

# THE INFORMAL NETWORKS OF INNOVATION

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## Abstract

*Innovation, and particularly innovation in information and communication technologies (ICT), continues to draw scholarly attention across a range of disciplines and intellectual communities. Scholars offer up a diverse range of theories regarding technological innovation in general and ICT innovation in particular. Through this paper we review these conceptualizations of innovation practices and posit that (1) innovation processes are likely to take place through network-like arrangements and (2) these networks are often informal and typically reflect long-standing relations. We argue that innovation is done through networks because these can best facilitate the exchange of innovative ideas and competencies. We further argue that innovation network structures are often based on extending and formalizing informal relationships among individual actors. Relative to our second point, we note there is little research which theorizes or investigates the nature and influence of these informal interactions and their network structures. In an effort to begin addressing this gap, we build here on a review of relevant existing literature to develop theoretical constructs which illuminate the constitution and the salience of informal networks of innovations. To advance an initial model of informal networks of innovation, we draw from the literatures of social network theory, communities of practice, invisible colleges, and actor network theory. Based on this review, a model of informal interaction is constructed which is constituted of human actors and social institutions, specific technological artifacts, and innovative concepts. We conclude by elaborating on the interactions of these network components.*

## Introduction

Through this paper we develop an initial conceptual model regarding the importance of informal ties in innovation networks. In doing this we argue there is a need for more scholarly attention and empirical research to raise our collective understanding of the extent to which ties within innovation networks hinge upon informal relations among individuals and, how these ties underlie innovation (Gulati 1995; Powell 2000). To do this we draw from current conceptual frameworks to our theorizing on the informal networks of innovation.

We theorize that technological (which we mean here to be ICT) innovation arises from a network structure that has four distinct characteristics. That is, we theorize that an innovation network is comprised of people, relevant and resource-providing firms (institutions), core concepts or ideas, and particular artifacts that illustrate core concepts or make visible core ideas. Core to our argument is that innovation networks extend and partially formalize pre-existing informal relationships among individual actors. In theorizing the centrality of informal relations among actors as the basis for innovation networks, we further argue that formal institutions, such as organizations where these people may work, play a secondary role in two ways: as temporary locations for people's work and as providers of resources.

To develop our argument regarding the constitution and the salience of informal networks of innovations we draw from the literatures of social network theory, communities of practice, invisible colleges, and actor network theory. Based on this review, we develop and discuss a model of informal interaction is constructed which is constituted of human actors and social institutions, specific technological artifacts, and innovative concepts. We conclude this theoretical essay by elaborating on the interactions of these network components.

## Innovation vs. Innovating

Naïve conceptualizations depict innovation as the achievement of a single individual. This makes for good stories but is not empirically supported and cannot be considered a viable model of innovating. A more common view, and the one underlying much of the writing in both economics and strategy, is that the firm is the locus of innovation. Within the firm, as depicted in the common view, some small group provides the innovating impetus which the firm then harnesses for economic value. This view implies that by controlling the innovation it can become a competitive advantage and the firm will be able to accrue the benefit of the innovation. Such thinking suggests that firms can develop, manufacture, market, distribute, and provide ancillary services related to the innovation. Building from this traditional view of innovation it follows that an internal research and development (R&D) unit is an indispensable strategic asset and perhaps even a formidable barrier to competitors in the market (Maclaurin 1949). And, each firm needs to control and guard its innovation processes from competitors.

Firm-centric models of innovation frame the process as a series of stages or phases of development. The activities within each stage are seen as exhibiting an orderly or cyclical equilibrium: an assumption of stability. Gordon and Greenspan (1988, p. 2) note, “we assume stability because only stable behavior persists; an unstable system in disequilibrium soon explodes and therefore, is only of transient interest”. To this end, innovation is generally attributed to the rational efforts of a small number of actors within an organization. These actors exert considerable control over the innovation process.

This firm-centric, linear process that is based on guidance from a small number of key actors stands in sharp contrast – in at least two places – to the detailed empirical findings of innovation processes (e.g., Hughes 1983b). The first contradiction is that the empirical work makes clear that innovation efforts are complex, non-linear and characterized by high degree of uncertainty. Second, the empirical work on innovation makes clear that the outcome is a product of multiple players’ participation. The knowledge needed to innovate is typically located with players who are parts of different institutions. This distribution suggests that innovation is not controlled (by one firm or set of actors) as much as it is emergent (across many firms and multiple actors).

These empirical findings suggests the linear model of firm-level innovation masks the actual nature of innovation, perhaps confusing desire to take value from an innovation with the nature of innovation work. The firm-centered linear model of innovation does not account for those features of innovation processes that do not seem to lend themselves to an equilibrium or set of stages. Thus, any efforts to cast the innovation journey into a set of quasi-stable stages fall short of accommodating intricacies of innovation work (Van de Ven 2005). The volatile and indeterminate nature of the innovation process has prompted a group of researchers to search for alternative perspectives (Hannan et al. 1989).

The linear model of innovation also seems ill-equipped to account for the multi-institutional nature of innovation. New technologies and businesses are seldom developed by a single firm (Chandler 1990; Nelson 1982). Necessary skills and know-how needed for such developments often lie across multiple firms (Powell 2000). Teece and Pisano (1987) note that large corporations are increasingly aware that innovation knowledge is situated outside their boundaries. And, contemporary organizations are becoming less self-sufficient in their ability to generate knowledge to fuel innovation processes (Fusfeld et al. 1985). This translates into an increasing reliance on inter-firm alliances, and external sources for R&D. In this context, innovative ideas are increasingly likely to originate outside the firm. And, boundaries of firms become more porous than is typical for traditional hierarchies, such that innovations and knowledge can traverse organizational boundaries (Chesbrough 2003).

## Characteristics of Innovation Networks

If the innovation process does not take place within boundaries of a firm, how might it ensue? Several competing theories attempt to address the question. For example *transaction cost* theories focus attention to the other extreme: the *market*. The core of these theories is transactions which involve more uncertainty and recur more frequently are more likely to be conducted within hierarchically organized firms. On the other hand, transactions that require no transaction-specific investments, and are more straightforward and less repetitive, will take place in a market. Firms organize transactions in a market when they seek to reduce production expenditures. The stereotypical competitive market is characterized by self-interested, non-cooperative, and unconstrained social interactions. In this theory of markets, price is recognized as the major organizing mechanism (Williamson 1979).

However, Powell (1991) notes the adherence to the twin pillars of hierarchy and market blind us to the emerging diversity of organizational forms. The current wealth of literature in the area of economic sociology suggests that if price is considered a simplifying mechanism; it is therefore incapable of explaining the intricacies of the idiosyncratic and dynamic exchanges that take place in innovation processes (e.g., Swedberg 2003). The exclusive focus on transactions - rather than the supporting relationships - can be misleading, as the primary unit of analysis may be poorly understood. Within the innovation process, a surprising proportion of inter-organizational exchanges are carried out in arrangements that do not necessarily reduce transactions cost. These sorts of exchanges are performed in order to provide concrete benefits or intangible assets that are far more valuable (Powell 1991). For instance, Helper et al (2000) observe that trends for automobile subcontracting turn into interdependent and deep relationships, which are not sustained based exclusively on cost reduction considerations. Inter-organizational networks are particularly useful in the production and dissemination of knowledge (Owen-Smith et al. 2004; Scott et al. 2007).

Knowledge transfer is germane to exchanges that arise in innovation processes. This knowledge could include qualitative expertise, technological capability, and the like (Polanyi 1967). An innovation network is constructed on the grounds of two underlying assumptions. First, no single firm is likely to possess enough resources and knowledge for completing the innovation process, leading us to believe that the process requires going beyond a firm's boundaries. As a result, each firm may be dependent on intangible resources controlled by others, and these intangible resources may be widely distributed. Second, gains are expected to accrue from the pooling of resources: there must be something that draws players together.

Beyond the relationships among individuals and firms, we know that knowledge is critical to innovation (Rogers 1995). Most flows of information in a hierarchy and most exchanges of information in a marketplace occur in order to produce information or acquire a commodity. Developing new meanings and novel interpretations is daunting; sharing this through hierarchies or across markets magnifies the difficulty. As discussed earlier, innovation knowledge cannot usually proliferate within a corporate hierarchy, possibly because it has no clear tangible value or easy-to-package message that can be shared up and down the hierarchy. Nor can innovation knowledge be easily traded in markets: the knowledge is too fluid, its value too amorphous (footnote 1). This is where network arrangements come into play. We know that knowledge is exchanged more freely in network arrangements, in contrast to markets and hierarchies (Powell 1991). This suggests that a central value of network arrangement has to do with their capacity for generating, sharing and interpreting information. The inherent dynamics of knowledge sharing networks has the potential to enable complex channels of communications which may be uncommon in the other arrangements (Kaneko et al. 1987).

Networks are complex webs of communication that can afford an unparalleled access to intangible assets, such as tacit knowledge and technological innovation, which cannot be as readily developed internally. The enhanced flow of information brings together different logics and novel combinations of ideas, which in turn serve to produce more innovation. In this light, an innovation network serves as a virtuous cycle (Powell et al. 2005). Ties external to organizations enhance innovation, and innovation outputs in turn encourage further collaborative linkages. These cyclic and generative effects of networks can enable self-sustaining, autopoietic mechanisms. Ahuja (2000) and Stuart (2000), note that firms with a better record of innovation are more likely to forge network alliances, underscoring the role that networks ties play in the recurring process of innovation and growth.

The advent of inter-organizational networks considerably raises the diversity of institutional actors and their interdependence in the innovation process. The synergy brought about by this diversity can provide access to new sets of information, resources, and technological capabilities (Gulati et al. 2000; Subramani et al. 2003). More diverse and broad networks relationships would lead to more diverse experiences, competencies, and added opportunities (Beckman et al. 2002). This is particularly evident in knowledge-intensive industries, in which the networks connecting R&D units are critical to knowledge proliferation. In this context, collaborative R&D efforts manifest themselves as a vehicle for developing strategic flexibility, and getting access to unprecedented assortments of innovation knowledge (Fritsch et al. 2001; Pisano 1990).

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1 This notion is being challenged by concepts of idea markets and "crowd sourcing." For more on this see Miller, Resnick, et al. (2005). We note only that the applications of these ideas are primarily for feedback.

## **Informal Networks vs. Formal Networks**

Powel (1996, p. 120) maintains that “beneath most formal ties lies a sea of informal ties.” The role of informal linkages may be the most important under-explored element in the innovation process since the formal structure of networks is largely contingent upon the solidification of pre-existing informal relationships. As Macneil (1985) posits, the cornerstone of networks are defined by inter-dependence, friendship, and altruism: a sharp contrast to the formalisms of hierarchies or the discretized and transactional nature of markets.

Many inter-firm relationships within networks are extensions from interpersonal ties, with a high degree of concurrent informality. For example, technology brokerage, which facilitates the transfer of innovative ideas across networks, is visible at the level of firms and industries. However, it is realized through interactions of individuals and teams who cross boundaries in the conduct of their work (Hargadon et al. 1997). These boundary spanners go about identifying, translating, and relaying information across engineering firms, for example (Fleming et al. 2007). They transfer information from firms where it abounds to firms where it is dear. These types of informal relations include but are not limited to participation in ad-hoc industry committees, executive education program, conferences, trade and professional association activities. The mobility of personnel among firms, and the shared norms and experiences that accrue to those with common educational backgrounds is also a driver for developing informal linkages across firms.

Informal links are salient because they can further formal and contractual alliances. The consolidation of formal ties seems stronger when they “rest” upon the strength of informal ties because of the complementarity and accommodating nature of network paradigm. Murray (2002) argues that in the life sciences, R&D partnerships emerge out of enduring co-authorship, mentor-mentee, and common training relationships which often display an informal spirit. These informal personal ties also hold a great potential to evolve into intellectual properties like patents, and thus to subsequently forge formalized contractual agreement among firms. The embedded nature of the informal ties can also enhance the distribution of complex information, mainly tacit and situated, making a substantial contribution to innovation practices (Granovetter 1985; Uzzi 1997).

Informal networks that co-evolve with formal arrangements can portray a different image than presented by formalized structure of networks. These links involve exchange of ideas, experience, or expertise between individual and groups. This is not to say that these links exist only between cooperating firms. They may even unfold where the formal network is formed in a highly competitive environment, which are characterized by opposing interests. Von Hippel’s (1986) study of US steel mini-mill producers exemplifies such situations. Based on his interviews with plant managers and engineers, he found that the exchange of proprietary information between competing manufacturers is not an uncommon practice. These “leaky” pieces of information were mainly centered on productions problems, matters of pollution control and safety, and industry-related concerns. The informal trade of information was reciprocal and based on the expectation that requests for helps would not remain unanswered. In addition, strong personal friendships (i.e. between former colleagues) that exist in research community would urge individuals to share some information which is unlikely to be transferred through formal conduits (Rogers 1982).

In stark contrast to their significance, very little attention in terms of research has been directed to informal ties. Many organizations are largely unaware of the extent to which formal activities are hampered or enabled by informal relationships (Cross et al. 2002b). As for research, a small but well-established stream of organization theory examines how informal connections relate to the formal structures of firms (i.e. Blau 1969; Dalton 1959). A few organizational researchers have investigated the impact of informal networking in large, multinational corporations, (i.e. Bartlett et al. 1990; Hansen 1999). Beyond these sterling examples, most empirical studies of the innovation networks have focused on formal ties established among firms (Powell et al. 2005).

Studies of formalized networks of innovation often focus on the effects of networks on patenting or codification of knowledge, and use patents or published papers as proxies for innovation. In such studies, patents are a dependent variable and formal relations are one of the independent variables. Although patents can be identified as a measure of knowledge creation (Griliches 1990), there are distinct limitations. For instance, patent analyses are incapable of identifying the mechanism of knowledge transfer (Jaffe et al. 2002). In addition, some types of innovations are not patentable (i.e. innovations in financial service products) (Jaffe 2000) and more importantly, a great deal of collaborations do not lead to any patents, but may lead to innovation. Nonetheless, the paucity of empirical investigations concerning informal networks is understandable. Informal interactions are often hard to trace due to their plasticity and heterogeneity. This means approaches that rely on post-hoc proxies of innovation will find it difficult to identify and analyze these interactions empirically, given their qualitative nature (Hienerth 2006).

To better understand the nature and value of informal networks relative to innovation, we draw on four existing strands of research as each helps to partially explicate how informal relationships unfold and subsequently affect innovation networks (see also the summary of this analysis in Table 1). These four areas of research are social networks perspectives, communities of practice, invisible colleges, and actor network theory. In what follows we briefly outline to what extent each conceptual framework can contribute to our understanding of the informal networks of innovation. We then propose a general model in which we integrate these partial insights into a more coherent and still tentative arrangement.

## The Social Network Perspective

A strong tradition of theory and research has explored different aspects of social networks (e.g. Burt 1992; Granovetter 1973; Merton 1957). These and other contributors to our understanding of social networks elaborate on the informational, status-providing, and resource advantages of having extended network relationships. This literature provides the basic conceptual underpinning of social networks. Social networks can be conceived of as links or ties between people (or nodes), these ties and nodes form a network of relation; this network is enacted by sharing of information between nodes and across ties. Beyond this basic conceptual value, social network theorists offer a number of theoretical constructs that can be employed for the analysis of informal networks. For instance, *the small world phenomenon* has been employed to elucidate the fast dissemination of knowledge in certain informal arrangement (Uzzi et al. 2005). In this view, small world is defined as a network that is both highly locally clustered and has a short path length, two network characteristics that are normally divergent (Watts 1999). Using the concept of small world, Newman (2001) studied coauthoring structures within seven different scientific communities and concludes that each relies on small world structures. He infers that the small world phenomenon might be the reason for swift transfer of ideas across disciplines. Along the same line, Uzzi and Spiro (2005) illustrate that small world arrangements inspire innovation, as they connect and mingle specialized knowledge and resources embedded within multiple clusters that would be isolated otherwise.

Early studies of social networks focused on informal interactions of individuals. Many of the more recent studies have shifted towards investigating formalized structures (Kilduff et al. 2003). This shift or drift turns scholarly attention from how networks form towards discussions of measuring, representing and analyzing the links and nodes: shifting attention away from the complexity of social realities. For example, Cross and Borgatti (2002a) explain how the social network perspective can be used to chart the structures of communication within an organization. They assert that "...conducting a social network survey is a straightforward process of obtaining a list of all people in the defined network and simply asking all members of the group to characterize their relationship with each other. In this process it is important to ensure that the kinds of relationships measured are appropriate for the task at hand and not unnecessarily inflammatory."(Cross et al. 2002a, p. 33) While this quantitative approach can help the researcher diminish the complexity of informal relationships, it fails to capture the multi-dimensional characteristics of informal connections. In the context of our interests, informal interactions among graduate students from different labs at a conference would not be captured. This focus on formality would also not capture the discussions of panelists from different organizations who come together at a conference.

Another limitation of network theories has to do with their emphasis on structure over action. Network theories generally posit that the attributes of actors are less important than their relationships with other actors within the network (Scott et al. 2007). This approach leaves less room for individual agency. In addition, most social network theories examine current social relations between actors (Hargadon et al. 1997). However, an individuals' knowledge represents ongoing relations as well as remains from ties that have been accumulated over time. As such, any informal network has presumably a temporal dimension, which embraces not only the ties at hand but also all relationships that an individual has developed over time, which tend to come and go over time. In short, there have been few studies of network dynamics, and those that exist do not tend to theorize strongly on the nature of the dynamics or the influence of the context on the dynamics.

## Community of Practice

The *community of practice (CoP)* literature focuses attention to the *voluntary* and *interest-driven* nature networks. A community of practice is a group of individuals sharing a similar set of interest, skills and expertise (Wenger 1999). These loose clusters of individuals are engaged in related work practices, but do not necessarily work in the same

place or for the same firm. A primary focus of the CoP concept is on learning as a social participation activity. CoPs demonstrate how permeable structures emerge spontaneously from largely informal networking among groups of individuals who share similar activities and interests (Lesser et al. 2001). Such networks may embrace formal and informal ties both within and among firms. From this perspective, while organizations are perceived as containing multiple and heterogeneous communities of practice, these communities may enable members to traverse organizational boundaries (Brown et al. 2001).

One of the significant benefits to members of a CoP is facilitated circulation of ideas. The information that is shared and transferred via a community of practice is boundless (Dalkir 2005). Brown and Duguid (1991) note that communities of practice are crucial to the innovation process because they constantly improvise, adjusting their activities to transcend the bounds of formal structures and canonical practices. CoPs, as a conceptual framework, provide a cogent vehicle for explaining the relative “likeness” of knowledge in innovative practices. CoP theories postulate that these communities stimulate innovative ideas, as “the process of innovating involves actively constructing a conceptual framework, imposing it on the environment, and reflecting on (Brown et al. 1991, p. 53). Such communities exert influence on knowledge dissemination within innovation networks, while they simultaneously emerge from and shape network structures. They constitute and constrain the inter- and intra-firms networks through which knowledge is acquired and conveyed (Lesser et al. 2001).

For instance, Saxenian (1994) reports that sharing of proprietary information goes on among engineers in Silicon Valley. The professional knowledge is shared on the grounds of strong commitments to peers in the community of practice rather than based on formal channels. Saxenian (1994) assumes the institutionalized informal knowledge sharing practice to make a considerable contribution to the fertile climate of innovation in Silicon Valley. In fact, the CoP framework emphasizes that information exchange is not fully under managerial control, although reciprocal interactions can be channeled by managerial involvements (Powell et al. 2005).

## **Invisible Colleges and Epistemic Communities**

An *invisible college* can be characterized as both a distinct intellectual space and as a particular form of community of practice. The general implications of both concepts also demonstrate a great overlap. However, because the literature on invisible colleges developed in parallel to the research on community of practice, we discuss it independently here. While CoPs can encompass any work practices, the concept of an invisible college denotes a group of researchers (mainly in the academic sphere) that work together closely. Like a community of practice, an invisible college includes not only people actually working together in a single organization, but also researchers who are distant in geographical space (Verspagen et al. 2003). These collaborations can go beyond a national scale, to incorporate “all other countries in which that specialty is strong” (Price 1986, page 119). In principle, such informal communication networks of scholars develop power and prestige for their members. An invisible college is signified when scholars “meet in select conferences; they commute between one center and another; they circulate preprints and reprints to each other; and they collaborate in research” (Price 1986, page 119).

Crane (1972) focuses on invisible colleges to demonstrate how knowledge is developed, and how the real structure of scientific communities influence its expansion. Typical invisible college studies investigate scientific networks in order to map the structure of co-authorship and citations (Newman 2003). For this reason, we argue that the concept of an invisible college is useful to uncover the situated interactions of scientific communities in the innovation process. This sort of insight has practical importance when significant portions of innovation processes engage basic research which is mostly practiced in the academic arena. The collective inventions, which lead to further development or problem solving activities within a new technological paradigms is typically built on an invisible colleges (Dosi 1988; Hull 1988).

Through a phenomenon-oriented lens, the research on invisible colleges reveals the nuances of the innovative practices of scientists. It posits that the research process is a largely social enterprise, in that an informal network of scientists, organized around an important research agenda (a phenomenon), makes crucial decisions. Indeed, young scientists and graduate students are enculturated into the value of both participating and perpetuating these invisible colleges, what Karin Knorr-Cetina (1999) has famously called epistemic communities. Members learn or are mentored to see any new technological breakthrough as either arising from within the community or as a result of the invisible college responding collectively to external breakthroughs. The invisible college—as an informal network of researchers—crystallizes attention, discourse and effort around some commonly shared intellectual interests, evidence and approaches (a “paradigm”) to study a common research idea. In this way, the invisible college endows researchers with a means to dispense with the uncertainty of the research process. The invisible

college of researchers and the respective paradigm provides researchers who are affiliated with the paradigm with a basis for security and stability in the wobbly world of research (Crane 1972).

Clearly, both *CoP* and *invisible college* perspectives provide insight into the formation and value of informal networks; however, both approaches suffer from a lack of explanation for the roles of artifacts in the network. In other words, artifacts essentially retreat to a secondary degree of importance. Price (1986) recognizes the material contribution of invisible college members, because he believes published documents to be relevant to the invisible college phenomenon. That is why much of the research in this area traces invisible colleges by investigating the links among publications (e.g. by using bibliometric analyses). However, this limited view of materiality is not able to account for other sorts of artifacts (i.e. information technologies). Similarly, *CoP* theories do not provide insights as to how the technological innovations, as the result of the network, themselves influence the network structures and performance. Neither *CoP* nor *invisible college* theories help us to explain how technologies embody knowledge and how they might affect the exchange of knowledge across these informal networks.

## Actor Network Theory

Actor network theory (ANT), has emerged from scholars in the sociology of science as a means for representing networks as embracing not only the human actors but also the physical artifacts and the concepts to which those actors relate (e.g. Callon 1986; Callon 1999; Latour 2005). This directly addresses the handicap of *CoP* and *invisible college* perspectives because ANT expands the notion of a network to reflect the technological capabilities and the knowledge that resides within (or is embedded into) artifacts. At the heart of ANT lies the concept of *generalized symmetry*. Generalized symmetry implies that all the heterogeneous elements of a network, both human and non-human, can be explained in the same terms. In this light, non-human (mainly technological) contributions are important, insofar as they are related to human components. The resulting network is defined as a chain made up of intermediaries, actors, texts, knowledge and scientific facts, each contributing in its own way to push forward innovation among those whom the network wishes to mobilize (Callon 1992).

At its core, ANT provides precedent for understanding the contribution of both humans and artifacts to the innovation processes. It explains how certain actors construct the identity of the other actors by making the latter act in accordance with the former's wishes. A group of actors plays a more significant role, as they try to advance innovative propositions, mobilize resources and translate the interests of others in hopes of engaging them. The heterogeneous network operates by virtue of multilateral agreements that derive from the translation of actors' disparate interests, which will eventually converge (Harrisson et al. 2002). From the ANT perspective, innovation networks are thus presented as a set of alliances among actors who negotiate and come to an agreement. In a nutshell, through concepts like *symmetry* and *translation*, ANT posits that not only can networks enhance innovation processes, but they also constrain it by circumscribing the kinds of innovations produced, their subsequent interpretations, and their final uses (Callon 2002).

The ANT conception of innovation networks also has limitations. For example, ANT is regarded as purely descriptive, and ANT scholars typically do not engage in explaining or evaluating particular social structures. In addition, ANT does not provide a means to clarify why a network takes the form that it does. Instead, ANT is more concerned with exploring how networks of actors are constructed, maintained, or destroyed. In addition, given its descriptive disposition, ANT has questionable utility for discerning which actors are instrumental within a network and which are not. Because of the heterogeneity of the network and the principle of general symmetry, ANT does not suggest any criteria to define the nature and score of the actors in advance. Latour notes that the concept of network "is also a way of getting rid of system and structure" (Crawford 1993 ,page20). Another issue with ANT is the desire to provide a complete description of the network. The number of potential elements to be identified is virtually infinite; while Callon (1991) argues, "the description (of the networks) has to cover all details, since every detail counts". Since ANT's holistic approach is not meant to leave out any details, the absence of a criterion for judging the relevance of the networks' elements can be theoretically unmanageable.

Perspective	Relevant Concepts	Focus	Insights	limitations
Social Network Perspective	<ul style="list-style-type: none"> <li>Exchange of information between nodes</li> <li>Small world</li> </ul>	The networks of individuals and their quantifiable ties	Elaborate on various dimensions of social networks	<ul style="list-style-type: none"> <li>Emphasis on structure over action</li> <li>Focus on current social relations (lack of</li> </ul>

Community of Practice	<ul style="list-style-type: none"> <li>• Network dynamics</li> </ul>			temporal dimension)
	<ul style="list-style-type: none"> <li>• Voluntary nature of relations</li> <li>• Shared interest, and expertise</li> <li>• Learning as a social activity</li> </ul>	CoP as a permeable and informal structures	Explain the “likeness” of knowledge in innovative practices	<ul style="list-style-type: none"> <li>• Limited view on materiality and the contribution of technologies</li> </ul>
Invisible College	<ul style="list-style-type: none"> <li>• Power and pedigree, Basic research, Scientific paradigms</li> </ul>	Distinct academic and intellectual spaces	Demonstrates how the structure of scientific communities influence knowledge dissemination	<ul style="list-style-type: none"> <li>• Limited view on materiality and the contribution of technologies</li> </ul>
Actor Network Theory	<ul style="list-style-type: none"> <li>• Heterogeneity</li> <li>• Symmetry between humans and non-humans</li> <li>• Translation of interests</li> </ul>	Heterogeneous network of human and technological actors	Explain both the contribution and the relations of technologies and humans in the innovation network	<ul style="list-style-type: none"> <li>• High level of abstraction</li> <li>• Little explanation of the score of the actors</li> </ul>

**Table1: Insightful perspectives for explaining the informal network of innovation**

## A Framework for Studying Informal Networks

Our review of relevant research reveals that existing conceptual frameworks each attend to some aspects of what we see as the informal network of innovation. This review leads us to agreeing with arguments put forth by Hargadon and Sutton (1997): networks of innovation are organized around different sets of physical artifacts, human actors, and concepts. To these elements, we also add the social structures of networks (See Figure 1). In the remainder of this paper, we discuss how each of these identified components emerges and constitutes the network.

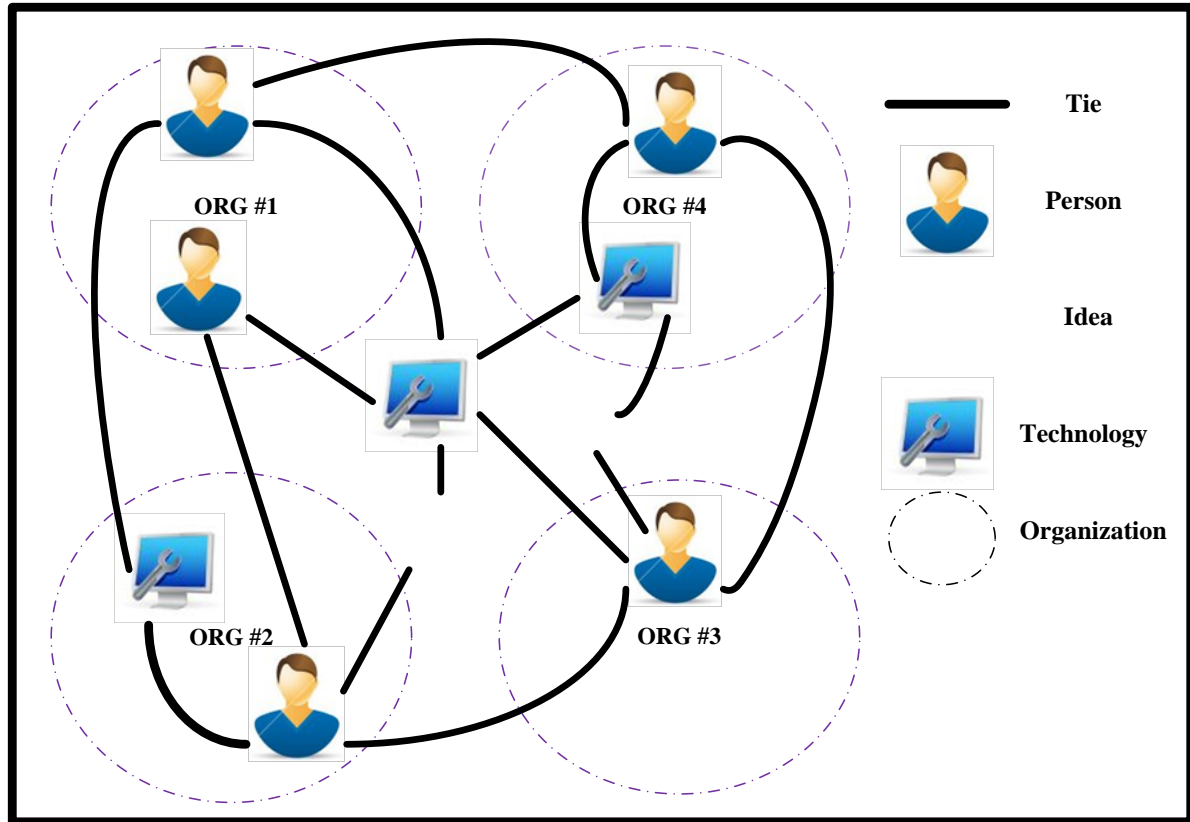


Figure 1: The informal network of innovation

### *Social Structures of the Network*

While social structures, as sets of rules and resources, are not external to actors, they can both enable and constrain subsequent interactions of network elements (Giddens 1986). Networks actors become engaged in the emerging network structure, also known as technological path (Garud et al. 2003), that is shaped by previous and ongoing interactions. The network elements are in fact embedded in the very inputs that they have produced through their current interactions and engagements with existing network structures. The networks' power is grounded in these social structures. The accumulation of inputs from different actors can then yield a momentum (Hughes 1983a) which harnesses the inputs of distributed actors. Once the momentum is created as a set of institutionalized social structures, it begins enabling and constraining the practices of involved actors (Dosi 1982; Garud et al. 1996).

The social structures cannot be attributed to any one individual actor, as they inherently involve the interplay of a multiplicity of actors (Bijker et al. 1992; Latour 2005). Furthermore, these structures are by no means stable: they do not reach any closure, as they are constantly enacted and reenacted by involved actors. As shown before, even the constitution of actors might undergo changes, since some may choose to leave at the same time that newcomers join the networks (Latour 2005). Even the involved actors may also reflect varying levels of engagement (Bijker 1987). In short, the social structures emerge from the ongoing accumulation of artifacts, tools, practices, rules and knowledge (Latour 2005) that in turn shape the relation of involved actors. *CoPs* and *invisible colleges* can be illustrative for identifying the role of these informal structures. They both unveil the relationships between the informal network structures and actors collective practice like knowledge dissemination.

### *Innovative Concepts*

Ideas and knowledge are crystallized into shared concepts which both help to shape innovation and facilitate innovation processes. In an innovation network, concepts are often a means of connecting people. That is, two scholars may have read the same material on the nature of gesture recognition in computing displays. This concept, and the evolution of people's understanding of this, evolves as part of the network of relations (Weick 1979b).

Elements of this concept are drawn on by scholars to shape other ideas and designs. As a part of the network concepts can be connected and such connections can proliferate into new sets of innovative ideas. These novel combinations are objectively new concepts on their own right, because they are built upon existing but previously unconnected ideas. Therefore, innovation processes involve the discovery of pre-existing concepts (Harper 1996; Knight 1971), and embrace the creation of new concepts through the combination and transformation of existing concepts and resources (Garud et al. 1998; Usher 1954; Venkataraman 1997). These concepts may never lead to an innovative outcome, but their combinations may.

Network structures contribute to this process by providing the means to connect people and concepts. For example, Thomas Edison's Lab is an exemplar whose products mainly reflected blends of existing but previously separate ideas (Hughes 1983a). To this end, inventions from Edison's lab were not considered entirely original, but rather extensions and blends of existing products and concepts. Those in Edison's lab achieved these innovations through interactions with disparate industries. For instance, *the phonograph* combined old and existing concepts rooted in telegraph, telephone, and electric motor industries as well as constructs developed by other entities with which the lab's engineers had previously worked (Hargadon et al. 1997). In this regard, our review illustrates that ANT can accommodate the roles that are played by concepts. In ANT something that is "material-semiotic", underscores the capability of explaining the connections that are simultaneously "material" (happens between artifacts), and "semiotic" (between concepts) (Law 1999). The literature on invisible college emphasizes that particular "concepts" attract researchers to network and serves to scaffold their collaboration structure.

### ***Physical Artifacts***

Like *concepts*, physical artifacts are directly crafted by human actors. And, the artifact can exert agency through providing or lacking certain material properties, inscribed by designer, which in turn influences peoples interactions (Orlikowski 2000). For instance, "tailorable tools," which can lend themselves to various local needs, enable various users to construct or customize a specific version (Malone et al. 1992).

Although cursory observations may suggest a linear trajectory, more detailed examinations reveal a complex web of interactions between the human actors and the physical artifacts that they create (Garud et al. 1994). In this regard, Weick (1979a) proposes that technologies lies in two intersecting arenas: the mental, and the physical. The interplay of these two arenas is captured by the notion of *enactment* through which actors "actively put things out there" (Weick 1979a ,page165), and construct the physical artifact. In turn, while human actors interact with their products, these artifacts can shape their behaviors toward particular ends. However, through the concept of symmetry, ANT makes this distinction between the technical and the social more tenuous (Callon 1986).

In our view, the notion of physical artifact is broad, encompassing both written documents and technologies (i.e. information and communication technologies). Documentary practices, such as academic papers, technical reports, or even emails, serve to generate and preserve innovative ideas and are critical to the success of any multi-institutional collaborations (Chompalov et al. 1999). These documents also constitute the "social memory" of collaboration in science. Other types of artifact, too, can play out proactively in the network, as they serve as an embodiment of knowledge. Thus, the relationships of actors are mediated by artifacts, into which the historical developments of the previous interactions are accumulated. The physical artifacts can be both enabling and constraining; they affect actors interactions with the historically collected experience and knowledge crystallized to it (Kuutti 1995).

### ***Institutions***

Social institutions play at least two roles with regards to the informal networks of innovations. First organizations offer resources for individual members and for the exchange processes that are central to social networks (Scott et al. 2007). These resources can be monetary. Of course, the structure and norms of organizations also constrain and enable individuals' behaviors: encouraging some activities and directing attention away from other choices (Orlikowski 2000). More broadly, people within a willing organization will have the freedom to interact with other individuals situated in other organizations, and to exchange information through network mechanisms. Second, organizations can take advantage of networks of innovation where they networks ties bring in information and resources. For instance, those in the Edison laboratory could more easily innovate because the lab, through its members, occupied a "structural hole" in the larger informal network of professional networks (Hargadon et al. 1997). The concept of structural hole denotes a gap in the flow of information between subgroups in a larger networks (Burt 1992). However, as the network paradigm demonstrates, individual firms are not the loci of

innovation. In fact, a social network of individuals, which is not totally contingent upon the organizations they are affiliated with, sustain the innovative exchange between individuals, such as the exchange of knowledge (Wasko et al. 2004).

### ***Human Actors***

Arguably, the most fundamental elements of the informal network are human actors. Knowledge creation and utilization are human and above all social processes (Brown et al. 2001; Davenport et al. 1998). Innovation processes involve knowledge-intensive activities, such as cultural production, scientific research, design work, and professional services. These practices substantively involve forms of tacit knowledge, embedded in particular people, which is difficult to codify (Powell 1991). These people represent “repositories” of innovative ideas that are also highly intangible and only partly mobile/removable. Furthermore, any one individual’s body of knowledge represents both past and present linkages to other people, concepts and artifacts they have connected with over time. These individuals are not just impartial role actors, but “they become embroiled in diverse, partisan, and increasingly embedded ways” (Van de Ven 2005 ,page369).

This helps make clear why organizations should not be regarded as the primary locus of innovation as the critical asset, human actors, may choose to walk away. Larsen and Rogers (1984) note the departure of a key worker can be catastrophic for any organization since the worker takes their knowledge and skills with them. The movement of actors from one context of knowledge use to another helps to circulate knowledge and experience within a network. This sort of transfer is not conducted entirely (or even primarily) through formalized channels. Innovative ideas are not created within formal structures: they emerge at the boundaries between mindsets. This is why firms can accrue networks externalities, by developing more multiplex ties with individual partners (Powell et al. 2005). As mentioned earlier, the concepts of invisible college and community of practice are illustrative for portraying these informal connections, and the way they coexist and interact with formal and contractual structures.

In short, the informal network of innovation centers on individuals, innovative ideas, artifacts (such as technologies), and the institutional nature of organizations. Individuals are connected through invisible colleges or communities of practice. Innovative ideas and technologies are also tied to, and connect, individuals. These non-human actors can travel across time and space and enable individuals to draw from the work of others. Within the network, organizations offer resources and take advantage of the flow of innovation knowledge, but are not the locus of innovation. The social structures of the network chart the boundaries of the network, while are enacted by the dynamics of actors’ interactions.

### **Conclusion**

We have argued that technological innovation is not a property of institutions or even formalized structures, noting in passing that it goes beyond the efforts of individual innovators. We have further argued that the skills and resources needed to take an idea from its inception to commercial use draws upon actors that may include non-human forms such as focal concepts and particular (and often technological) artifacts.

We have developed an initial model of informal networks of innovation founded on the logic that most of the inter-organizational relationships among people, concepts and artifacts are based on, and often grow from, informal ties among individuals. Moreover, we have argued that these informal ties play a critical but under-theorized (and thus under-studied) role in the innovation process. Drawing from several relevant literatures, we have shown that informal networks facilitate the exchange of innovative ideas and experiences among different groups of actors. In the model we develop here, we argue that the innovation process can be presented as a group of *people* that are linked by *concepts* and *artifacts* which are influenced by informal (and formal) *structures* that have evolved over time. This model, depicted simply in Figure 1, places human actors as the main fabric of the network, but attend to the body of knowledge and experience they accumulate. Building on the ANT argument, the model also highlights the concepts and artifacts that interact at the theoretical level with human actors. The social structures define the boundaries and scope of a network. As the result of previous interactions, they would in turn shape the current interactions of actors within the network.

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