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Social networks in the R&D process: the case of the wireless communication industry around Aalborg, Denmark

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Abstract

Whether social networks diffuse knowledge across firm boundaries has been the topic of much debate. To inform these theories, this article considers two questions. First, who has contacts across firm boundaries? And second, when do these relations diffuse knowledge? Our empirical evidence comes from a survey of 346 engineers in the wireless communication industry around Aalborg in Northern Denmark. Our analysis finds that social contact between these engineers is frequent and is used to diffuse knowledge that receivers find useful. More experienced engineers are more likely to receive valuable knowledge from their networks. These findings show that the long-term relationships, which are more likely based on trust and reputation, are also more likely to be a channel valuable knowledge.
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1. Introduction

How do social networks among R&D engineers carry knowledge between firms? Is knowledge actually shared through interpersonal communication between engineers in

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separate organizations? Why do some engineers have many social contacts, while others have few? What is the relationship between the probability of acquiring knowledge and the individual characteristics of engineers? These are the central questions addressed in this article. And though they have been part of the research agenda for several years in the fields of sociology, economics, and business, as well as in economic geography, they continue to be issues of debate.

To address these questions, we examine social networks of informal contacts between employees in the wireless communication industry around Aalborg in North Denmark, analyzing the genesis of these informal contacts and their role in knowledge diffusion. The analysis takes place at the micro level, in this case treating the engineer as the unit of analysis. This provides a better picture of the social network of informal contacts than many of the previous studies that have, for example, been based on interviews with managers. Such studies cannot completely reveal the extent and importance of networks. Since the manager serves as the only source for information regarding internal firm dynamics and employees' social relations, the results are likely to be biased towards official firm policy and the manager's personal opinion.

The purpose of this article is to determine which factors influence the likelihood that an individual engineer will be an active participant in the social networks linking firms. We investigate the likelihood that an engineer receives knowledge, and more specifically, knowledge of high value. Our findings come from a questionnaire survey of personnel in the wireless communications industry around Aalborg (labelled as NorCOM). The survey includes more than 300 engineers employed in 19 different firms. We also investigate the antecedents of these informal social relations.

The remainder of this article is structured as follows. The next section reviews theories of the importance of social networks and knowledge diffusion through informal contacts and builds models from this theoretical framework. Section 3 describes the NorCOM questionnaire and presents descriptive data. Section 4 reports the results, which are then discussed in Section 5.

2. Social networks and knowledge diffusion

Knowledge flows have long been considered a part of social networks across firm boundaries. The diffusion of knowledge between firms can take place either through formalized collaborations or through informal social networks. The latter in particular have been a subject of much study. Allen and Cohen (1969) claim:

''No research and development laboratory can be completely self-sustaining. To keep abreast of scientific and technological developments, every laboratory must necessarily import information from outside''.

Allen and Cohen analyzed two different means of obtaining this information: published scientific and technical literature, and knowledgeable people outside the laboratory. They found that the so-called *sociometric stars* in the technical communication network in an organization, which served as an information resource for their colleagues, used outside sources more than others. These stars also had rather

extensive social networks of informal contacts outside the organization compared to the majority of other employees.

For describing the dynamics of such diffusion networks in local industrial communities, the idea of collective invention is useful (Allen, 1983). Collective invention is characterized by positive feedback, high invention rates, and fast knowledge accretion, though the mutual disclosure of information among competing agents. It is driven by the exchange and circulation of knowledge and information within networks of socially connected individuals. Allen's idea of collective invention arose from a case study of the blast furnace industry in Cleveland (UK) in the middle of the 19th century. Producers there shared knowledge about their furnaces, allowing them to discover, as a group, the positive relationship between productivity and the furnace height (Allen, 1983). Subsequent case studies – such as McGaw (1987) history of the mechanization of paper manufacture in the Berkshire area (New England) from the beginning of the 19th century, and Lamoreaux and Sokoloff (2000) study of the American glass industry from 1870 to 1925 – have corroborated Allen's characterization.

Although the idea of collective invention is appealing, it nevertheless seems most relevant to industries where firms do not spend substantial amounts on the development of new knowledge, or where it is expensive or nearly impossible to exclude others from these developments (Allen, 1983). Furthermore, Cowan and Jonard (2000) highlight two qualifiers of collective invention that are noteworthy in the context of knowledge diffusion. First, participation in such communities requires a high level of technical knowledge and skill to contribute to, and take advantage of, developments within these communities. Second, reputation effects are very important, because the provision of information in these communities is motivated primarily by an expectation of reciprocity.

In general, it also seems apparent that information does not necessarily flow freely among all agents in a given industry located in a given region. Several factors limit the size and extent of social networks and communities. Physical proximity does not imply the existence of social proximity, since such epistemic communities (see Cowan et al., 2000; Steinmueller, 2000) never include all members of the local community. Knowledge may be far from accessible even to most of those located nearby its origin (Breschi and Lissoni, 2001). Rather than flowing freely within local communities, knowledge circulates in small communities, centred around individual firms (Lissoni, 2001).

The sociology literature also provides additional insight on the social structures and interactions that contribute to the diffusion of knowledge in these communities. According to Ingram and Roberts (2000), social networks of informal interpersonal relationships are embedded in a social structure. In communities within a geographic region, divisions of a company, groups within a profession, or members of a team, agents specialize within social circles and integrate via bridges across them. Opinion, behavior and information are more similar within than between these groups. Information also flows more routinely inside of them.

Another structural aspect of social networks from the sociology literature is the presence of gaps, or structural holes (Burt, 2004), between groups. Structural holes form gaps in the information flow. Burt (2004) argues agents that bridge across disparate social groups have an advantage, since they can access information from different sources. They also have earlier access to a broader diversity of information and are more familiar with

alternative ways of thinking and behaving. They can also translate across divergent coding schemes in different organizations and become technological gatekeepers (Allen and Cohen, 1969). Burt (2004) analyzed the structural holes in the social network of managers who ran the supply chain for a large US electronics company. He found that the managers who spanned structural holes (defined as having low network constraint) produced better ideas, earned higher salaries and received earlier promotions than managers confined in dense networks characterized by a high degree of constraint. This notion, that different agents in the social network access and utilize different information, is highly influenced by Granovetter (1973) theory of the strength of weak ties in the diffusion process. His argument is that agents with many weak ties are better located in the network. Weak ties maximize the amount of non-redundant information that the agent receives by connecting the agent to a wider variety of social groups.

The value of this breadth, however, must be balanced against a number of other factors, such as the reliability and firm-specificity of the information (Ingram and Roberts, 2000). Since the transfer of information through informal contacts takes place without a formal agreement, the sender has few means of controlling what will happen to the information. This creates uncertainty concerning the recipient's transfer of the information to others. Løvås and Sorenson (2004) argue that indirect ties reduce this uncertainty. Mutual acquaintances between the agents reduce the uncertainty of reciprocity by increasing the importance of reputations and by facilitating monitoring and sanctioning. There is nevertheless a trade-off between cohesion in knowledge transfer and non-redundancy in the information available. Which ties best facilitate the transfer of information depends on the situation; an effective design for one type of network is not necessarily effective for another (Ingram and Roberts, 2000).

When these insights are applied to the question of inter-firm knowledge exchange, the existing literature (e.g. Rogers, 1982; von Hippel, 1987; Schrader, 1991), suggests that knowledge diffusion through informal channels occurs in the form of information trading. This type of informal exchange between firms is a frequently observed phenomenon in product development, production and technological innovation (see Martilla, 1971; Allen, 1984; Czepiel, 1974). Information trading refers to the informal exchange of information between employees working for different and sometimes competing firms (von Hippel, 1987). Colleagues in different firms provide each other with technical advice, expecting that their favors will be returned in the future. For instance, an employee in the production process might solve unforeseen technical problems by communicating with a colleague in a competing firm using the same production equipment. The colleague in the other firm has to decide whether to provide the information. If it creates disadvantages for his firm, he might want to keep it to himself. Otherwise, he would disclose it with a future favor in mind (Schrader, 1991).

These arguments are complementary to the terminology of social capital. In his discussion of social capital in the creation of human capital, Coleman (1988) argues that information channels are important forms of social capital, since they allow agents to access information. Social capital is important for information trading. Obligations, expectations and trustworthiness are key elements in facilitating the transfer of knowledge. The agent providing information must trust the other agent to reciprocate the favor (obligation) in the future.

Another facet to consider is the genesis and evolution of social networks. The creation of informal social networks goes through several phases, from relations between two individuals to entire networks (Maskell et al., 1998). The transformation begins with the transfer of knowledge between two individuals. Repeated interactions between agents reduce the costs of future interactions through the development of routines and conventions, thereby stabilizing the relationship. Both vertically and horizontally related firms may benefit from a climate of trust and mutual understanding. This exchange will then facilitate more informal contacts and interaction both at the level of the firm and among individual employees (Maskell, 2001). Firms can then learn from the success and failure of others. In this way, they participate in a continuous learning process by comparing different solutions, selecting, imitating and adding their own ideas.

Employees must also play a role in the evolution of inter-firm networks. If strong ties are concentrated within small communities separated by structural holes with only weak ties connecting them, then localized job mobility becomes quite important to the evolution of network structure. Granovetter (1973) argues that job changes help to build social networks across groups of firms by bridging the holes between them. The previous experience of working together facilitates future information flows, since trust and common coding schemes already exist.

The transfer of knowledge also represents a potential cost to the transferring firm. Whether or not it does represent a cost depends on the competitive context. Schrader (1991) points to three factors influencing these expectations. First, the rents that the firm can expect to gain from a given piece of information vary with the degree of competition. If the firm transfers information to a non-competing firm, the change in rent is likely to be zero, unless the other firm transfers this information to another competing firm. Also, if the two firms have different competitive goals, the receiving firm might still benefit without the transferring firm losing rent (see also Hamel et al., 1989). Second, the availability of alternative information sources has an effect on rent expectations. Similar knowledge and information can often, for example, be acquired from other sources, such as suppliers or competitors. Consequently, the competitive advantage accruing to a piece of information can erode even if the transferring firm refuses to release it. Third, the rents are affected by whether the information relates to a domain on which the two firms compete. Firms nonetheless compete along many dimensions, such as price, quality and consumer services.

On the other hand, firms might also benefit from transmitting information or knowledge. Studies by von Hippel (1987) and Rogers (1982) show that the transfer of knowledge is part of a relationship based on mutual exchange. Schrader (1991) points to two different approaches. The first assumes that the partners are interested in continuing the relationship. A firm would weaken the relationship if it did not return the favor, thereby excluding it from rents associated with future knowledge exchange. The other approach builds on the possible social aspects of exchange relationships. Unwillingness to return a favor may induce feelings of guilt and lead to a poor reputation. It is, therefore, generally believed that receiving a benefit enhances the probability of the favor being returned. Moreover, the greater the benefit, the higher is the likelihood that the favor is repaid. Obviously, however, even if the receiver wishes to return the favor, the initial transmitting firm receives no gain from the relationship if the receiver cannot offer any beneficial knowledge. Therefore, Carter (1989) suggests that firms engaging in information trading tend to prefer partners

that offer the most useful knowledge in return. Clearly, a firm is more interested in establishing relationships with firms near the forefront of technological development.

Breschi and Lissoni (2001) are critical of some of these ideas. Drawing on detailed studies of knowledge transfer, they make two main points. First, knowledge sharing through informal contacts is not likely to involve more than the sharing of relatively small ideas, which will not jeopardize the originators' competitive advantage. Second, interpersonal communication is relatively more important for sharing knowledge with customers than with competitors (Lissoni, 2001). This is in contrast to Ingram and Roberts' (2000) results in the Sydney hotel industry. They find that friendships among managers have a positive and significant impact on a hotel's yield, and that this improvement is larger for friendships among managers of competing hotels. The cohesive networks support anticompetitive social norms. The greater overlap of interests among competitors also improves the depth and quality of the information they offer relative to non-competitors (Ingram and Roberts, 2000).

In analyzing the Brescia mechanical industry, Lissoni (2001) finds that communities consist of individual engineers linked by personal ties of trust and reputation. Although they arise from successful commercial partnerships and deals, the communities are not based on inter-firm arrangements, but respect the appropriation strategies of each firm. Similarly, Breschi and Lissoni (2001) argue that there might be several competing networks of firms in a local community. These networks evolve over time though the cooperation of partners, suppliers and customers. As a result of long lasting inter-firm cooperation, engineers in these groups have created their own 'codebooks' and specific knowledge, which cannot easily be understood by competing groups. Even in epistemic communities containing members from competing networks, the engineers retain their loyalty towards the firm or the network they belong to. They exchange general rather than more specific knowledge. Although local communities, like the present case, are seen as homogeneous knowledge communities, firms still tend to specialize in narrow market niches with customized products. As a result, only a fraction of firm-specific knowledge can possibly diffuse through social networks (Lissoni, 2001).

In summary, earlier theoretical contributions argue that knowledge is diffused through informal contacts. Agents specialize within social groups and integrate via ties of different strength across them. Networks allow agents to acquire non-redundant information from different groups. These agents are central in providing the organization with new and unique information. There is, however, a trade-off between cohesion in the social network and non-redundancy, usefulness, reliability and firm-specificity of the knowledge. Across firms, agents provide each other with advice and solutions to problems, but not all social contacts diffuse knowledge. But sometimes they disclose even valuable firm-specific knowledge with future favors in mind despite the fact that it could disadvantage their own firm in the short run. This view has been criticized, however, by other scholars (e.g. Breschi and Lissoni, 2001; Lissoni, 2001) arguing that agents will not disclose firm-specific knowledge to external agents because of their loyalty to the firm. They will only exchange more general knowledge of low value. Based on these views, propositions are developed below.

The propositions deal with the type, extent and causes of informal contacts. The extent of social networks between engineers in the wireless communication industry around

Aalborg can be expected to be rather large in terms of direct and indirect ties. The engineers are working within the same specialty within a small geographical area, and many have graduated from the local university. This would increase the likelihood that each individual engineer's social network includes contacts working in other firms. The social network gets formed when people meet through work, studies or friends and build social capital. There are many different specialized sub fields within wireless communication technology, but there are also overlaps in the knowledge base. The probability of knowledge diffusion through informal contacts can be expected to be higher in a homogeneous knowledge community. A large share of the social contacts in this context, however, likely diffuse general information and gossip rather than knowledge applicable to engineers' own job functions. The questionnaire applied in the data collection for this study addresses this distinction by asking the engineer whether he/she acquired knowledge through informal contacts that can be used in his/her own work. Then, the engineer is asked to value that knowledge (as high, medium or low).

Social contacts involve informal exchange relationships. They are stable over time, since the creation of informal contacts takes time and involves trust and frequent interaction. Working together or being former classmates helps build social capital and allows for future interactions. At first, only low-value knowledge is traded through a specific informal contact because of uncertainty about the relationship. But as the number of successful transactions and the level of trust increases, it is possible that more valuable knowledge will be traded. Engineers from this particular local university might even be more likely to diffuse knowledge through informal contacts, since the curriculum emphasizes problem solving in groups.

As Granovetter (1973) notes, a job change can bridge social networks. Employees tend to maintain contact with former colleagues and classmates as they change jobs within a local industry. If the engineers were used to working together, they may also feel more comfortable exchanging knowledge. This social capital is likely to persist after the job change and is expected to increase the probability of future knowledge diffusion. The mobility of the engineers could also produce more ties between different groups and, consequently, make it more likely that the mobile engineer acquires knowledge. Through a long working experience, an engineer develops contacts with more people and is employed in different project groups and firms. This builds trust and a reputation and further increases the number of contacts. But there are also forces working against knowledge diffusion. The employer has an incentive to prohibit the transfer of certain types of knowledge through informal contacts. In order to minimize the loss of competitive advantage from valuable knowledge, the firm wants to limit the possibility of employees disclosing valuable information about their businesses. This summary leads us to ask the following questions to be investigated empirically:

- What are the factors explaining the engineers' likelihood of having social contacts?
- With whom are they most likely to be in contact?
- When are these contacts used to acquire knowledge?
- Who acquires useful knowledge through the informal social contacts, and what is the relationship between the probability of acquiring valuable knowledge and the various characteristics of engineers?

3. Data and method

This article draws on data from a questionnaire survey conducted in November/December 2001. A questionnaire was sent to engineers in the NorCOM firms. NorCOM is the name of a formal organization formed by some of the firms in the wireless communications industry around Aalborg in North Denmark. When the survey was carried out, 25 out of the 35 local firms were members of NorCOM. The questionnaire was sent to the managers of the 25 NorCOM member firms. Nineteen of these managers agreed to endorse the questionnaire to their employees with engineering degrees (including computer scientists). The remaining six managers did not respond to our request. To increase the response rate and the managers' willingness to recommend the survey to their employees, we chose to give the respondents total anonymity. This means that we cannot identify which firm each respondent comes from.

The history of the wireless communication industry around Aalborg dates back to the mid-1960s, but the main entry of firms and growth in the number of employees occurred during the past twenty years. NorCOM was founded in 1997 as an association of firms together with the local university, Aalborg University. In 2000, NorCOM was formally incorporated as an association with a board of directors. The role of NorCOM is to represent the common interests of the group. The association interacts with the press by providing them with contact to specific firms or material on the local industry. It is also acts as a forum for the managers and university faculty, where they meet and discuss general developments in the industry and how these affect the local group of firms. Through the association, the firms are trying to influence policy makers and university faculty to support their needs.

Employees are not involved in these meetings, and the firm's membership in NorCOM does not seem likely to affect the extent of ordinary employees' social networks. The firms that were not members in late 2001, when the questionnaire survey was conducted, were generally smaller firms compared to the members. Five of these were rather young firms founded in 2000 or 2001. The rest of the non-members were local companies, who for various reasons did not want to be members of the association. We have no reason to expect that the employees of these firms do not have social contact with employees from members of NorCOM and visa versa. Whether the managers' unwillingness to join the association is an indicator of a restrictive managerial regime is uncertain. Based on our knowledge of these firms, we do not suspect any significant difference between their employees and those of members of NorCOM in the extent of social networks and their willingness to diffuse knowledge.

Engineers are the single most important resource for research and development in NorCOM. In almost all of the firms, engineers account for a high proportion of total employment. After contacting the managers personally, we received information about the number of employees in this category. Of the 791 questionnaires we sent to the 19 firms, 346 questionnaires were returned to us, a 44 percent response rate.

After asking for some basic information and educational background, we inquired about the following issues:

(i) work experience in communication technology and in different locations;

(ii) characteristics of the present job as well as important parameters in the job selection process;
(iii) reasons for job changes;
(iv) contact with engineers from other firms;
(v) contact with university staff;
(vi) the need for, and use of, further educational opportunities;
(vii) the importance of, and reason for, membership/non-membership of labor unions;

Table 1
Distribution of observations across the categorical variables

Variable	Number of observations	Percentage of observations	Cumulative number of observations	Cumulative percentage
Informal contact				
No	87	25.14	87	25.14
Yes	259	74.86	346	100.00
Knowledge acquisition				
No	240	69.36	240	69.36
Yes	106	30.64	346	100.00
Value of knowledge acquired				
No knowledge	242	69.94	242	69.94
Low	38	10.98	280	80.92
Medium	57	16.47	337	97.40
High	9	2.60	346	100.00
Function-speciality in firm				
R&D	260	75.14	260	75.14
Other specialities	86	24.86	346	100.00
Contact with former colleagues				
No	175	50.58	175	50.58
Yes	171	49.42	346	100.00
Contact with former classmates				
No	216	62.43	216	62.43
Yes	130	37.57	346	100.00
Contact with private friends (within local industry)				
No	223	64.45	223	64.45
Yes	123	35.55	346	100.00
Previous formal projects				
No	277	80.06	277	80.06
Yes	69	19.94	346	100.00
Educational institution				
Local university	180	52.02	180	52.02
Other institutions	166	47.98	346	100.00
Competition clause				
No	290	83.82	290	83.82
Yes	56	16.18	346	100.00

Source: NorCOM survey.

(viii) the entrepreneurial spirit and opportunities for establishing new firms in the future. When the engineers were questioned as to whether they received knowledge, we asked them only to consider knowledge that they could use directly in their current job function.

In the questionnaire, we define an informal contact as a person working in another firm (in the same local industry) with whom the engineer has a social relationship, which is not part of a formal agreement between the two firms. We use 13 different variables in our studies of the likelihoods of having informal contacts, acquiring knowledge and acquiring high-value knowledge. Most of these variables are categorical and derived directly from the survey. The only exceptions are work experience and mobility rate. Experience is calculated as the number of years of work experience since graduation. Mobility rate counts the number of job moves divided by years of experience. The distributions of the categorical variables are shown in Table 1.

The table shows that the 75% of the respondents are in informal contact with employees in other firms; 30% of the respondents acquire knowledge through these contacts, but only 2.6% of the sample acquires high-value knowledge. The majority of the respondents are working primarily with R&D assignments in their firm. Almost 50% are in contact with former colleagues; almost 40% with former classmates (52% of the respondents are graduates from the local Aalborg University) and 35% are private friends with their contacts (i.e. they meet in a social context not related to work). Twenty percent of the engineers have previously been involved in a formal project with other firms in the local industry. Sixteen percent of the respondents have non-compete covenants or competition clauses in their employment contracts.

Table 2 shows descriptive statistics for all variables, and includes a correlation matrix. The table reveals that the average age of the respondents is relatively low (33.2 years). This is due to the rather rapid growth of the local industry in the mid- to late-1990s, when many firms also had recruitment problems due to a paucity of available and qualified labor. The correlation matrix shows a considerable number of significant correlation estimates.

4. Results

We investigate three different types of models in our analysis. First, we estimate a logistic regression model (Model 1) on the probability that a respondent has one or more informal contacts with employees in other local industry firms. Second, we examine the probability that a respondent acquires knowledge through the contact that can be used in the respondent's own work, also using logistic regression models (Models 2a–c). Finally, we investigate the probability that the respondent acquires high-value knowledge using three different ordered probit regression models (Models 3a–d). The results of the first estimations are reported in Table 3.

The first model investigates the factors that may have significant influence on the likelihood of having informal contact with employees in other local firms in the industry. Three factors have highly significant effects on the likelihood. Most notably, the educational institution and whether there is a competition clause in the respondent's

Table 2
Basic descriptive statistics and correlation matrix

	Variables	Mean	S.D.	Min.	Max.	1	2	3	4	5	6	7	8	9	10	11	12
1	Age	33.21	6.62	23.00	59.00												
2	Informal contact	0.75	0.43	0.00	1.00												
3	Knowledge acquisition	0.31	0.46	0.00	1.00	**0.37**											
4	Value of knowledge	0.52	0.86	0.00	3.00	**0.35**	**0.90**										
5	Contact with former colleagues	0.49	0.50	0.00	1.00	**0.57**	**0.23**	**0.24**									
6	Contact with former classmates	0.37	0.49	0.00	1.00	**0.44**	**0.16**	**0.12**	0.03								
7	Contact with private friends	0.35	0.48	0.00	1.00	**0.41**	**0.20**	**0.16**	**0.22**	**0.21**							
8	Previous formal projects	0.19	0.40	0.00	1.00	**0.14**	**0.20**	**0.21**	**0.19**	0.03	0.07						
9	Experience	8.60	6.45	1.00	34.00	−0.04	**0.11**	**0.15**	**0.26**	**−0.36**	−0.05	**0.26**					
10	Educational institution	0.52	0.50	0.00	1.00	**0.20**	**0.12**	**0.16**	−0.02	**0.34**	0.04	0.09	**−0.13**				
11	Competition clause	0.16	0.37	0.00	1.00	−0.14	−0.04	−0.02	**−0.18**	0.05	−0.05	0.00	−0.02	0.06			
12	Mobility rate	0.35	0.29	0.05	2.33	**−0.04**	**−0.12**	**−0.13**	**−0.24**	**0.20**	0.05	**−0.16**	**−0.50**	0.00	0.06		
13	Function-speciality in firm	0.75	0.43	0.00	1.00	0.02	**−0.11**	**−0.14**	−0.07	0.14	−0.07	−0.08	**−0.28**	−0.04	0.09	0.08	

Source: NorCOM survey.
Note: Figures in bold have associated *p*-values lower than 0.05.

Table 3
Results of the logistic regressions

Variables	Model 1		Model 2a		Model 2b		Model 2c	
	Parameter estimate	S.D.	Parameter estimate	S.D.	Parameter estimate	S.D.	Parameter estimate	S.D.
Dependent	Informal (prob = yes)		Knowledge (prob = yes)		Knowledge (prob = yes)		Knowledge (prob = yes)	
Formal projects in the past (vs. no)	0.44**	0.203	0.38**	0.155	0.37**	0.157	0.37**	0.1559
Experience	−0.02	0.025	0.04*	0.233	0.03	0.024	0.03	0.025
Educational institution (vs. other)	0.45***	0.140			0.18	0.138		
Function-speciality (R&D vs. other)	0.14	0.162			−0.22	0.153		
Competition clause (vs. no)	−0.48***	0.172					0.07 0	0.182
Mobility rate	−0.41	0.504					−0.66 0	0.560
Contact with former colleagues (vs. no)			0.36***	0.135	0.38***	0.136	0.35**	0.138
Contact with former classmates (vs. no)			0.42***	0.144	0.38**	0.151	0.43***	0.144
Contact with private friends (vs. no)			0.34**	0.132	0.33**	0.134	0.35***	0.132
Intercept	1.43***	0.447	−0.80***	0.265	−0.68**	0.299	−0.43	0.400
Observations	330		330		330		330	
Concordant	65.9		71.9		73		71.8	
Likelihood ratio	24.859***		44.507***		48.745***		46.112***	

Source: NorCOM survey.
Note: (*) $P < 0.1$, (**) $P < 0.05$, (***) $P < 0.01$; Models 1 and 2a–c are logistic regressions.

Table 4
Results of the value-ordered probit regressions

Variables	Model 3a		Model 3b		Model 3c		Model 3d	
	Parameter estimate	S.D.	Parameter estimate	S.D.	Parameter estimate	S.D.	Parameter estimate	S.D.
Dependent	Value (prob. = high)		Value (prob. = high)		Value (prob. = high)		Value (prob. = high)	
Formal projects in the past (vs. no)	0.22**	0.086	0.20**	0.087	0.20**	0.087	0.20**	0.087
Experience	0.03**	0.013	0.03**	0.013	0.02*	0.013	0.02	0.014
Educational institution (vs. other)			0.20***	0.077	0.19**	0.078		
Function-speciality (R&D vs. other)					−0.13	0.084		
Competition clause (vs. no)							0.07	0.100
Mobility rate							−0.28	0.304
Contact with former colleagues (vs. no)	0.23***	0.076	0.23***	0.076	0.24***	0.076	0.23***	0.077
Contact with former classmates (vs. no)	0.23***	0.079	0.18**	0.083	0.19**	0.083	0.24***	0.080
Contact with private friends (vs. no)	0.13*	0.074	0.15*	0.075	0.14*	0.076	0.13*	0.074
Intercept 3	−2.17***	0.206	−2.28***	0.213	−2.18***	0.222	−2.00***	0.260
Intercept 2	−0.95***	0.152	−1.02***	0.157	−0.92***	0.171	−0.78***	0.222
Intercept 1	−0.55***	0.147	−0.61***	0.152	−0.50***	0.168	−0.37*	0.220
Observations	330		330		330		330	
Concordant	68.1		69.6		69.1		68.1	
Likelihood ratio	43.751***		50.788***		53.059***		44.964***	

Source: NorCOM survey.
Note: (*) $P < 0.1$, (**) $P < 0.05$, (***) $P < 0.01$; Models 3a–d are value-ordered probit regressions.

contract are significant. The likelihood of having informal contact increases if the respondent is a graduate from the local university. On the other hand, the likelihood decreases in cases where the engineer has a competition clause. Employees in the more closed firms, which strongly control their employees with competition clauses, also have fewer informal links to the outside. Additionally, the likelihood of having informal contacts increases if the engineer has been part of a formal cooperative project in the past. Years of work experience, function in firm and the mobility rate do not have any significant effects on the likelihood of having contacts. The likelihood ratio for the model is highly significant, indicating that the model has a good fit. The concordant ratio is 65.9%, showing that the model better predicts the outcome than the random 50/50 baseline.

The second issue is the likelihood that respondents will acquire knowledge from their informal contacts that they can use in their current job. This is examined in Models 2a–c. Similar to the previous model, the likelihood of acquiring knowledge is also significantly affected if the engineers were previously part of a formal cooperative project with another firm. This variable is positive and significant in all three models. Furthermore, engineers that form relationships with former colleagues and former classmates or are private friends with other engineers employed in the local industry have a relatively higher probability of acquiring knowledge from these contacts. The dummies for contact with these parties are also significant and positive in all three models. Work experience is only significant in the first model, giving only weak support for the idea that engineers will be more likely to acquire knowledge as they gain work experience. Competition clauses, educational institution, mobility rate and function in the firm have no influence on the likelihood of acquiring knowledge. The likelihood ratio is again highly significant and positive, and the predictive power of the models is also high (71.9–73%).

The likelihood of acquiring highly valuable knowledge is investigated in the four variations of Model 3 shown in Table 4. The likelihood of acquiring valuable knowledge increases if the engineer has previously been part of a formal cooperative project. The variable is positive and significant in all four estimated models. The contact variables have similar effects, although the dummy for contact with private friends is less significant relative to the two other contact dummies. This suggests that relationships with former colleagues and classmates have stronger effects on the likelihood that an engineer acquires more valuable knowledge. In contrast to the previous models, experience is significant (except for Model 3c) and positive, indicating that experience is more of an advantage when looking at the likelihood of acquiring valuable knowledge. The educational institution dummy is also positive and significant when included in Model 3, suggesting that engineers with a degree from the local university might occupy more central positions in the network, increasing the likelihood that they acquire valuable knowledge. On the other hand, the variables on function in firm, mobility rate and competition clauses have no effect on the probability in this model. The concordant ratio indicates predictive powers just below 70%, while the highly significant likelihood ratios indicate that the models have good fits.

5. Discussion

Our study shows that the work experience of engineers does not have an impact on whether the engineers have informal contacts. Neither does there seem to be a relationship

between work experience and the likelihood of acquiring knowledge. Experience does not seem to increase the likelihood of having contact or acquiring knowledge. However, when looking at the likelihood of acquiring valuable knowledge, the engineer experience has a more significant impact (except for Model 3d). Experience increases the likelihood of acquiring valuable knowledge. This suggests that the engineers are better at using their contacts to acquire valuable knowledge the more experience they have. They know whom they have to contact in order to acquire the most valuable knowledge or to get help to solve their particular problem. Or, experience may build reputation, as argued by Maskell et al. (1998), making some of the weaker ties stronger and more able to disclose valuable knowledge. Though this result also relates to the debate on social cohesion versus knowledge uniqueness (e.g. Granovetter, 1973; Ingram and Roberts, 2000), our data cannot answer this question. But the overall picture is that the relatively more experienced engineers are not more likely to have contacts or acquire knowledge than other engineers, but in general the knowledge that they do acquire is of higher value to them.

The initial contact between engineers from two firms may be created by a formal joint project. If they work together on a specific joint project their relationship may last longer than the project itself. Working together across firm boundaries also increases the probability that engineers connect across structural holes, as described by Burt (2004), and that they can bridge disparate coding schemes across organizations (Allen and Cohen, 1969). Engineers previously involved in formal projects with employees from other firms are more likely to have informal contacts than engineers not previously involved in such projects. It is plausible that some of these informal contacts arise directly from these formal projects. They are also more likely to acquire knowledge and also more valuable knowledge. This clearly suggests that the relationships created through formal projects persist even after the project. Project participants remain in social contact, which increases the probability that knowledge is shared.

Who the engineers are in contact with is also important. Engineers that have social relations with former colleagues, former classmates or are personal friends with other engineers (from other firms in the local industry) have a relatively higher probability of acquiring knowledge from these contacts. This is what one would expect based on the literature (e.g. Allen and Cohen, 1969; Granovetter, 1973; Ingram and Roberts, 2000). Relationships with former colleagues and classmates also have strong effects on the likelihood that an engineer will acquire more valuable knowledge. Previously working or studying together with other engineers increases the strength and trust of connections, increasing the likelihood that valuable knowledge will be shared later.

Education is the centre of the concept of human capital as used by Burt (2004). Engineers form social networks during their education and maintain contact with their classmates.[1] However, the dummy for educational institution (Aalborg University vs. other institutions) is not significant for the probability of having informal contacts or acquiring knowledge in our estimations. But engineers educated at this university do have a significantly higher probability of receiving more valuable knowledge. This might be

[1] Fifty-two percent of the engineers in the sample are graduates from the local university.

because the engineers have a more central position in the social network or have larger networks. Our data, however, cannot map individual engineers' social networks to explore this further.

Granovetter (1973) argued that mobility might be important for the extension of informal contact networks. To investigate this, we examined whether a higher relative mobility rate increased the probability of having at least one informal contact. However, the mobility rate has no effect on the likelihood of informal contact between engineers or of acquiring knowledge from others. So although engineers have important contacts with former colleagues and project partners, a higher rate of mobility does not increase the probability of having contacts or getting knowledge. All in all our results show that engineers have the strongest and most important connections (in terms of acquiring higher valued knowledge) with their previous colleagues and project partners, and they are more likely to get valuable knowledge, if they maintain these relationships. But this likelihood is not influenced by the rate of mobility.

Firms might also discourage their employees from, or even actively try to prevent, sharing knowledge with outside parties (von Hippel, 1987; Schrader, 1991). Managerial regimes and culture can have an effect on the extent of informal relationships across the boundaries of firms. Competition clauses can, for instance, limit the employee's opportunities for taking a job in a competing firm or working with the same products immediately after ending the contract. Here we can use the clauses as a proxy for a firm's actions towards limiting the disclosure of knowledge to other firms through informal channels. Firms that include these clauses in the contracts of their employees are also more likely to have policies and norms preventing or discouraging their employees from sharing the firm's knowledge through informal contacts.

The engineers that have competition clauses in their contracts are less likely to have at least one informal contact outside the firm. This shows that firms with restrictive managerial regimes – that is, with competition clauses in the contracts – are successfully limiting informal networking between their employees and those in other cluster firms. However, the presence of a competition clause does not have an impact on the likelihood of receiving useful knowledge or on the value of knowledge received. So once the contact and network connection is established, competition clauses do not hinder knowledge diffusion, but they can prevent people from establishing networks.

6. Conclusion

This article describes how previous claims that knowledge is diffused through informal social networks have been criticized recently by scholars stating that agents will not generally disclose firm-specific knowledge to external agents, because of loyalty to their firms. They argue that employees will only tend to exchange more general information of low value that will not disadvantage their firms. Our survey shows that some engineers actually do acquire valuable knowledge from informal social networks. In particular, engineers, who have previously been part of formal projects with other firms and who are in contact with their former colleagues and classmates, are much more likely to receive knowledge of higher value.

The overall conclusion of this article is that these long-term relationships, which are more likely to be based on trust and reputation, are also more likely to channel the diffusion of valuable knowledge. Experience, contact with former colleagues and formal projects from the past are the most important factors explaining the likelihood that engineers will acquire valuable knowledge. These relationships are potentially very strong and likely involve a considerable degree of trust.

Certain limitations of this study should be considered in future research. These are important relative to the broader questions raised in the literature and in this article. This study shows that social networks and informal communication are diffusing knowledge between firms in a coherent group of firms located within in a rather small geographical area. Future research also should ask the individual to compare the value of the knowledge thus acquired with other sources of knowledge (e.g. colleagues in their workgroup, other colleagues in their firm, the internet, university-based research contacts, technical journals or similar sources). This would add to our understanding of how more specific information and knowledge is actually exchanged within and across organizational boundaries. Individual engineers, however, should remain the unit of analysis, since the results may become more biased if the interviews and surveys are conducted at the level of the firm. It is impossible for managers to know the full extent, value and usefulness of each of their employees' informal social contacts.

This article provides insights on the existence and value of informal relationships to the individual employee. However, little is still known about the value to the firm and the effects of these relationships on firm performance. Future surveys linking the inter-firm informal contacts with firm performance may provide interesting evidence on how firms are influenced both positively and negatively by their employees' social networks. The knowledge flowing through informal contacts is often considered in a positive light in the literature. But knowledge trading also has a downside. For example, the loss of valuable knowledge to competitors could potentially weaken firm performance.

Furthermore, it would be constructive to know more about how individuals are linked in networks of informal relationships across firms. Identifying how networks and epistemic communities operate in different sectors and on regional levels could shed some light on how widely knowledge is exchanged through a network. A limitation in the questionnaire used in this article is the anonymity of the engineers. By asking engineers to name, say, their three most important informal social contacts in the local industry, it may be possible to map a web of informal contacts and to gain a more accurate picture of the extent of the social networks. This important issue is still to be addressed in the debate on the importance, characteristics and borders of these networks.

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