). Researchers often use network analysis to construct network structures of social influence (cf., Bothner, 2003; Van den Bulte & Lilien, 2001). As the phenomenon of word-of-mouth becomes more pronounced with more advanced telecommunication technology, marketing research group also studies diffusion process from this perspective and built several sophisticated models. Among various models, heterogeneous diffusion model can capture all the key aspects of contagion process - the infectiousness of the innovation, the focal actor's susceptibility to social influences, and the focal actor's exposure to the network of previous adopters. Network structures of the focal actor can capture both "world of mouth" and status competition among structurally-equivalent groups (Bothner, 2003; Burt, 1982; Stuart & Ding, 2006; Van den Bulte & Lilien, 2001). Many organizational scholars often employ this modeling strategy to detect diffusion patterns (i.e., fads or fashion) of once popular managerial practices (i.e., TQM, business reengineering technique, etc.). Thus, if one focuses on the question of why some innovations make market success when others die quickly, insights from this line of research, in tandem with social network analysis, help resolve the question.

Of note in this theoretical account is one social-psychological mechanism that links social influence to adoption behavior. The focal actor is more likely to adopt the innovation when she observes the adoption by influential peers whose approval she values. Note the similarity between this mechanism and the mechanism of "signaling value" or "legitimacy" that connects status and adoption behavior. Thus, this paper can broaden the notion of "legitimacy" that operates along the horizontal axis of network structures as including the value of social approval and the value of normative pressure. More macro-level mechanism suggested by the diffusion literature is "positive externalities". This occurs when the benefits of adoption increases with the number of prior adoptions. This mechanism can also easily be explained by "information value" mechanism proposed in the network perspective. In network terms, the focal actor's adoption behavior is a function of her network exposure to weak ties as it is through these ties that global information is delivered. However, this explanation also depends on the characteristics of the innovation, such as its complementarity with other practices that the actor previously adopted (i.e., adoption of a new Apple product depends on not only how many others have adopted, but also whether this new product is compatible or complementary with other products that the focal actor has previously adopted).

6. Conclusion

This study has reviewed some of the strategic management and sociological literature that broadly takes a network approach to study innovation process. In particular, this study has focused on the main mechanism that each research line emphasizes. The information mechanism is shown to be most important in both generative and contagious aspect of innovation. Most research stresses the importance of examining how the circulation of information is facilitated via network structures. Thus, the focus is more on the information mechanism that operates along the horizontal dimension of network structure. Furthermore, innovation researchers also suggest that actors do care about the sources of information, whether the information carrying actor is strongly connected to the focal actor or whether her approval is important to the focal actor. Trust, credibility, and legitimacy are all operative in the case of social contagion of innovation.

What is less obvious, though, is how these mechanisms operate differently in the more complex innovation context that involves both resource exchange and information communication (e.g., Azis & Amir, 2020; Fazar, 2020; Haghi, 2013). Complex situations entail a careful balancing operation between sets of competing logics across the vertical-horizontal dimension (e.g., Vu, 2020). This leads us to the question of how useful the concepts are that

transcend the horizontal-vertical distinction. As an exemplary concept that transcends the horizontal-vertical boundary, this study cites "a family of redundancy trade-offs", introduced by Reagans and Zuckerman (2008). Understanding the sets of trade-offs (brokerage vs. closure, exploitation vs. exploration, generalism vs. specialism, and focused identity vs. multi-vocalism) should help better design network research that involves complex situation - for example, as in inter-firm collaboration. Another strategic dilemma suggested is understanding who to benchmark in competitive situations. Would status concern take primacy over comparison with peer groups?

An intellectual gap identified pertains to a situation where the trade-off between power and information is expected, such as inter-firm collaboration network. For example, what would be the optimal network structure of inter-organizational R&D collaboration where power/dependence, legitimacy, and information are all operative? By focusing only on information flow, most existing research does not adequately address the dynamics that occur between them. As mentioned in the opening section, a careful study design, which is tailored to a specific study context, leads to a stronger causal claim based on the empirical result (i.e., Amchang & Song, 2018; Aujirpongpan & Hareebin, 2020; Han & Yim, 2018; Seo & Kim, 2018). Thus, a particular care is required in studying complex situations like organization-level collaborations, where many contingencies confound the effect of a particular network structure on outcome (e.g., Li & Li, 2017; Seo, 2015; Xiao, 2013; Yu & Wang, 2018). Also, the mode of research enquiry – whether it be via simulation, survey or archival research – should be decided considering the specific research questions and objectives. Some of theoretical criticisms against network analysis research can be alleviated with network modeling (i.e., agent-based modeling) at relatively low cost. Researchers further need to consider the fact that often real-world empirical research at the organizational level is conducted under substantial data-constraint, and the fact that network data is harder to obtain as compared to other demographic data.

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