Electronic Knowledge Networks: Processes and Structure

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August, 2006, Pre-publication draft of:

Faraj, S., Wasko, M., and S. L. Johnson (forthcoming). Electronic Knowledge Networks: Processes and structure in I. Becerra-Fernandez and D. Leidner (eds.), *Knowledge Management: An Evolutionary View of the Field.* Armonk, NY: M.E. Sharpe, Inc.

Introduction

Practitioners and researchers in the area of knowledge management have focused almost exclusively on how knowledge is stored, transferred, and used within organizations. However, much knowledge is exchanged in open online forums that cross organizational boundaries. We define an electronic knowledge network (EKN) as a self-organizing, open activity system that focuses on a shared interest or practice and exists primarily through computer-mediated communication. These networks are sustained through a range of technology including e-mail (Finholt & Sproull, 1990; Wu, Huberman, Adamic, & Tyler, 2004), USENET newsgroups (Butler, 2001; Jones, Ravid, & Rafaeli, 2004), and organizational discussion groups (Constant, Sproull, & Kiesler, 1996; Ravid & Rafaeli, 2004; Wasko & Faraj, 2005). In electronic knowledge networks individuals congregate based on shared interest and use the asynchronous nature of the technology to overcome the same-place same-time limitation inherent in face-to-face settings. Activities such as the exchange of technical advice now link thousands of people who lack previous familiarity, physical proximity, and are unaware of each others' demographic characteristics, organizational setting, or even national culture (Fulk and DeSanctis 1995, Preece and Maloney-Krichmar 2003, Sproull and Faraj 1997, Sproull and Kiesler 1991, Wellman and Gulia 1999).

EKNs are important new ways of organizing that have not been well studied so far (Butler, 2001; Fulk & Desanctis, 1995). As with any new phenomena a number of researchers have offered different definitions, each based on a specific emphasis. For example, EKNs focused on practice have been called electronic networks of practice (Wasko, Faraj, & Teigland, 2004). Those focused on a task have been called virtual groups (Ahuja, Galletta, & Carley, 2003), and those focused on shared interests and social support have been called virtual

community (Rheingold, 1993). We use the electronic knowledge network definition to emphasize the communality of these collectives in terms of electronic mediation, knowledge exchange orientation, and social network structure. This chapter is based on the premise that knowledge exchange in EKNs is sustained by both individual and network influences, and that the network's structure of ties influences individual participation and network dynamics, which results in the exchange of messages that add value to the network and create a public good of collective knowledge.

EKNs overcome the limitations of knowledge repositories by supporting knowledge exchange and new knowledge creation through conversation rather than static documentation. The advice accessed through EKNs is useful because EKNs provide access to knowledge from more diverse resources and from better resources (Constant, Sproull and Kiesler 1996). EKNs are critical information resources for knowledge workers because they bridge the gap between knowledge available in codified form, (including knowledge stored in knowledge management systems) and the actual requirements of knowledge work (Brown and Duguid 1991; Wenger 1998). EKNs overcome the limitations of knowledge maps by promoting self-identification of expertise, encouraging the voluntary participation of individuals willing and able to assist, and creating a codified record of the knowledge as it is exchanged. These electronic knowledge networks are also having an impact on a number of organizational activities. For example, electronic networks support distributed R&D efforts (Orlikowski, Yates, Okamura and Fujimoto 1995), enable open source software development (von Hippel and von Krogh 2003), and extra-organizational work practices (Wasko and Faraj 2005).

The purpose of this chapter is to summarize how EKNs sustain themselves by promoting voluntary participation and knowledge exchange. We focus on two major aspects. First, we

examine the factors that explain individual participation and knowledge exchange behaviors with an emphasis on individual motivations, social ties, and critical mass theories. Understanding why and how individuals exchange knowledge in EKNs is an important factor for the success of Knowledge Management Systems (KMS), as EKNs help fill the knowledge gaps left by knowledge repositories and knowledge maps. Next, we investigate studies that explore structural factors associated with knowledge exchange in EKNs. Recent advances in social network analysis have enabled the study of large scale networks based on network properties and are useful for deepening our understanding of interaction patterns on EKNs. We offer a summary and an evaluation of recent empirical and simulation work that focuses on whether interaction patterns follow competing theories of reciprocal exchange, generalized exchange, or critical mass. In summary, this chapter contributes to theories of new organizational forms by answering open questions as to the structure of electronic knowledge networks (DeSanctis and Monge 1999) and offers an early evaluation of the social and structural factors that both drive and limit individual participation in EKNs. Finally, from this emergent body of research findings, some evidence-based recommendations can be made for practitioners and organizations concerned with the building of effective EKNs.

The Role of Technology in Electronic Knowledge Networks

The purpose of this chapter is to examine how and why individuals use technology to voluntarily exchange advice and ideas in EKNs. It should be noted that one of the most prevalent theories shaping our understanding of technology-supported communication to date is media richness theory (Daft & Lengel, 1986). Media richness theory proposes that communication media can be arrayed along a continuum of media "richness" based on differing objective characteristics of the communication channel. Media richness has been referred to as a “cues

filtered out" approach because it predicts that the richness of the communication media "will result in predictable changes in intrapersonal and interpersonal variables" (Culnan & Markus, 1987). Media richness has been interpreted to suggest that since media forms differ in their ability to convey information, technology imposes constraints that restrict and ultimately determine the outcomes of actors. This objective, deterministic view of technology is not generally appropriate and is particularly inadequate in the case of information technologies (Orlikowski, 1992). According to Dennis and Kinney (1998), the limiting factor may not be the communications media, but "rather our preconceived perceptions of their limitations" based on media richness theory.

In reality, despite the pessimistic characterization of computer-mediated communication as a lean channel of exchange, there is ample evidence that people are using technology to support a wide variety of social interactions. Communication media have objective characteristics that determine the capacity of the media to carry information, but in using technology, individuals interpret, manipulate and appropriate technology in different ways. Technology is physically constructed, but is also socially constructed by users through the various features they emphasize and use, as well as the meanings that individuals attach to the technology (Orlikowski, 1992; Panteli, 2004). Media richness has become a popular "straw man" theory, set up to be easily refuted. There are currently such a wide variety of electronically enabled collaborative networks, contrary to the early prediction of media richness theory, that media richness now has little validity in predicting how media are used today. Electronically enabled collaborative network activities range from primarily social purposes, such as social software (i.e. facebook.com) and personal blogs, (i.e. livejournal.com), to informational collaboration and repository sites such as wikipedia. There are sites that started primarily for the

purpose of e-commerce but evolved into EKNs, such as the BTX website where Bruce Springsteen fans started using the ticket exchange functionality to send messages to each other (Culnan 2005). Technology is used to coordinate the efforts of a worldwide network of volunteers devoted to the creation of complex software through open source software development sites like sourceforge.com. Additionally, collaborative technologies are no longer limited to text-based asynchronous exchange. The technology supports both synchronous (i.e. chat and instant messaging) and asynchronous exchanges consisting of text, voice, graphics, or a combination of these.

Rather than compare and contrast how these different characteristics of the technology influence knowledge exchange across the different forms, we limit the scope of this chapter to focus solely on EKNs that are text-based, asynchronous, and support the exchange of special interest or practice-related knowledge through message posting and response.

Individuals in EKNs limited to text have found ways to adapt this technology to convey a variety of signals and symbols. Individuals create faces using colon and parentheses keys (emoticons) to convey emotion. Individuals SHOUT AT EACH OTHER using capital letters to convey anger, frustration or to gain attention. Individuals translate common sayings through the use of the symbols available in text, such as “let me add my $1/50 worth”, or by creating shorthand symbols (FWIW, BTW, IMHO). Individuals build complex pictures using text characters to imitate the drawing of lines. Thus, despite the objective aspect of the technology that limits communication to text, the use of the technology is adapted, based on social context, to suit the various needs and practices of communicating individuals.

How Technology Impacts Participation Dynamics In EKNs

In EKNs, although technology is adapted to meet the needs of the users, the primary communication channel of asynchronous computer-mediated communication does influence how knowledge is shared and exchanged. First, knowledge must be codified in the form of a text-based message and posted to an electronic discussion forum. Participation generally includes posting questions with various purposessuch as seeking a specific answer, general advice, or opening a debate. Participation can also include posting of announcements, messages of gratitude, follow-up questions, or messages intended to inflame others. However, the principal source of value in EKNs comes from the response messages posted to address the concerns of forum participants. Posting responses provides a dual value. First, it directly helps the knowledge seeker. Additionally, passive knowledge seeking occurs through lurking—reading the postings of others without actively engaging through public posting. Messages and their contents are typically made available to all participants in the network regardless of an individual's participation in the original exchange. The messages are often archived for future reference, thereby creating a searchable electronic help desk. It is also worth noting that this visibility provides network members with complete information about the online conduct of other network members, and sharply contrasts with the ephemeral, typically private conversations between a limited number of individuals that occur in face to face communication.

Another unique aspect of EKNs is that they are generally self-organizing, in that they consist of individuals who voluntarily choose to participate. The technology underlying EKNs supports communication between thousands, even tens of thousands of people (Sproull & Faraj, 1995). EKNs also provide a high level of anonymity to participants. Individuals are able to choose what personal information they reveal and there is little way to know if individuals do not

portray accurate online depictions. Individuals also choose when they participate, how often, and the level of effort they are willing to invest. These characteristics of voluntary and relatively anonymous participation create situations in which the barriers to entry and exit are low, enabling individuals to actively participate for a time and then withdraw, or to ask a question without intending to become an invested participant.

The technology underlying EKNs creates obvious benefits to knowledge seekers. The personal costs of posting a question to an EKN are generally small, as there is both relative anonymity and little social stigma incurred by seeking advice from others in these forums. EKNs provide seekers with access to expertise distributed throughout the world, regardless of physical location or personal familiarity. The effort required to post a message electronically is low, and experts typically have no expectations that seekers help others, or even return to the EKN. In sharp contrast, there are potentially high costs associated with seeking knowledge from personal ties, such as expectations of reciprocity or a sense of embarrassment about admitting ignorance on a topic (Borgatti and Cross 2003). Research indicates that knowledge seekers are typically motivated to participate in EKNs for personal gain, by receiving answers to a specific question, having questions answered quickly, and finding valuable information that is more up to date than other sources (Wasko and Faraj 2000). Not only do individuals exchange advice in EKNs, but they also share tools and computer code that are not available through other means, often for free (Wasko and Faraj 1999; Wasko and Faraj 2000).

However, the primary problem with seeking knowledge on EKNs is that it requires depending upon the "kindness of strangers" (Constant et al. 1996). Because participation in EKNs is open and voluntary, participants are typically strangers. Knowledge seekers have no control over who responds to their questions or the quality of the responses. There are also

significant costs associated with contributing knowledge to others. Contributing knowledge eventually causes the possessor to lose their unique value relative to what others know (Thibaut and Kelley 1959), and benefits all network members except the contributor (Thorn and Connolly 1987). Knowledge contributors have no assurances that those they are helping will ever return the favor, while seekers and lurkers may draw upon the knowledge of others without contributing anything in return. As management in many organizations has discovered, the availability of electronic communication technologies is no guarantee that knowledge sharing will actually take place (Orlikowski 1996; Alavi and Leidner 1999). While interest in the organizing processes of EKNs continues to grow, we know surprisingly little about how or why these networks are sustained (Desanctis and Monge 1999; Lin 2001). As noted above, it is easier to understand why individuals turn to EKNs when they need advice. However, the primary source of value in EKNs comes from the propensity of individuals to provide their valuable knowledge and insights to strangers (Rheingold 1993; Kollock and Smith 1996; Wasko and Faraj 2000), but why individuals participate in this activity when there is no obvious benefit to them is not well understood. The purpose of the following section is to investigate why people invest their valuable time and efforts to help strangers in EKNs.

Why People Contribute Knowledge And Help Others In EKNs

Theories of collective action and public goods provide an overarching framework for the examination of why people contribute knowledge in EKNs. One unique characteristic of EKNs is that the interaction, posting and responding to messages, produces and maintains a continuous stream of relevant practice knowledge that all participants may access. These messages become a public good, available to everyone with an interest in the network. Public goods are typically associated with two characteristics: nonrivalry and nonexcludability. The most basic definition of

a public good is that it is a good that is nonrival, meaning a good that is not used up or depleted in its consumption (Shmanske 1991). Typical examples of public goods include tangible goods such as public parks and lighthouses, as well as intangible or information goods such as public television and radio. The second characteristic often associated with public goods is nonexcludability (Head 1962). Nonexcludability occurs when noncontributors cannot be excluded from consuming the good The nonrival nature of a public good allows the good and its benefit to be offered to everyone in the collective, and nonexcludability influences individual decision-making about participation in the production, maintenance, or consumption of the public good. In particular, the issue of nonexcludability results in the tendency to free-ride, i.e., to consume the public good without contributing to its production or maintenance. In fact, the optimal individual decision is to free-ride and consume the public good without contributing anything in return.

However, if everyone decided not to contribute, the public good would not be created and everyone in the collective would be worse off. The paradox that rational individual decisions lead to collectively irrational outcomes suggests that it is impossible for rational individuals to cooperate and engage voluntarily in the creation of public goods. As with the production of any public good by a collective, the ability of individuals to free-ride on the efforts of others without contributing in return poses a major threat to the development and sustainability of EKNs. Thus, the key factor underlying the success and sustainability of these electronic networks is the propensity of individuals to voluntarily participate and provide their valuable knowledge and insights to others, even though there are no assurances that anyone will reciprocate the favor (Rheingold 1993; Kollock and Smith 1996; Wasko and Faraj 2000).

EKNs and other public goods are often created and maintained through collective action, even in the face of self-interest and the ability to free-ride. Collective action theories attempt to explain why individuals forego the tendency to free-ride and instead contribute to collective benefits. In EKNs, the collective action is exhibited through the activity of posting and responding of messages to the network. Collective action is described as action based solely on the voluntary cooperation of individuals (Marwell and Oliver 1993) and typically involves the production of a public or semi-public good (Heckathorn 1996). In contrast to theories that focus on the voluntary actions of individuals in isolation (TAM), collective action theories take into account that individuals and their actions are interdependent with others'. These interactions stemming from individuals engaged in a shared purpose become a significant source of social capital that can be leveraged to sustain collective action.

Social capital is typically defined as: "resources embedded in a social structure that are accessed and/or mobilized in purposive action" (Lin 2001 pg. 29). In recent years, social capital concepts have been offered as explanations for a variety of pro-social behaviors, including collective action, community involvement, and differential social achievements that the concept of individual-based capital (such as human or financial capital) is unable to explain (Coleman 1990). There are two widely recognized constructs underlying social capital, structural social capital and relational social capital (Nahapiet and Ghoshal). Structural social capital reflects the overall structure of ties in the network, and relational social capital takes into account that these structural ties vary in their relational strength or quality (Granovetter 1983). Relational social capital is important to network dynamics because it influences the development of common understandings, norms and cooperation among network members (Coleman 1990). The key difference between social capital and other forms of capital is that social capital is embedded in

the social realm. While other forms of capital are based on assets or individuals, social capital resides in the fabric of relationships between individuals and in individuals' connections with their communities (Putnam 1995).

In EKNs the posting and responding to messages represent interactions between individuals, creating this sense of mutual interest and engagement in a shared practice. Therefore, in addition to the sum of the attributes of the individuals in the network, collective action theories focus on the additional importance of network influences in encouraging voluntary contributions. This suggests that in order to understand the dynamics of knowledge exchange in EKNs, we must take a multi-level approach and examine both individuals and their attributes, and the unique relational and social structures that emerge at the network level. Collective action theories focused on understanding the production of a public good break down into three inter-related areas: 1) the attributes of the individuals in the collective; 2) the development of the relational dimension of social capital - for example commitment and cohesion; 3) the structural component of social capital specifying the pattern of ties between individuals in the collective creating an overall network structure. Each of these areas and how they pertain to EKNs is reviewed in the following sections.

Individual Motivations and Resources

The first stream of collective action research proposes that the population's heterogeneity of resources and interests affects collective action and the production of public goods (Olson 1965; Hardin 1982; Oliver, Marwell and Teixeira 1985). In most volunteer networks, individuals have differing levels of interest in helping others as well as differing motives for participating, which in turn affects their levels of contribution (Marwell and Oliver 1988). Research in this area focuses on the attributes of the individuals within the collective, such as an individual's level of

motivations in seeing the good realized, and the amount of resources that he or she can leverage toward the effort.

One of the primary motivations for participating in the creation of a public good is when there is no other alternative available. In other words, individuals are more likely to actively volunteer and engage in collective action when no other private solutions are available (Hardin 1982). In EKNs, this suggests that individuals who do not have access to knowledge and advice through their personal, private networks will be more likely to participate and share knowledge with strangers. There is some evidence from prior research that supports this, where the ability to access and interact with colleagues has been found to be an especially importance motivator for individuals who are geographically isolated from others, creating a unique opportunity to remain in contact through EKNs (Wasko and Faraj 2000). Another study indicates that individuals who did not have access to co-located colleagues were more likely to contribute knowledge in EKNs (Wasko and Teigland 2002). These studies suggest that individuals are more likely to invest time and effort to sustain the network by contributing knowledge, because they have no other way to access practice related knowledge.

There is evidence that individuals receive tangible returns for their participation in EKNs. Grounded in Olson's (Olson 1965) premise that collective action may be enhanced by providing selective incentives, recent work suggests that there are a variety of potential private returns for participating in EKNs (von Hippel and von Krogh 2003). For instance, prior research has consistently found that enhancing one's reputation within the network is an important source of motivation (Wasko 2002; Lakhani and von Hippel 2003). Active participation may also be motivated by a desire to gain recognition (Gu and Jarvenpaa 2003), or to influence others in the network (Firth 2004).

Another source of motivation comes from a desire for self-actualization and to gain intrinsic benefits associated with participation in EKNs. People who are motivated by self-actualization seek opportunities where they are able to use their skills and knowledge to reach their creative potential (Ghiselli 1971). According to Deci (1975; 1980), people are born with a need for competence and self-determination, suggesting that these needs motivate people to seek novelties, challenges and incongruities to solve. Bandura's social-cognitive theory (1986) suggests that self-evaluation, based on competence and social norms, is an important source of intrinsic motivation and engagement in activities for the activity itself, rather than extrinsic rewards. There is ample evidence that intrinsic motivations are an important driver of participation in EKNs. Researchers have found that individuals contributed knowledge simply because they enjoyed helping others (Constant et al. 1996; Wasko and Faraj 2005). Other sources of intrinsic motivation stem from the perceptions that participation is entertaining and fun, providing answers to others helps refine one's own thinking and provides an opportunity to receive feedback on ideas, and because participation in EKNs is a great way to learn new things (Constant et al. 1996; Lakhani and von Hippel 2003; Wasko and Faraj 2000).

Finally, research suggests that not only do people participate in EKNs out of self-interest, or self-actualization, but people are also concerned with their EKNs as a community and participate out of a sense of moral duty (Schwartz 1970). Etzioni (1988) argues that individual behavior is significantly affected by moral consideration, not simply personal gain, and that people forego the tendency to free-ride out of a sense of public duty and fairness. Prosocial behavior occurs when people wish for good outcomes not only for themselves but also for others, whereby people weigh the social good of sharing more heavily than their personal cost (Constant, Kiesler and Sproull 1994). There is evidence that individuals are motivated by a sense

of moral duty or fairness, because they are interested in helping advance the professional community as a whole, and because they world is a better place when people help others - everybody wins through the open sharing of ideas (Wasko and Faraj 2000).

In addition to motivations, the distribution of individual resources is also an important factor supporting collective action (Hardin 1982). For networks focused on creating and maintaining a public good, individuals within the network must have access to the required resources. These resources generally include money, energy, and influence (Oliver et al. 1985). In EKNs, prior research has found that people who have higher levels of professional expertise and organizational tenure are more likely to contribute knowledge (Constant et al. 1996). There is also evidence that tenure in the shared practice is a strong predictor of contributing knowledge to the network (Wasko and Faraj 2005), and individuals who felt their expertise was inadequate, were less likely to answer others' questions (Wasko and Faraj 2000). Other resources might include time, access to technology, or position in the shared practice.

Relational Social Capital

People who participate and contribute knowledge to EKNs are not engaged in direct, reciprocal relationships. Rather they are making their participation visible and open to the network as a whole. In addition, these participants are members of overlapping communities, the EKN, the organizational community and the wider occupational community. Participation in an EKN connotes not only the process of taking part, but also the development of relations through mutual engagement with others in the network (Wenger 1998). This mutual engagement results in relationships, and these relationships can be a significant resource for social action due to the emergence of relational capital, which enables prosocial behavior and collective action. While other forms of capital are based on assets or individuals, social capital resides in the fabric of

relationships between individuals and in individuals' connections with their communities (Putnam 1995).

When networks are characterized by a high degrees of trust, obligation, and identification between individuals and the network as a whole, individuals within the network are more likely to view their interests as aligned with those of the network's, leading to more positive interactions (Jones, Hesterly and Borgatti 1997). Additionally, the identity of individual network members is more likely to matter, thus compelling members to engage with each other with at least some minimal level of courtesy and consideration (Williamson 1991). Prior research in EKNs indicates that trust in others' ability, benevolence, and integrity is related to a desire to both give and receive information (Ridings, Gefen and Arinze 2002). Individuals with a strong sense of identification and attachment to electronic networks are more likely to participate and assist others (Wellman and Gulia 1997). There is also evidence that individuals are more likely to help others when they feel a sense of identification with the network and the network's goals (Lakhani and von Hippel 2003). However, in one EKN, prior research indicates that individuals who contributed the most helpful answers reported lower levels of commitment to the network (Wasko and Faraj 2005). This may simply imply that participants who receive the most help are more likely to feel committed to the network, indicating that the influence of social capital should be examined with regards to different forms of participation in the network.

Structural Social Capital

In EKNS, individual motivations and resources are distributed throughout the network. Individuals in EKNs voluntarily and individually determine how they participate and what they contribute. Individuals with collective interests may benefit from creating and sustaining a public good, however they may not necessarily act collectively to pursue that good. What seems to set

collective action in motion and sustain it is the formation of a "critical mass" of motivated and resourceful individuals (Marwell and Oliver 1993). Borrowing from nuclear physics, the use of the term critical mass refers to the idea that a certain threshold of participation or action has to form before a social movement may come to exist and produce the public good (Oliver and Marwell 1988). This core of activists is necessary because most other participants may not have the efficacy to engage in collective action and may free-ride, hoping that others will create the public good. Marwell and Oliver's critical mass theory (1993) begins with the assumption that free-riding does not necessarily prohibit collective action in large groups. Since the public good is nonrival, free-riders are not a burden to the collective. This suggests that some minimum number of individuals is needed to attract the participation and contributions of others in order to sustain collective action, and it is this subset that constitutes the critical mass.

Critical mass is particularly relevant for collectives where the costs of providing the good are fixed regardless of the number of individuals contributing towards its provision. In other words, collective action may be relatively easier to achieve in cases where the good can be created and sustained through the efforts of only a few, rather than equal participation by all. This is the case in EKNs. The costs for posting a message are the same, regardless of the number of individuals who benefit, and knowledge contribution may be sustained through the efforts of a few, active individuals. Therefore, it is not necessary that all or even most members of the network actively participate. The essential issue is whether there are enough individuals who are interested and resourceful enough to provide the public good for others (Marwell and Oliver 1993). This results in what Olson refers to as the "exploitation of the great by the small" (Olson 1965). This situation may occur when at least some subset of interested members has an

incentive to see the public good provided, even if they have to bear the full burden of providing it themselves (Olson 1965).

Individuals constituting the critical mass are likely to have access to more resources, more personal ties, and are more likely to be in a position to benefit from those ties, taking on central positions within the network (Burt 1997; Hansen et al. 1999). Central individuals have been shown to be important determinants of helping behaviors and knowledge sharing in organizations (Borgatti and Cross 2003). Studies in informal organizational structures indicate that central individuals were perceived to be more innovative (Ibarra 1993), had better work reputations (Krackhardt 1990), and high degrees of interpersonal influence (Friedkin 1993). In addition, individuals that hold central positions in the network are more likely to have access to timely information and know where to go for specific advice (Burt 1992). The influence of a critical mass may be even more pronounced in EKNs because formal structures are weak or nonexistent, and the higher resources of the critical mass attracts additional individuals to engage in collective action. For instance, Ahuja et al. (2003) found that an individual's network centrality in an electronic R&D group was associated with helping behavior and performance, and Gu and Jarvenpaa (2003) found that contributions to an electronic network of practice increased the more other users contributed. Additional research indicates that the structure of one EKN resembled a star, with a critical mass in the center providing the majority of responses, surrounded by a group of peripheral members engaged equally in posting and responding to questions, but the vast majority of individuals simply posted once or twice, flitting in and out of the network to seek specific advice (Wasko and Teigland 2002).

In summary, we have offered insight from theories of social capital and critical mass to suggest alternative explanations to individual motivation as an explanation of why individuals

participate, share knowledge, and sustain the EKN over time. Specifically, the voluntary nature of the exchange, the unequal distribution of motivations and resources and the ability of the network to be sustained by a small subset or critical mass of participants, has interesting implications for how EKN networks are structured, and how these structures generate value and sustain themselves. Network structure and implications for EKN success is examined in the next section.

Network Aspects of EKNs

Our review thus far has offered a social view of knowledge exchange, focusing on the motivations and social influences of individual participants in electronic knowledge networks. In general, these psychological/social views emphasize an individualistic perspective that gives primacy to what participants “feel” or at least "say" about their experience rather than what they "do". In contrast, the structural approach gives primacy to the relationships between participants and the resulting structures formed by those relationships. This complementary perspective seeks to identify and explain how persistent patterns of interactions between participants consistently arise within EKNs.

The sheer size and scope of the phenomenon complicate this approach. The theories and methods most consistent with a structural perspective, those drawn from social network analysis, are historically based on small group interactions (e.g., Hawthorne's bank wiring room studies). Until the late 1990's the majority of social science research has been limited to networks numbering no more than a few hundred members due to the difficulty in gathering larger data sets and to the computational limitations of then-current technology.

In recent years the proliferation of advanced Information Technology has not only facilitated the collection of large-scale network data but also increased the availability of large-

scale network data analysis tools and techniques. This has led to an explosion of interest in large network research in fields spanning biology, physics, mathematics, and social sciences. Popularized in books including Barabasi's (2002) Linked: The New Science of Networks, Strogatz's (2003) Sync: The Emerging Science of Spontaneous Order, and Watts' (2003) Six Degrees: The Science of the Connected Age, this new science of networks explores structural characteristics common across all types of large-scale networks - not only social networks, but also informational networks, technological networks, and biological networks (c.f., Newman, 2002).

Due to their prevalence across a wide range of domains, there are two network properties in particular that have drawn a great deal of attention in the new science of networks: small-world networks and scale-free networks. Researchers have empirically established the presence of both properties in real-world networks of metabolic reactions, foods webs, transportation networks, board-of-director interlocks, scientific collaborations, and WWW link structures (Watts, 2004).

The small-world phenomenon occurs when all pairs of nodes in a network are connected by shorter-length paths than would be expected in a randomly formed network of the same size, and the network also has a high degree of local clustering (Watts & Strogatz, 1998). This is conceptually similar to the famous studies by the sociologist Milgram (1967) that asked people to get a post card to a stranger in another part of the United States. Milgram found that the average number of intermediaries in successfully completed paths was six - a surprisingly small number considering the total population of the United States. Two practical implications of the small-world phenomenon are that "smaller-world" networks are more vulnerable to transmission

of infections and, more positively, can more readily diffuse knowledge than a "larger-world" network.

Small-world networks are particularly relevant in settings where network visibility is restricted. For example, when participant interactions are private and knowledge of network participants is transmitted through existing relationships, then small-world properties are quite salient. In those settings, the shortest connection between two network nodes (measured by path length) and the likelihood of redundant paths (measured by clustering coefficients) are indicative of probabilities for successful communication. Alternatively, in the open settings more characteristic of EKNs, where current and past participation is typically visible to all participants and active participants are readily identifiable, these small world properties are less indicative of the efficiency or effectiveness of future communication patterns.

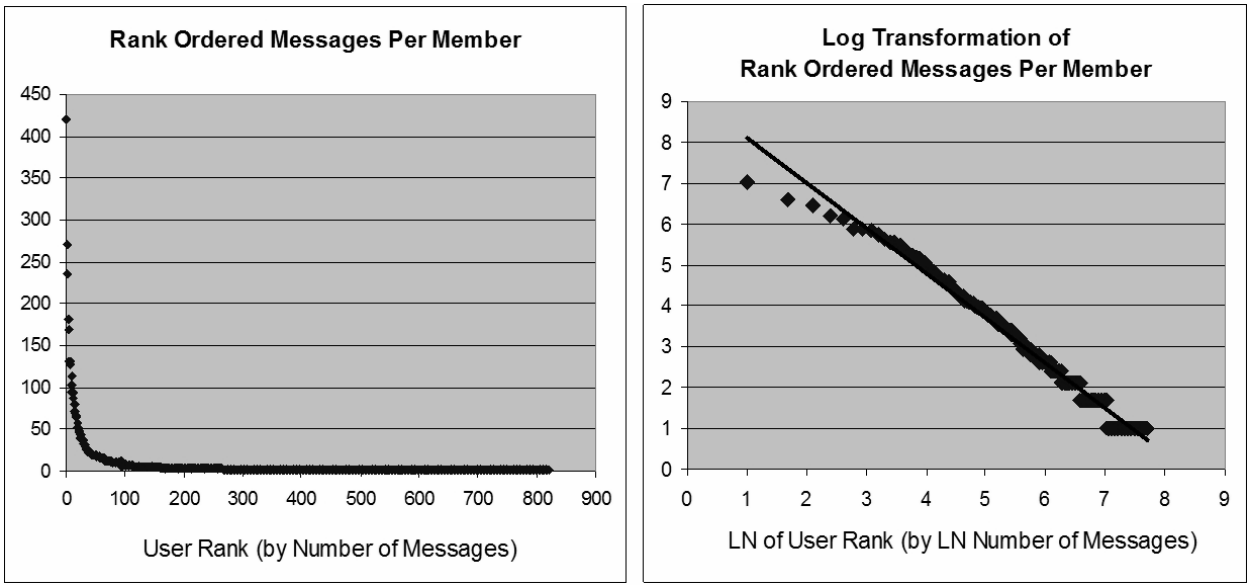

Figure 1: Power Law Distribution - Log-Log Transformation to Linear Representation

The second major characteristics of large-scale networks, scale-free networks, are characterized by a power-law distribution[1] in terms of node degree. The degree of a node refers to the number of different connections existing with other nodes. Like many other networks that are characterized by power-law distributions, it turns out that in EKNs a small number of participants have an extremely large number of links to other participants. Graphically, a power law distribution is readily identifiable when a "log-log" transformation of a rank-ordered list yields a straight line. Figure 1 shows both the untransformed and log-transformed distribution of the number of messages posted by 821 participants of a typical EKN. These power-law distributional properties of participation on EKNs have so far been found in every group studied so far by the authors. Examples of power-law distributions related to EKNs include the frequency distribution of links to websites (Adamic & Huberman, 2000), recipients of email (Wu et al., 2004), and participants on message boards (Adamic et al., 2003; Ravid & Rafaeli, 2004). Taken together, these studies confirm the power-law nature of EKNs' size distribution and participation within EKNs. The implications of such distributions for EKN research and management are explored in later sections.

Electronic Knowledge Network Empirical Research

Empirical studies adopting the social view of knowledge exchange have typically researched EKNs at the individual-level of analysis. Most studies to date have been qualitative studies or surveys of participants from a single EKN. As a whole, the empirical results and theoretical developments described in the first half of this chapter provide a helpful starting point for research based on a structural perspective. That is, studies from a social perspective bolster theory-based hypothesis on the structural characteristics of EKNs.

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[1] The terms scale-free network and power-law distribution both frequently appear in large-scale network literature to refer to the same phenomenon. We use these terms synonymously.

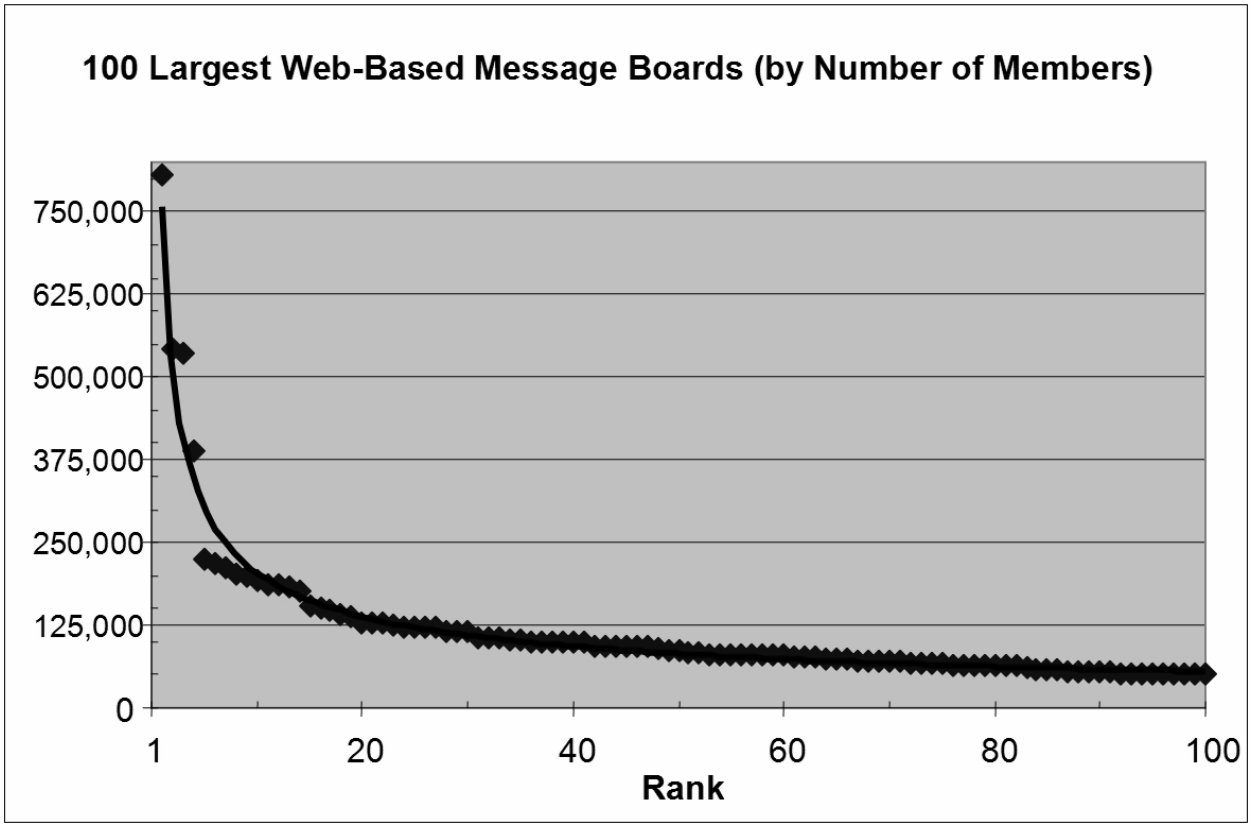

Figure 2: 100 Largest Web-Based Message Boards Form Power-Law Distribution

Some early studies have looked at the structure of EKNs as a dependent variable rather than as context. Butler (2001) investigated the participation dynamics of 284 EKNs (all e-mail based listservs). He found that as listservs gained members they were more attractive to new members yet also had higher rates of membership loss. The net effect of these opposing forces, a net membership gain, is consistent with Barabasi and Albert's model of preferential attachment and the formation of a power law distribution. Although the distribution of group membership size is unreported by Butler (2001), the descriptive data and the log-transformation in measurement models are both consistent with a power law distribution. As represented in Figure 2, the rank-ordered distribution of the 100 largest web-based bulletin boards using commercially available hosting technology (http://www.big-boards.com) follows a power law distribution

(R^2=0.98). This is further evidence that the relative popularity of EKNs (as measured by membership size) follows a power law distribution.

Jones et al. (2004) analyzed the structural characteristics of 600 EKNs (Usenet newsgroups). Focusing on the relationship between the volume of group member interaction and message complexity, they theorize that groups have a maximum stress point where a high volume of group interaction creates cognitive information overload for its group members. They find that group members prefer to send and receive shorter messages at a point of information overload. Also, they find that group members are more likely to cease participating at the maximum stress point, a finding consistent with Butler's (2001). In summary, although larger EKNs may be more attractive to new participants than smaller ones, participating in a large EKN is a qualitatively different experience than participating in a smaller one.

Nature of Network Interactions

An important open question in the structural perspective of EKN is to understand the nature of the interactions that explain the development of stable structural properties. Recent research on EKN formation has emphasized the competing role of three network formation mechanisms: mutuality, generalized exchange, and preferential attachment (Faraj and Johnson, 2005; Johnson and Faraj, 2005).

Mutuality is the inclination to respond to a participant with whom an individual has previously communicated. This motivation to reciprocate has a strong theoretical grounding in social exchange theory (e.g., Blau, 1964). Similarly, from a structural perspective, we can speak of the degree to which the participation patterns of a network as a whole exhibit a tendency towards mutuality. That is, when considering all of the interactions between participants in an electronic knowledge network, do reciprocated interactions occur with a higher, lower, or equal

likelihood, as expected for a random network of the same size? There is strong theoretical evidence - based not only on human behaviors in similar social situations but also on the study of individual EKN participation motivation - that lead us to predict that mutuality is indeed a structuring element in electronic knowledge network formation.

Another motivation for electronic knowledge participation is generalized exchange. The nature of online exchange, in particular, can make it difficult for participants to directly reciprocate - participants have unequal abilities and opportunities to contribute. Therefore participants may be motivated to contribute to the common good as much as to directly reciprocate back to individual member of an electronic knowledge network. Again, from a structural perspective, we can speak of the degree to which an electronic knowledge network as a whole exhibits this tendency.

Finally, another motivation of particular interest from a structural perspective is preferential attachment. It is an important concept in large-scale network formation, being proposed by Barabasi and Albert (1999) as the common mechanism for the formation of scale free networks. The core elements of their model have withstood numerous critiques and enhancements (c.f. Newman 2002, Watts 2004). The key conditions for scale-free network formation are (1) an open -growing - system, where (2) new entrants decide on preferences based on the expressed preferences of previous entrants.

An example of preferential attachment in a consumer setting is when you go to a music store and decide what CD to buy not from listening to music or researching artists but, instead, by automatically picking the top-selling album from the previous week. In this way, the preference that you express through your purchase is based on the preferences expressed by other buyers through their past purchases. In the most extreme case, where there is a very large number

of new buyers each week that follow this strategy (compared to the number of independent-minded buyers), a "winner-takes-all" market emerges where a single album would forever dominate future sales. The fundamental insight of Barabasi and Albert's model is that just these two simple conditions together, an open growing system (e.g., new buyers each week) and preferential attachment (e.g., picking the previous top-seller), can combine to form power law distributions.

Of particular relevance to EKNs is the relationship between preferential attachment and critical mass. To sustain an electronic knowledge network, a critical mass of core members is required to maintain continuity and ensure that the group retains currency and relevance. How is a group of core members established? The preferential attachment process is one such mechanism. The majority of EKNs are voluntary organizations that are typically established in an ad-hoc process. There is no pre-existing set of core "off-line" elites who are already known to new members, nor is there a large number of participants paid to be active contributors. The far more likely scenario is that as new members join a group they observe who the most experienced and tenured members are. Indeed, many EKNs provide status cues and explicit indications of member reputation, join dates, or number of contributions. Thus, as new members join, they are most likely to be drawn into interaction with the more active existing participants, thereby reinforcing those existing participation patterns. This preferential attachment process can lead not only to a power law distribution but can also build and reinforce a core set of participants to form the sustaining critical mass.

Emerging Research Directions

As social communication networks, EKNs share common characteristics - both structural and otherwise - with other social networks (Monge and Contractor, 2003). Earlier sections of this

chapter explored the social aspects of EKNs as social networks. Likewise, as large-scale networks, EKNs share similarities such as power-law distributions with other technical, informational and biological networks (Newman 2003). The complexity of the rigorous study of EKNs calls for a multi-theoretical multi-level approach (Monge and Contractor, 2003). In this section we describe an on-going stream of research by two of the chapter's co-authors (Johnson and Faraj) that answers this call. Ibarra, Kilduff, and Tsai (2005) have recently noted the emerging trends of connecting individuals and collectives in organizational network research. By adopting a structuralist perspective that is heavily informed by the findings of studies of individual participation motivations, we are moving from viewing the electronic knowledge network as merely a context for research to a multi-level object of study.

Determinants of Network Size

Much of the research described earlier in this chapter describes the motivations for individuals to participate in EKNs. The implicit assumption behind this research question is that participants have already identified a network in which to participate. A less-researched question is what attracts members to choose among competing EKNs. What are the predictors of electronic network size?

The most thorough treatment of this question to date (Butler, 2001) adopts a resource-based model. Butler (2001) found that potential members are, indeed, attracted to sites that provide members with more resources. Unfortunately, members are also turned off by larger sites, resulting in higher levels of membership losses as sites grow (Butler, 2001). Participation structures, mechanisms for reducing cognitive complexity, are suggested as one method for reducing membership losses (Butler, 2001). For example, message threads, digests, and topic forums are technology features for structuring participation in mailing lists and web-based

bulletin boards. Community-specific practices, such as message title naming practices, are another method of organizing participation.

Our own study of 576 EKNs both supports and expands upon Butler's (2001) findings. Whereas earlier studies have focused on e-mail based EKNs, we studied ones formed through web-based discussion boards; in this case, a set of comparable EKNs sharing a common technology engine (vBulletin by Jelsoft). We analyzed the characteristics associated with differences in inception-to-date membership statistics. We found that larger EKNs tend to have been in existence longer, have higher levels of administration intensity, have higher levels of participation intensity, and utilize more participation structures. Surprisingly, we found no association between EKN size and moderation intensity. Specifically, we found no statistically significant relationship between the inception-to-date membership of an EKN and the number of site moderators or the likelihood that a site used an optional feature that allowed individual users to report objectionable content to site moderators.

Whereas Butler (2001) clearly demonstrates that large groups have both positive and negative effects, our study provides hope that EKN managers can act in ways to limit those negative effects. For example, we found that more message threads and more message forums (collections of related threads) were both associated with larger groups. And, if an EKN sponsor is faced with a decision between investing in site administration or content moderation resources, our findings are that active site administration has a much stronger association with EKN size.

Structuring Mechanisms: Early Empirical Evidence

A challenge to adopting a multi-theoretical, multi-level approach to network research is identifying appropriate empirical methods. Monge and Contractor (2003) advocate the p* method for multi-level multi-theoretical hypothesis testing of communications networks. The

MultiNet software application provides researchers with a low-cost Windows package that can effectively test hypothesis on networks with thousands of nodes (Seary & Richards, 2000; Richards & Seary, 2004).

The p* method, a form of Logit regression modeling for network data, is based on a comparison of observed network characteristics against a Markov random-graph with the same number of nodes and relationships. Statistical tests in a p* analysis provide both an overall measure of fit (used to compare competing models) as well as significance levels for individual coefficients. Faraj and Johnson (2005) detail the use of the p* method for testing the tendency towards mutuality, generalized exchanged, and preferential attachment in EKNs. Based on the methods detailed in Johnson and Faraj (2005), the results of p* analysis of three weeks of message history for three EKNs are described below. The four structural tendencies that we analyze are choice (the non-random formation of links), reciprocity (the likelihood that there is a link from B to A when there is a link from A to B), generalized exchange (the likelihood that there is a link from B to C when there is a link from A to B), and preferential attachment (the likelihood that there is a link from C to B when there is a link from A to B).

Our analysis shows a consistent pattern across these EKNs. First, sequential tests of nested models, whereby each network tendency is added one at a time (first, choice, then reciprocity, then generalized exchange, and, finally, preferential attachment) support the inclusion of all four tendencies in a full model. That is, a model with all four structural mechanisms has greater explanatory power than models with one or more of the mechanisms excluded.

Tendency	Measure	Electronic Knowledge Network		
		PRES	CNEW	DEEG
	# of Nodes	36	58	55
	# of Links	57	155	143
Choice	B	-4.67	-5.26	-4.40
	Exp(B)	0.01	0.01	0.01
	Std. Err	0.31	0.23	0.16
	PL Wald	232	545	749
	p	< 0.01	< 0.01	< 0.01
Reciprocity	B	1.83	3.92	1.12
	Exp(B)	6	50	3
	Std. Err	0.39	0.25	0.27
	PL Wald	22	246	17
	p	< 0.01	< 0.01	< 0.01
Generalized Exchange	B	0.46	0.17	0.22
	Exp(B)	1.59	1.18	1.24
	Std. Err	0.06	0.02	0.02
	PL Wald	67	81	143
	p	< 0.01	< 0.01	< 0.01
Preferential Attachment	B	-0.47	-0.04	-0.16
	Exp(B)	0.63	0.96	0.85
	Std. Err	0.09	0.02	0.03
	PL Wald	29	3	24
	p	< 0.01	< 0.10	< 0.01

PRES=programmersresource.com; CNEW=codenewbie.com; DEEG=deegruenig.com/forum

Table 1: p-star Analysis of Three Electronic Knowledge Networks

Next, as summarized in Table 1, the significant coefficient ($p<0.01$) for the Choice tendency for all three networks provides evidence that these EKNs form non-randomly. The significant coefficient ($p<0.01$) and positive sign for all three EKNs for the reciprocity coefficient ($b=1.83, 3.92, 1.12$) supports the presence of reciprocation as a participation motivation in each EKN. During the three-week observation period, participants in all three groups were far more likely to send messages to someone who had sent them a message than to participants who had not. This tendency was particularly pronounced in the CNEW group. The

significant coefficient ($p<0.01$) and positive sign for the generalized exchange coefficient ($b=0.46, 0.17, 0.22$) supports the presence of generalized exchange as a participation motivation. When a participant received a response to their own message they were more likely to also respond to a third party.

Finally, a surprising result is the lack of empirical support for the presence of preferential attachment. Among the four mechanisms, the inclusion of preferential attachment provided only a marginal improvement to the overall model fit. It is significant ($p<0.01$) in only two of the three EKNs (PRES, DEEG) and in those groups the coefficient is negative ($b = -0.47, -0.16$). We conclude from these results that when controlling for generalized exchange that there is no evidence of the presence of a tendency for preferential attachment and, indeed, that there is tentative evidence suggesting a preference away from preferential attachment in two of the three groups. These findings demonstrate the power of using a sophisticated multi-level, multi-theoretic method to analyze networks.

Structuring Mechanisms: Agent-Based Simulation

The publication of articles in Nature (Watts & Strogatz, 1998) and Science (Barabasi & Albert, 1999) were followed by rapid advances in the study of large-scale networks (c.f. Newman, 2002). Early on, by focusing on characteristics considered universal across wide domains, researchers were able to make simplifying assumptions that led to mathematically solvable sets of equations. Then formation models grew more complex, including, for example, multiple generation mechanisms. Researchers also sought to test their models against multiple outcomes, for example, to match both the range of small-world and power-law distribution values observed in the real world. When dealing with networks, even a small increase in

complexity can quickly render a model intractable. Many studies, therefore, also rely on simulation methods to test network formation models.

When applied to EKNs the strength of the classic large-scale network formation models, their attempt to be universal, is also their weakness. The most common technology for EKNs - the web-based discussion board - institutes constraints on participants that limit network formation. For example, whereas a generic network model typically assumes that any node can connect to any other node at any time, in a threaded web-based discussed board a connection can only be made by responding to a message that has not already been responded to. Furthermore, for the sake of computational simplicity, large-scale network formation models have focused on simple outcome measures that can be directly calculated or reasonably estimated through tractable solutions. To overcome these limitations, Johnson and Faraj (2005) use an agent-based simulation to test electronic knowledge network formation models.

Thus, they can investigate to what extent participant behaviors in EKNs are motivated by structural characteristics of the network. Specifically, their study tests the role of preferential attachment and mutuality in EKN formation. They develop a simulation model of a thread-based asynchronous EKN. By applying variance reduction techniques (Law & Kelton, 2000) they isolate the relative impact of mutuality, preferential attachment and random links on three outcome variables (power law distribution, clustering coefficient and mutuality index). Figure 3 provides an example representation of a communication network derived from a simulated threaded-discussion board.

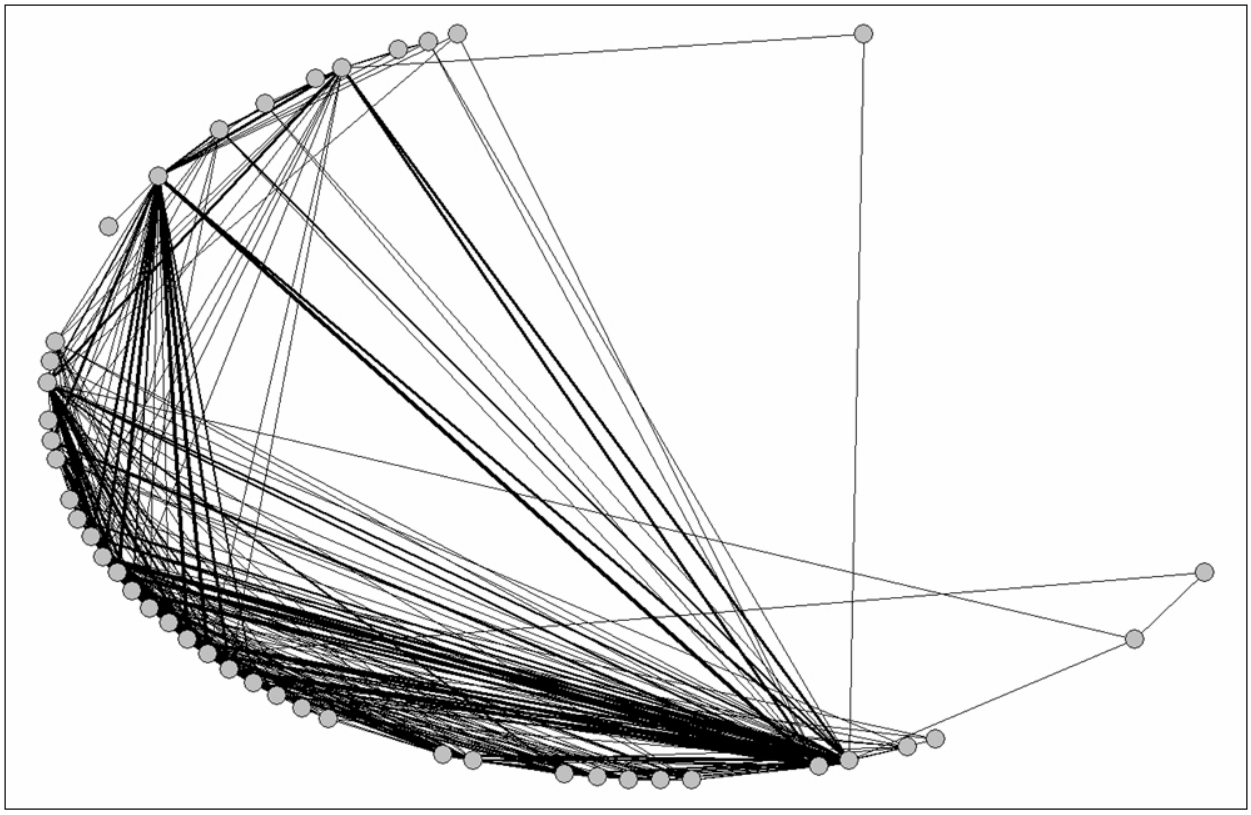

Figure 3: Network Representation of Agent-Based Simulation

Johnson and Faraj (2005) develop three related representations of a threaded electronic knowledge network. First, they develop an agent-based model that describes the behaviors, rules, and tendencies that govern a thread discussion group. Next, they propose an analytical model, including specific functional forms and distributions for a threaded EKN. Because of the limited amount of existing research in this area, they use empirical observations from reference groups to derive some of the analytical model and simulation parameters. Their third representation of a threaded electronic knowledge network is the implementation of the analytical model in an experimental simulation design. They run this experimental model 330 times to simulate over 3.6 million messages generated by almost thirty-nine thousand authors.

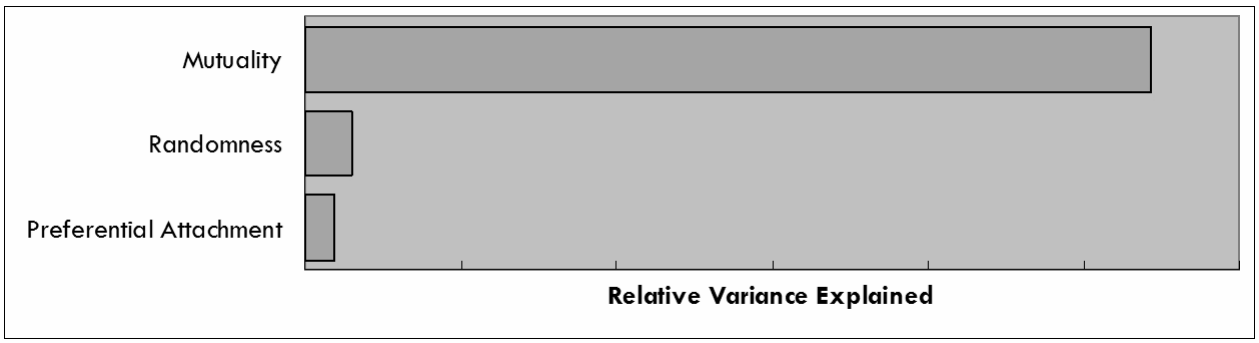

Figure 4: Relative Effects on Mutuality Index (MI)

By using a simulation method and focusing on a specific network platform, Johnson and Faraj (2005) extend previous mathematical models of network formation to a richer, more realistic setting. Their findings are visually represented in Figures 4 and 5. They find both mutuality and preferential attachment to have strong effects on the formation of network structure. Unsurprisingly, changes in mutuality (the agent-level preference) have the most significant impact on mutuality index (a network level measure).

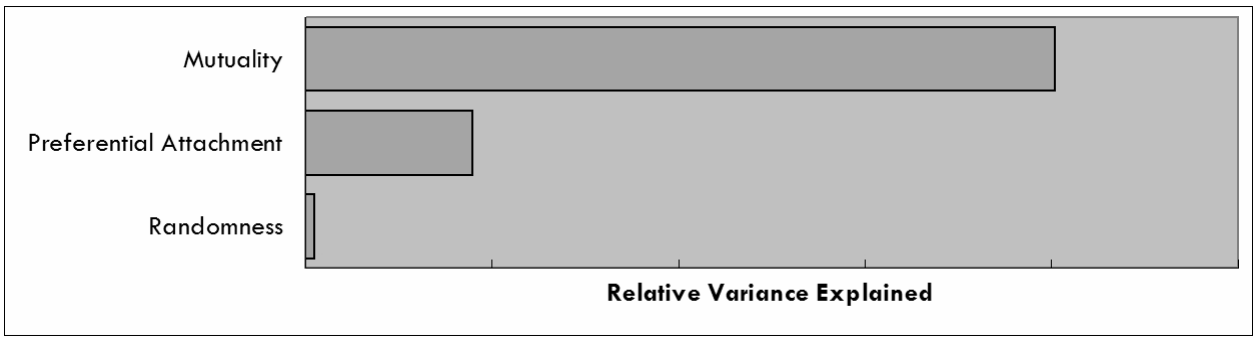

Figure 5: Relative Effects on Power-Law Distribution Coefficient

More surprising, however, is the finding that mutuality is also important for the emergence of power law distributions observed in EKNs. One explanation for this finding is that in the constrained environment of a thread discussion board - where each message can directly receive only a single response - mutuality may play an important role in generating more opportunities to interact with the most popular participations. If the group norm is strong toward direct and immediate reciprocation, that provides a powerful fuel for the "rich get richer" cycle

of reinforced popularity. This finding demonstrates the power of context-specific modeling as well as the importance of a considering both strength and symmetry for mutuality.

Conclusion

This chapter has presented current research thinking and early findings on EKNs. EKNs are emerging as alternative sources for knowledge exchange for organizational actors. Because the primary communication channel for EKNs is asynchronous computer-mediated communication, the technology has a profound influence on how knowledge is shared and exchanged. From an organizational standpoint, EKNs offer unique challenges to management in that they extend across organizational boundaries and are characterized by the free exchange of knowledge. Attempts to restrict participation by organizational members have a dual edge: knowledge not only flows out from organizations but also flows in. To date, we know little about whether organizations benefit or suffer from their members' participation in such settings. For organizational actors that increasingly view their loyalty and identity to be part of a specialization or a small community of practice, the continuous development of EKNs seems to indicate that participation in these free flowing knowledge forums is valuable.

Some specific findings reported in this paper require further elaboration. Most important, a number of theories related to social capital, collective action, and critical mass appear to have emerged as complements to traditional individual views of why people participate. Some individuals may be motivated by notions of gain and reputation building but evidence is accumulating about the importance of social ties and interpersonal issues such as norms and obligations in support of the continued operation of EKNs. These results have implications regarding how EKN managers may want to manage online interactions in order to allow the positive aspects of online community to emerge. It may also mean that the early phase of the

development of a community is absolutely critical and that there is a need to nurture a critical mass of "givers" who will sustain the group during its difficult periods.

The findings related to EKN structure are significant in terms of understanding interaction patterns over time. Empirical evidence suggests that EKNs are scale-free networks and thus are characterized by highly skewed distributions in terms of sizes as well as highly skewed participation within by individuals. An implication is that EKN managers need to differentiate between participants. Some posters are more equal than others. This is confirmed by the emergent practice by EKN managers to often give titles and recognizable signatures to frequent posters. Clearly, if 20% of the posters are responsible for 80% of the posts, then it becomes crucial to ensure that the constructive lead posters are recognized and rewarded while the negative lead posters are quickly brought under control.

Our findings have implications for the study and management of emergent Web technologies for knowledge publishing, sharing, and linking. The development of publicly edited collaboratories such as Wikis, and networked self-publishing such as Blogs are changing the nature of the Web experience but are little understood so far. For example, hundreds of thousands of people have contributed to Wikipedia and there are more than 20 million active blogs. The theories discussed here offer a starting point to understand these highly social technologies. The structural analysis and methods used to study EKNs are also highly relevant to study Wiki participation and blog connectivity because in the final analysis, no matter the changing underlying technology, the interactions are social interactions.

This chapter has offered early evidence of the interaction mechanisms that take place in EKNs. Explanations built on reciprocity, generalized exchange, and preferential attachment have been tested empirically as well as through simulation studies. The findings regarding the

importance of reciprocity and generalized exchange are consistent with the theories of social capital and collective action that developed from the direct study of participants. Together, these various strands of EKN explorations have opened an important window on how and why individuals participate in EKNs. Yet, as EKNs grow in importance and encompass ever more diverse areas, exciting new research possibilities abound.

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