

Rich Ties and Innovative Knowledge Transfer within a Firm

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We show that contacts in formal, informal and especially multiplex networks explain transfer of innovative knowledge in an organization. The contribution of informal contacts has been much acknowledged, while that of formal contacts did not receive much attention in the literature in recent decades. No study thus far has included both these different kinds of contacts in a firm, let alone considered their combined effect. The exact overlap between formal as well as informal contacts between individuals, forming multiplex or what we call rich ties because of their contribution, especially drives the transfer of new, innovative knowledge in a firm. Studying two cases in very different settings suggests these rich ties have a particularly strong effect on knowledge transfer in an organization, even when controlling for the strength of ties. Some of the effects on knowledge transfer in an organization previously ascribed to either the formal network or the informal network may actually be due to their combined effect in a rich tie.

Introduction

Knowledge is frequently considered to be the most valuable asset of an organization and a key source for sustained competitive advantage as it allows for innovation (Grant, 1996; Teece, Pisano and Shuen, 1997). Yet, at the same time, it is a difficult resource to manage at the level of the organization (Szulanski, 1996). As knowledge is spread throughout the organization, it may not be available where it can best be put to use (Cross *et al.*, 2001; Hansen, 1999; Hansen, Mors and Lovas, 2005). Scholars have emphasized that effective transfer of innovative knowledge within an organization increases the organization's inno-

vativeness (Hansen, Mors and Lovas, 2005; Tushman, 1977). Although transfer of knowledge within the organization has received attention in the literature (Borgatti and Halgin, 2011; Foss, Husted and Michailova, 2010; Hansen, 1999), comprehensive empirical studies of the transfer of innovative knowledge at the intra-organization level are lacking (Paruchuri, 2010).

Knowledge transfer within a firm can be studied from a network perspective (Borgatti and Halgin, 2011). Such a perspective views a firm as a series of social relations with specific contents and objectives (Emirbayer and Googwin, 1994). When studying the network in which innovative knowledge is transferred, the innovation network (Aalbers, Dolfsma and Koppius, 2013; Harrison and Laberge, 2002; Rodan, 2010), the focus is mostly on the position of individuals in such a network (Aalbers, Dolfsma and Koppius, 2013; Cross and Prusak, 2002; Whelan *et al.*, 2011). At the aggregation level of the organization as a whole, we analyse the structure of intra-organizational networks as antecedents of inno-

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vative knowledge transfer (Borgatti and Halgin, 2011). An organization's formal and informal networks are well-recognized, distinct patterns of social relations in the literature (Gulati and Puranam, 2009; Rizova, 2007) and have been noted as antecedents for transfer of innovative knowledge (Obstfeld, 2005). These formal and informal networks, however, have not both been included in a single study that seeks to explain transfer of new, innovative knowledge in an organization. Most network studies emphasize the importance of informal ties for effective knowledge transfer (Borgatti and Foster, 2003; Hansen, 1999; Krackhardt and Hanson, 1993; Reagans and McEvily, 2003; Rizova, 2007). Attention to the informal ties dominates the larger research agenda as well (Foss, Husted and Michailova, 2010; Gulati and Puranam, 2009). Although some older studies point to formal ties potentially contributing to knowledge flows in organizations (e.g. Darr, Argote and Epple, 1995; Nonaka, 1994), formal networks have rarely been investigated in detail recently and, even when they have been, they are often equated with the organization chart (Cross and Prusak, 2002; Foss, Husted and Michailova, 2010; Krackhardt and Hanson, 1993; see Hansen, Mors and Lovas (2005) for an exception).

Individuals in the organization can relate to each other in a number of different ways. In this paper, at the dyadic level, we determine the extent to which the shape of the innovation network is explained by those of the formal and the informal networks. The formal and the informal networks can each have their own distinct role in stimulating the transfer of new, innovative knowledge. Conceptually and empirically identifying formal and informal networks in a firm, we determine whether these networks, separately, as well as in 'multiplex' combination where they exactly overlap, explain innovative knowledge transfer. When several dimensions of interaction between individuals overlap, these individuals have a multiplex tie (Brass, 2012; Burt, 1983; Robins and Pattison, 2006) and hence 'quite different networks exist simultaneously within the same organization' (Lincoln and Miller, 1979, p. 182; Robins and Pattison, 2006; Smith-Doerr and Powell, 2005). When individuals connect both formally and informally at the same time, forming multiplex relations that constitute a network in itself, this gives rise to qualitatively different inter-

actions (Brass, 2012; Burt, 1984; Smith-Doerr, Manev and Rizova, 2004). Multiplexity, the extent to which two actors are linked together by more than one relationship, has been largely overlooked in studies that apply a network approach to intra-organizational settings (Agneessens and Skvoretz, 2012; Brass, 2012; Grosser *et al.*, 2012). The few studies that have included multiplexity, studying different phenomena than the one studied here, empirically indicate that individual benefits derive from entertaining multiplex ties. These benefits include increased intimacy of relationships and increased levels of trust (Burt and Minor, 1983; Soda and Zaheer, 2012), greater temporal stability of relationships (Burt and Minor, 1983; Ibarra, 1995; Rogers and Kincaid, 1981) and reduced uncertainty at the individual level (Albrecht and Ropp, 1984).

Our research contributes two findings to the literature. First, using broadly accepted and well-founded definitions and measures derived from organization theory, social network theory and network methodology (Borgatti and Halgin, 2011; Marsden, 1990; Wasserman and Faust, 1994), we find that formal relations contribute at least as much to knowledge transfer in a firm as informal ones. This is a vindication for the role of formal structures for knowledge transfer in the firm. We define formal structure to include the organizational chart as well as formally mandated yet possibly temporary quasi-structures (Brass, 1984; Schoonhoven and Jelinek, 1990). Research has tended to emphasize the contribution to knowledge transfer of informal networks, yet to managers formal networks are the default, constituting the relations between individuals that they can more readily influence (Cross, Borgatti and Parker, 2002). Shaping the formal network thus *can* stimulate knowledge transfer (Rizova, 2007). After a first study to qualitatively compare the separate contributions of formal and informal networks to knowledge transfer (Gulati and Puranam, 2009), we now provide a comprehensive, quantitative comparison.

Second, in addition to analysing how the formal and the informal networks contribute to knowledge transfer separately, we determine their combined, multiplex contribution to innovative knowledge transfer. Combined informal and formal ties, forming a multiplexity network, turn out to be rich ties since they stimulate knowledge transfer more than ties in the formal-only and

informal-only networks. Our analysis, conducted at two purposefully different firms (Cross and Cummings, 2004; Levin and Cross, 2004), allows us to suggest, but not definitively claim, that our findings are robust. Further studies should, of course, indicate how representative they are.

Innovative knowledge transfer in organizations

A central insight from the network approach to knowledge transfer in a firm is the observation that relations between individuals within an organization play a significant role in knowledge transfer (Allen, 1977). Monge and Contractor (2001) define a network as ‘the patterns of contact between communication partners that are created by transmitting and exchanging messages through time and space’. While many different kinds of relations can be distinguished, a broadly accepted focus in the management literature is on formal networks of organizationally mandated relations on the one hand and informal networks of emergent relations on the other (Allen, 1977; Allen and Cohen, 1969; Gulati and Puraman, 2009; Ibarra, 1993). These two networks can be argued to be the prime ways in which people interact within an organization (Blau and Schoenherr, 1971; Blau and Scott, 1962; Simon, 1976). Involvement in these networks would also, arguably, make transfer of innovative knowledge in a firm more likely.

Informal network

Blau and Scott (1962) observed that it is impossible to understand processes within the formal organization without investigating the influence of the informal relations within that organization. The network of informal relations refers to the interpersonal relationships in the organization that affect decisions within it but either are omitted from the formal scheme or are not consistent with that scheme (Simon, 1976). Such relations thus relate to ongoing activities in the firm. Informal networks consist of the contacts actors have with others within the organization that are not formally mandated. These contacts are discretionary or extra-role in the sense of being initiated by individuals themselves – the informal network is the emergent pattern of interactions between

individuals within organizations and the basis of shared norms, values and beliefs (Gulati and Puranam, 2009; Smith-Doerr and Powell, 2005). Failing to maintain such a tie will not be a matter of negative evaluation by a superior (Gibney, Zagenczyk and Masters, 2009). Some have observed that when organizational issues in relation to knowledge processes are discussed in the literature, ‘organization primarily means informal organization’ (Foss, 2007; Foss, Husted and Michailova, 2010). Culture, trust and communities of practice, rather than formal governance mechanisms, are then referred to.

The informal network provides insight into the general way ‘things are getting done’ within the organization, possibly bypassing and sometimes undermining the formal structure (Lazega and Pattison, 1999; Schulz, 2003). When communication via the formal network takes too long, or when the relations required to get certain things done have not been formally established, the informal network (‘the grapevine’) may come into play as it cuts through the formal structures and functions as a ‘communication safety net’ (Cross, Borgatti and Parker, 2002). Even though an informal network can be elusive and not transparent and can lead to clique formation where new knowledge upsetting a status quo will not be accepted, Albrecht and Ropp (1984) suggest that employees tend to transfer new ideas with colleagues in their informal network first. Additionally, Hansen (2002) argues that informal relations allow one to tap into new knowledge more easily. Informal relations provide the opportunity for information and knowledge to flow in both vertical and horizontal directions, contributing to the overall flexibility of the organization (Aalbers, Dolfsma and Leenders, 2014; Cross, Borgatti and Parker, 2002). Informally, individuals may be willing to exchange information and favours beyond what the organization has formally mandated them to do (Dolfsma, Van der Eijk and Jolink, 2009). This extra-role behaviour can sometimes be contrary to formal instructions and expectations but has been indicated to benefit the individuals involved as well as the organization when it occurs (Bouty, 2000). Informal ties have been argued to be the primary basis for the creation of interpersonal trust, which is necessary for innovative knowledge transfer at the firm level to take place in practice (Szulanski, Cappetta and Jensen, 2004).

Formal network

Formal relations have been a historical focus of research among management scholars and sociologists (Aiken and Hage, 1968; Blau and Schoenherr, 1971), albeit without a strong emphasis on transfer of innovative knowledge. Research on formal structures – ‘the planned structure for an organization’ (Simon, 1976, p. 147) – focuses on relations as stipulated by corporate management, most prominently in the organizational chart (Kilduff and Brass, 2001). Foss (2007) has argued that when knowledge processes and innovative knowledge transfer are discussed, formal organizations are ‘seldom if ever integrated into the analysis’ or are even neglected. Since the review by Damanpour (1991), the formal organization has not been the subject of much research in the field of innovation studies. Earlier research in management, however, mostly focused on the structural, mandated contacts in an organization as they followed from a formal employment contract and work protocols. The work of Mintzberg (1980) is an example of this. Formal networks have often been equated with the organization chart and were believed to indicate who reports to whom. In the most recent decades, academic attention has moved to more transient, informal organizational phenomena (Cross and Prusak, 2002; Foss, Husted and Michailova, 2010; Krackhardt and Hanson, 1993). Some scholars argued that formal relations or networks hamper creativity and demotivate individuals (Krackhardt and Hanson, 1993; Robertson and Swan, 2003). Others have indicated that formal networks reduce the autonomy of individuals involved in complex, non-routine activities (Tsai, 2001). Formal networks have been claimed to reduce the flexibility of an organization to adapt to new circumstances and challenges.

In line with earlier network studies (Brass and Burkhardt, 1992; Gulati and Puranam, 2009; Mehra, Kilduff and Brass, 2001) we define the formal relations, which together form the formal network, as the prescribed roles and linkages between roles stipulated in job descriptions and reporting relationships. Formal structures are not limited to the organizational chart and include quasi-structures such as committees, task forces, teams, and dotted-line relationships that are formally mandated by the firm as well (Ibarra, 1993; Schoonhoven and Jelinek, 1990; Soda and Zaheer, 2012). Even though the relationships in

these quasi-structures can be more temporary than relationships represented by the organizational chart, they are mandated by the firm and are part of the execution of daily operations in the firm (Adler and Borys, 1996).

Formal structures, including quasi-structures, are relatively transparent. They allocate responsibility, and may thus prevent conflict and reduce ambiguity (Adler and Borys, 1996). When an organization grows in size, a formal structure is required to stay in control and allow for specialization of tasks and knowledge (Adler and Borys, 1996; Blau and Schoenherr, 1971). The location of expertise is more easily determined and obtaining resources, e.g. for innovation, may only be possible by formal mandate. Thus, the formal structure dictates to a large degree who interacts with whom (Damanpour, 1991; Gulati and Puranam, 2009) and it is this formal interaction that could thus provide a foundation for innovation by the firm. As employees start to exchange simple, routine knowledge, this builds shared understanding, as well as absorptive capacity and competence trust at the dyadic level (Gabarro, 1990; Lane and Lubatkin, 1998), which can subsequently facilitate transfer of more complex, innovative knowledge. In innovation management, the mandated involvement of employees in temporary project teams has been much studied in a more recent past and shown to contribute to innovative performance (e.g. Cooper and Kleinschmidt, 1986).

Defining formal relations as those relations that are designed and mandated by the organization and informal relations as emergent and discretionary patterns of inter-personal interaction, we then suggest the following proposition:

P1: Relations in both (a) the formal as well as (b) the informal network in an organization contribute to transfer of new, innovative knowledge within that organization.

Rich ties in a multiplex network

Few studies include these different kinds of networks in a single analysis, certainly not in the context of innovative knowledge transfer (Foss, Husted and Michailova, 2010). A relation between two individuals can, but need not, have both a formal dimension and an informal dimension. Lazega and Pattison (1999), Rank, Robins and

Pattison (2010) and Soda and Zaheer (2012) emphasize the importance of multiple overlapping or interconnected networks in understanding organizational structures. If a relation between individuals combines several dimensions of interaction relation into a single tie, it is considered multiplex (Burt, 1983; Robins and Pattison, 2006). Multiplexity does not indicate, conceptually or empirically, the aggregation of different networks in a specific social setting, but rather that 'quite different networks exist simultaneously within the same organization' (Lincoln and Miller, 1979, p. 182; Robins and Pattison, 2006; Smith-Doerr and Powell, 2005). This is in contrast to formal-only or informal-only ties that only bolster one specific dimension of social interaction among two individuals. Networks may thus overlap but remain conceptually separate. Multiplexity has been shown to produce beneficial results to the individual, personally and professionally, and to his social environment such as a firm (Burt, 1984; Ibarra, 1995; Smith-Doerr, Manev and Rizova, 2004; Soda and Zaheer, 2012). Multiplexity has been related to such issues as the increased intimacy of relationships and increased levels of trust (Burt and Minor, 1983; Soda and Zaheer, 2012), greater temporal stability of relationships (Burt and Minor, 1983; Ibarra, 1995; Rogers and Kincaid, 1981), reduction of uncertainty (Albrecht and Ropp, 1984), higher status (Albrecht and Ropp, 1984), heightened performance (Roberts and O'Reilly, 1979) and better diffusion of information within networks (Burt and Minor, 1983).¹

We focus, as argued above, on combined formal and informal relationships, constituting a network in itself, since these two different networks best typify workplace situations (e.g. Gulati and Puranam, 2009; Rank, Robins and Pattison, 2010). Multiplex relationships are characterized as more intimate, voluntary, supportive

¹Albrecht and Hall (1991) refer to the *content* of the knowledge transferred, rather than the kind of network relation individuals are involved in, when discussing multiplexity. They find that multiplexity in the sense of transferring different kinds of knowledge in a single relation between two persons contributes to transfer of innovative knowledge. By defining multiplexity in terms of the content of the knowledge transferred, a comparison of findings across contexts (generalizability) is problematic. In this paper we thus follow the recent social networks and management literatures in defining multiplexity in terms of different aspects of a relationship that can connect employees.

and durable ties in comparison with formal-only or informal-only ties and thus trust may grow (Granovetter, 1973; McAllister, 1995). Informal relations between individuals augment formal relations in getting things done (Lazega and Pattison, 1999). By combining different relational aspects such multiplex relational ties may transform into *rich* ties: when individuals are connected in a number of different ways, more as well as more reliable information tends to be exchanged (Sias and Cahill, 1998). Individuals who are connected simultaneously in different networks will have different sources of information, one source possibly compensating another (Soda and Zaheer, 2012). A relation of one kind may keep in check the negative side-effects of a relation of a different kind (Marsden, 1981). People are also in a better position to predict and interpret how someone will behave in one context if his behaviour and attitude is known from a different context, thus reducing uncertainty (Aalbers, Dolfsma and Koppius, 2013). Role ambiguity is significantly reduced in case of multiplexity as people understand better what is expected of them (Hartman and Johnson, 1979). In the case of rich ties between individuals in a multiplex network, each tie is also likely to be stronger, and social capital between the individuals will be larger for that reason as well (McEvily, Perrone and Zaheer, 2003). Rich ties in a multiplex network thus come along with advantages that are necessary for the transfer of innovative knowledge, specifically if such knowledge is socially or technically complex (Hansen, 1999).

The informal component of a rich tie in a multiplex network constitutes the trust that is necessary to be willing to share complex, innovative knowledge. The formal component of a rich tie in a multiplex network signifies the shared purpose and understanding and helps secure resources necessary to be able to share complex, innovative knowledge. We submit that the multiplex combination of formal and informal relations in a firm's network structure in the form of rich ties proves a qualitatively different foundation for innovative knowledge transfer from ties that are formal-only or informal-only. We thus submit the following proposition:

P2: Transfer of new, innovative knowledge in an organization is more likely to occur in the multiplex network of rich ties (i.e. overlapping

ties in both the formal and informal networks) compared with the networks of formal-only and informal-only ties.

Method

Organizational setting

Our study is based on findings at two separate companies, one a subsidiary of a European multinational electronics and engineering conglomerate (Alpha), the other a leading European financial service provider (Beta). The two companies selected differ in terms of size, organizational design and type of industry to indicate the robustness of our findings. Worldwide Alpha Company employs over 400,000 people. Over 6.8% of revenues are spent annually on R&D by this high-tech firm. The subsidiary studied, operating since the late 19th century, employs over 4000 employees. Revenue generated by this subsidiary is equivalent to some 6.5% of total revenue for the conglomerate. Beta Company is one of Europe's largest and most innovative payment processors, leading the market for secure payments and card processing solutions. With an annual processing volume of 7 billion payments and 1.9 billion point of sale and automated teller machine transactions, the company's market share within the Eurozone is over 10%, employing 1500 employees. Access to both companies was negotiated through the senior innovation managers, in each case operating directly under the supervision of the board of directors.

Alpha Company is organized according to a divisional structure (Mintzberg, 1980). Recently, the company shifted towards offering integrated, market-oriented solutions to its customers, based on its technical competences that cross division boundaries. The company has thus reorganized its activities according to a number of strategic multidisciplinary themes some years before we collected the data for this study. We focus on one specific theme: transportation – a theme given high priority by corporate management. A company in the financial sector, Beta Company is organized as a machine bureaucracy (Mintzberg, 1980). It is highly routinized, with a large operational unit and a separate unit to develop new business. Innovation activities at Beta Company are focused around the theme of innovative payment methods, which are receiving significant attention by corporate management.

Focusing on knowledge transfer related to a single theme offers two advantages. First, reliability of the data gathered is enhanced as the context for the questions is clearer and closer to the respondents' day-to-day activities. Second, identifying a clear theme allows for a precise specification of the boundaries of the network to be investigated (Laumann, Marsden and Prensky, 1983). Several interviews with relevant senior management revealed which divisions are involved in innovative activities with a view to the data collection process.

Data collection

Data were collected at Alpha Company in 2005 under the condition of a grace period of data confidentiality of three years and in 2009 at Beta Company under the condition of a grace period of data confidentiality of two years. Both companies are located in the Netherlands. We collected both quantitative and qualitative data at both companies through semi-structured interviews and a network survey to gather information on the intra-organizational networks and their participants. Agendas, minutes, project plans and other written materials were also consulted to add insight in interpreting our quantitative findings and to help avoid bias in the sampling of respondents. Interviews, 20 at Alpha Company and 30 at Beta Company, served several purposes. The first was to become familiar with both organizations and to test the appropriateness of the survey tool. Second, the interviews served as the first round in our snowball sampling in our data collection procedure. Interviews for instance helped to identify isolated individuals and groups that might otherwise have been inadvertently ignored (Marsden, 1990, 2002). Third, the interviews helped to interpret the quantitative findings from the network survey data. Interviews at both companies typically lasted one hour, and were recorded, transcribed and coded separately by each author.

Snowball sampling is especially useful when the target population is not clear from the beginning as, for example, when the population cuts across unit boundaries (Wasserman and Faust, 1994). Collection of network data through snowball sampling matches the relative absence of formalization typical of innovation activity (Aalbers, Dolfsma and Koppius, 2013). The target population emerges in several rounds of surveying, where

Table 1. Descriptives – frequency of tie types

	Alpha Company (114 individuals ^a)		Beta Company (281 individuals ^a)	
	Number of ties	Of which: corresponding tie in innovation network	Number of ties	Of which: corresponding tie in innovation network
Multiplex tie ^b	116	91	379	318
Formal tie only	69	26	66	34
Informal tie only	11	6	36	18

^aCount of individual actors based on presence in any of the three network ties, hence deviating from the number of actors depicted in Figure 1 (innovation only).

^bFormal and informal tie overlapping between same actors.

contacts mentioned in one round determine who should be approached as a respondent in a subsequent round. To exclude the risk of ignoring ‘isolates’, individuals who do possess relevant knowledge to a particular subject but who are not well connected, we targeted respondents who were generally acknowledged as key figures in the innovation communities under investigation with diverse backgrounds in terms of department affiliation, tenure and hierarchy in our first round (Rogers and Kincaid, 1981). Starting with a single or a limited number of relatively similar individuals when gathering data on who is involved in a network might lead to a situation in which some individuals might be erroneously ignored. The selection of the first round of respondents to fill in the questionnaire was based on the expertise of the innovation management departments at both companies. The lead innovation manager was asked to create an overview of employees who were perceived as most active in the innovation community of each of the companies. This resulted in a list of employees in the functional divisions that were involved. This initial selection was validated by seeking the judgement of the full innovation management team and division directors.

Through consecutive rounds of respondent identification until no further individuals were mentioned for any of the three network name generator questions included in the survey, by respondents or management, we can be sure to have identified all relevant respondents. Table 1 and Figure 1 give descriptives on network configuration and insight into the knowledge transfer ties between network actors. Our sampling method endogenously infers network membership of individuals and delineates the network boundary. By surveying this set of individuals, we

overcame the boundary specification problem common to network studies (Laumann, Marsden and Prensky, 1983; Marsden, 1990, 2002).

The social network survey data were collected in three rounds in each of the companies. Beyond the first round that we conducted through interviews, a digital survey was distributed, accompanied by a personalized cover email co-signed by the senior innovation manager to increase response rates. The names mentioned at Alpha Company by this first round of respondents (nine) formed the input of respondents for the second round (42), who named a further set of names of respondents. Closure was reached after this third round of surveying. The full network studied consists of 114 individuals partaking in any of the three networks, of whom 83 employees constitute the innovative knowledge transfer network. Respondents who did not reply initially were personally interviewed. The final overall response rate at Alpha Company was 96%. Only 4% did not respond to the first mailing and the later three reminder mailings. Following an identical procedure a comparable response was achieved at Beta Company, with an overall response of 93%. Thirty employees at Beta Company partook in the first round, naming another 54 employees who together formed the second survey round. The full network studied at Beta Company consists of 281 individuals partaking in any of the three networks studied, of whom 241 employees together comprise the innovative knowledge transfer network.

Measures

Table 2 presents a description of the measures we employ, in the same order as in the network survey. Most important among them are ‘name generator questions’ (see Table 2) providing

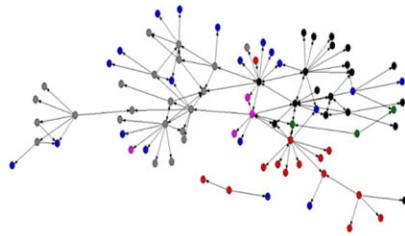
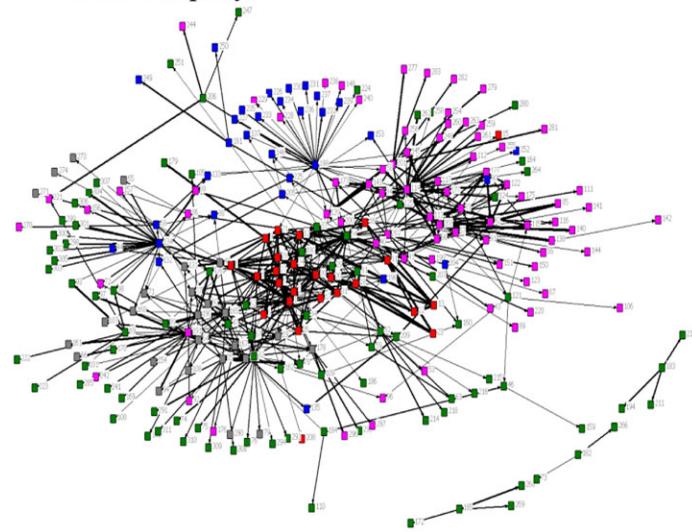
Alpha Company:**Beta Company:**

Figure 1. The innovation networks at Alpha and Beta Company: 'Who are the people you connect with to formulate and discuss new ideas and innovations relevant to the company'

Note: Not all actors included in the survey hold a tie in the innovation network; not all nodes in the innovation networks are presented in these figures for clarity – colours indicate business unit membership (full innovation network at Alpha Company, $n = 83$, and at Beta Company, $n = 241$).

Table 2. Network survey questions

Network	Name generator questions	Type	Sources
Formal network (workflow)	Contacts prescribed by the organization to carry out daily job: Q: Who are the key people that you connect with to successfully carry out your daily activities within the organization, the contacts that are prescribed or mandated by the organization?	Valued/ directed	Mehra, Kilduff and Brass, 2001; see also Brass, 1984; Brass and Burkhardt, 1992; Cross and Cummings, 2004; Whitbred <i>et al.</i> , 2011
Informal network	Contacts useful in staying informally informed about what is going on within the organization: Q: Who are the people that you connect with to discuss what is going on within the organization to get things done that are of personal relevance to you?	Valued/ directed	Mehra, Kilduff and Brass, 2001; Smith-Doerr, Manev and Rizova, 2004
Multiplex network of rich ties	No separate name generator question. A multiplex rich tie is defined when formal and informal contacts between any two individuals exactly overlap. Other ties then are formal-only or informal-only		Ibarra, 1993
Innovation network	Contacts useful in helping you to be creative and innovative in your job, such as helping you to generate new ideas: Q: Who are the people you connect with to formulate and discuss new ideas and innovations relevant to the company?	Valued/ directed	Aalbers, Dolfsma and Koppius, 2013; Cross and Prusak, 2002; Rodan, 2010

precise information about the shape and size of a network. Since formal ties are the prime reference for the respondents, this name generator question was asked first. Next came another salient question for respondents, the question about their informal contacts. Innovation con-

tacts being perhaps less salient to respondents, this question was asked last. We acknowledge that any sequence of questions in a survey can prime respondents but believe that by staying close to their life-world, particularly at the start of the survey, this possible bias is reduced.

The dependent variable is the innovative knowledge transfer network, where we asked individuals with whom they exchange *new* ideas, *innovations* and substantial *improvements* to products and services that are not part of their day-to-day activities (Aalbers, Dolfsma and Koppius, 2013; Cross and Prusak, 2002; Rodan, 2010). Whereas the name generator question for the formal network measures the connections resulting from exchange of routine issues and day-to-day information, the name generator question for the innovative knowledge transfer network asks about the transfer of new or complex knowledge that was specifically *not* perceived as related to the ongoing business of the organization (Aalbers, Dolfsma and Koppius, 2013; Harrison and Laberge, 2002).

It is increasingly recognized that the organization chart is a poor indicator of interpersonal relations under today's organization dynamics (Krackhardt and Hanson, 1993). An organization chart is often focused more on hierarchical, vertical reporting relations, ignoring formally mandated horizontal relations or more temporary quasi-structures such as innovation project teams. When studying knowledge transfer in an organization, this is a shortcoming. We measured the formal (workflow) network by asking respondents with whom they interact to successfully carry out their daily activities within the organization that were prescribed or mandated by the organization (Mehra, Kilduff and Brass, 2001; see also Brass, 1984; Brass and Burkhardt, 1992; Cross and Cummings, 2004; Whitbred *et al.*, 2011). The explicit focus is on *existing* products and services that have already been developed, or relations that had already been established and follow from the respondent's role or position in the organization.

Following Ibarra (1993) and Brass (1984) we measured the emergent, informal network by asking respondents with whom they discussed what is going on within the organization to get things done that are of personal relevance to them (Mehra, Kilduff and Brass, 2001; Smith-Doerr, Manev and Rizova, 2004), allowing us to capture the 'organizational grapevine' (Umphress *et al.*, 2003), often bypassing the formal communication structure (Schulz, 2003).

Formal relations are thus designed or mandated by the organization, while informal relations are emergent, discretionary or extra-role.

Employing these well-founded name generator questions yields matrices containing data on who is related with whom. Our third independent variable is the multiplex network of rich ties. By comparing the data about the informal emergent and the designed formal networks, we identify the networks that are formal-only, informal-only, and the multiplex network of rich ties.

The specifically formulated name generator questions are extensively validated in the literature. In the first rounds of interviews, in the reminder interviews with respondents to increase the response rate to one that is required for network analysis, and in subsequent interviews with management it was established that respondents were keenly aware of the differences between the three kinds of contacts they were asked about. To reduce ambiguity, network questions were formulated in the native language (Dutch). Authors and a native speaker independently translated questions to converge on the proper phrasing in the native language and pilot-tested the questionnaire. No language barriers existed between the researchers and the research participants.

Name generator questions can strongly suggest that a number of names should be provided, or it can leave the number of names each respondent provides open. Each approach may introduce a bias. The first might make some respondents with a limited number of contacts list contacts they have tenuous contact with, and might make those with many contacts list only their most important ones. The latter, the free-recall method, relies on respondents' memory but is suggested to be most suitable in a study where network boundaries cannot be determined *a priori*. The free-recall approach is believed to be less biased (Friedman and Podolny, 1993). However, we did gently suggest naming six contacts so that only the most important contacts would be mentioned. Our survey asked about the strength of each tie mentioned by respondents. This helped address the potential problem of having to rely on respondents' memory so that only the most important contact would be mentioned. Knowing the strength of the ties mentioned in the survey allowed us to determine, quantitatively, if ignoring weaker ties made a difference for the results we found. This analysis – not included, but available on request from the authors – showed that tie strength does not alter the findings. We may thus conclude that the free-recall approach to network

data collection has not biased the findings we present.

Analysis

Since our aim is to explain, at firm level, the exchange of new, innovative knowledge by considering other organization level network variables, we employ quadratic assignment procedure (QAP) regression as our statistical method. We combine quantitative network data with qualitative data. Individuals in a network might have an incomplete or biased view of the full network that they are in. The qualitative data we use can thus possibly not provide sufficient indication. A method for statistical regression analysis at the network level, QAP is commonly used in social network analysis for analysing dyadic data sets, i.e. data sets where pairs of entities are analysed, and provides a specific type of permutation test which keeps intact the dyadic data structure under varying permutations (Borgatti and Cross, 2003; Borgatti, Everett and Freeman, 2002; Krackhardt, 1987, 1988; Simpson, 2001). A conservative estimation procedure that unfortunately does not allow for the inclusion of (non-network) control variables, QAP's semi-partial regression solves the serious issue of auto-correlations in network data.² By permutation of rows and columns of the original data matrix for the dependent variable, as a sampling procedure, the QAP procedure re-estimates the original regression model repeatedly to determine how likely it is that the observed network structure could have evolved purely by chance. The structure of the formal-only, informal-only and multiplex networks will be used as the independent variables explaining the structure of the innovation network.

The findings for the quantitative analysis were confronted with qualitative data that we collected. Qualitative data were separately coded by each of the authors. Authors checked all relevant elements in the qualitative data for possible confirmation, rejection or qualification of the findings

²For the purposes of our analysis QAP regressions are most appropriate (Borgatti, Everett and Freeman, 2002). Due to the dyadic permutation procedure that QAP regression involves, no statistical comparison of weighted effects between the different models we present can be undertaken, nor does this analysis allow for inclusion of controls at the individual node level.

Table 3. Innovative knowledge transfer in organizations – QAP regressions

Type of relation	Model I	Model II	Model III	Model IV ^a
Alpha Company				
Informal	0.704***	–	0.369***	0.137***
Formal	–	0.722***	0.444***	0.283***
Multiplex	–	–	–	0.697***
R ² (adj.)	0.50	0.52	0.58	0.58
Beta Company				
Informal	0.803***	–	0.329***	0.215***
Formal	–	0.844***	0.572***	0.155***
Multiplex	–	–	–	0.836***
R ² (adj.)	0.64	0.71	0.75	0.77

QAP semi-partial regressions (UCINET; Borgatti, Everett and Freeman, 2002). Coefficients standardized; 5000 permutations.

^aFormal-only and informal-only relations net of multiplex relations.

***1% significance.

from our quantitative analysis. Relevant material is presented in the Results section.

Results

Table 1 shows the frequency of tie types in our sample in relation to knowledge transfer for Alpha and Beta Company – for a visual presentation, see Figure 1. The majority of ties are multiplex rather than formal-only or informal-only, even though the underlying formal and informal networks measure separate networks that are theoretically independent and methodologically different, as argued above. Such frequent occurrence of ties in the formal and the informal networks between any two individuals was found by others as well (Gulati and Puranam, 2009; Hansen, Mors and Lovas, 2005; Smith-Doerr, Manev and Rizova, 2004). Informal-only ties are, remarkably perhaps, much less common than formal-only ties.

Table 3 presents the results of our QAP analysis of the influence of different kinds of relations on innovative knowledge transfer for Alpha and Beta Company separately. Models I and II analyse the influence on knowledge transfer of the informal and, separately, the formal network structure. In model III we include both the formal and the informal networks as independent variables to again explain the innovative knowledge transfer network as our dependent variable. Results in Table 3, models I and II, show that both the

formal and the informal relations each, separately, explain innovative knowledge transfer in an organization. Including both these two networks in model III also indicates that formal and informal network structures contribute to innovative knowledge transfer within an organization. Propositions 1(a) and 1(b) are therefore supported. What may be remarkable is that betas for the formal network appear to remain larger than for the informal network in models I, II and III.

Model IV includes the multiplex, formal-only and informal-only networks to explain the shape of the innovation network. Model IV shows that, for both firms studied, the multiplex network of rich ties is better at explaining the shape of the innovation network than ties in the other, formal-only and informal-only networks. Thus, the multiplex network of rich ties, combining both formal and informal aspects in a relation between two individuals, is thus particularly fruitful for innovative knowledge transfer. This finding is in support of Proposition 2.

Combining formal and informal contacts thus, as we suggested in the theory, gives rise to advantages that do not exist when individuals only maintain a uniplex tie. One respondent at Beta Company provides empirical support for this in the context of transfer of new, innovative knowledge:

It was when my old mentor with whom I continued to remain acquainted informally introduced me to this group that had gathered around a new technology closely aligned to my prior experience that I got involved with the innovation community. This informal circle played out to be the basis for a formalized project that is currently developing into a new product.

Elaborating on the social antecedents for innovative knowledge transfer an employee at Beta Company stated:

When I first joined the company it was hard to get drawn into the innovative activity that was going on, even though my formal role and ascribed contacts implied I was in the midst of things. It was not until I had established a place in the informal circuit that I could really connect with others and I truly got involved with innovation.

Here, the privileged access to knowledge that is more likely to be reliable is stressed. A project manager at Alpha Company highlighted related

benefits of trust and reduced role ambiguity from a joint informal and formal dimension as follows:

Being informally in the loop of things has helped me to be a good judge of with whom to collaborate professionally and whom to avoid. As innovation activities are typically far from crystal clear as they unfold over time, it is important for me to know whom to bank on as I develop activities into a formal project.

Another employee at Alpha Company sees multiplexity in his relations as a prerequisite for involvement in the exchange of innovative knowledge, highlighting the importance of being able to predict how someone else will behave:

When I find myself collaborating fruitfully on something really novel it generally seems to be because we understand each other and trust each other beyond just being colleagues or anything like that. . . . At the same time I also experience that a certain understanding of each other's professional field of work is required to really get going.

The results from our quantitative data thus indicate that rich ties in a multiplex network are conducive to the transfer of new, innovative knowledge. Our qualitative data indicate what benefits the combination of both formal and informal elements into a rich tie secure beyond each contact in isolation.

Discussion, implications and limitations

Knowledge transfer is necessary to increase the innovative potential of an organization, contributing to its dynamic capabilities in a turbulent economy (Janssen, van den Bosch and Volberda, 2006). Informal relations in particular have been emphasized as contributing to knowledge transfer, while formal connections have received less attention in the literature since the late 1980s (Cross, Borgatti and Parker, 2002; Damanpour, 1991; Stevenson and Gilly, 1991). Taking a network perspective of the firm, we study the transfer of innovative knowledge in formal, informal and multiplex networks. Responding to recent calls for further and more substantive empirical evidence in this area (Gulati and Puranam, 2009), our study quantitatively compares how much these different networks contribute to innovative knowledge transfer within a firm

(Hansen and Lovas, 2004; Hansen, Mors and Lovas, 2005). We find that it is not just informal relations that contribute to innovative knowledge transfer: formal relations are a substantial driver of transfer of new, innovative knowledge as well. This is a first important contribution of this paper.

Our second, and perhaps most important, contribution is to point to the importance of a multiplex network of what we call rich ties for transfer of new, innovative knowledge. Relations that combine formal as well as informal aspects into a single relation between two persons have a genuinely distinct and significantly positive effect on innovative knowledge transfer within organizations. Such ties thus are rich not just because multiple dimensions of a relation are combined, but they may be referred to as rich particularly because they contribute significantly to transfer of new, innovative knowledge. Rich ties in a multiplex network drive the transfer of new, innovative knowledge transfer more than formal-only or informal-only networks. Our findings add an important element to the research of what drives transfer of new, innovative knowledge (Ibarra, 1993; Kalish and Robins, 2006; Teigland and Wasko, 2009; Tsai, 2001; Whelan *et al.*, 2011). The focus of previous research on uniplex ties can be enriched by including rich ties in a multiplex network. Knowledge transfer effects that in previous studies were attributed to informal (or formal) networks only may in fact need to be attributed to rich ties in a multiplex network. Results in Table 3 suggest, but do not prove, that part of the explanatory power that loaded onto either the formal or the informal network in model III turns out not actually to be a consequence of a formal-only or an informal-only tie but rather the consequence of a rich tie in a multiplex network. Explanations of innovative knowledge transfer within a company should thus focus on both informal and particularly formal networks, as well as on how these two combine to constitute a multiplex network of rich ties.

Our findings have important managerial implications since they provide guidance to management on how to intervene to contribute to a firm's innovative capability, one of management's prime strategic objectives (Dyer, Gregersen and Christensen, 2011). Since formal relations are typically more purposefully malleable than informal ones, and as formal relations may provide the

basis on which informal relations develop (Han, 1996) to form rich ties, management may actively seek to enhance a firm's innovative capabilities by purposefully shaping the formal structures in their organization. Management can influence knowledge transfer more purposefully than much previous research emphasizing informal relations has led scholars and managers to believe. With a view of the full networks in an organization, managers can seek to alter existing network structures and communication patterns to facilitate the innovative activity within the organization. A board member of one of the companies studied argued that:

No manager can truly see everything that is going on at the shop floor. But being able to identify who are in the midst of things [offered by a network perspective of an organization] really helps in not losing touch with what will shape the future of our company.

Our findings that rich ties facilitate the transfer of innovative knowledge can, for instance, help management to tap into an under-utilized potential contribution to innovation activities in a firm by 'enriching' a formal- or informal-only tie that only has one dimension with a second dimension. The rich ties that would emerge are likely to enhance transfer of new, innovative knowledge more than the informal- or formal-only ties and are more resilient as well. This insight may be a basis for intervention by management to enhance the transfer of new, innovative knowledge as well as a lead for the study of the effects of management interventions (DeChurch and Marks, 2006; Okhuysen and Bechky, 2009).

Limitations

This study has a number of limitations. The extent to which our findings are generalizable is unknown, and we emphasize the exploratory nature of this study. We studied two large companies from different industries. Although finding the same results for each firm, despite the different environments they are in, offers an indication of the robust nature of our investigation, further research is needed. Both firms are large firms and, much like other large firms that have similar structures, they maintain a somewhat formal organizational culture (Mintzberg, 1980; Pugh, Hickson and Hinings, 1969); the findings for

much smaller firms could be different. Even though the findings are so similar for the firms we include in our study, industry- and firm-specific effects may be at play. Fully determining these effects may be difficult as it is impossible to combine the network data for different organizations into a single analysis: cross-sectional analysis of network data is meaningless. Employees of Alpha Company cannot be expected to interact in any meaningful way with those of Beta Company.

There is another aspect to the non-independent nature of network data that needs to be highlighted. Non-independent data violate an important assumption that underlies most standard statistical techniques. Although we know that the independence assumption is violated in social network data, we nevertheless decided to present results based on ordinary least squares (OLS) regressions because they allow more readily interpretable results to be presented. Statistical theory suggests that the parameter estimates in the OLS model are likely to have little bias.³ In addition to the statistical problem of properly establishing the representativeness of our findings across a large number of different organizations, there is a methodological problem. Social network data are very difficult to collect, for instance because high response rates are imperative. Even though we included all individuals involved with innovation on a subject area in both organizations that we studied, we have only studied two firms. Scholars familiar with social network analysis will know this to be unproblematic (Cross and Cummings, 2004). Despite the fact that the two organizations we study are quite distinct, we do find the same results. This, we suggest, is an indication of the robust nature of our findings. Needless to say,

³The lack of independence of our observations may affect the width of confidence intervals and, as a result, can make inferences based on OLS models lack in conservatism. To address this, as a robustness check we conducted a bootstrap procedure (Davison and Hinkley, 1997; Efron, 1979; Efron and Tibshirani, 1986; Snijders and Borgatti, 1999) to estimate empirical confidence intervals, both parametrically and non-parametrically. We conducted an *m*-out-of-*n* bootstrap (Bickel and Ren, 1996; Bickel, Goetze and van Zwet, 1997) based on 10,000 resamples, each with a size of 50% of the original sample, with replacement. The *m*-out-of-*n* approach was chosen because it strongly reduces potential dependence effects in the data. Findings from this bootstrap analysis, in the software programme R, were similar to those we present.

however, we hope other researchers will replicate this research and confirm, extend or possibly refute our findings.

Third, the substantive contribution of innovative knowledge transferred to actual innovation and, subsequently, to firm performance we unfortunately cannot analyse here. Because of the highly specific name generator questions, validated extensively in the literature, we know *generally* what kind of knowledge is transferred. The specific knowledge content of what is transferred we do not know, and so determining what novel innovations will emerge from the transfer may not be possible.

Finally, the rich synergy between formal and informal ties in a multiplex network would ideally be investigated over the course of an extended period of time, where extensive analysis of quantitative as well as qualitative information would be needed. Such a study would determine whether the results we find depend on the level of network interactions, the market situation of an organization, or past and expected management involvement.

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