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Knowledge Flows through Social Networks in a Cluster: Interfirm versus University-Industry Contacts

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Abstract:
Knowledge spillovers from a university to the local industry play an important role in clusters, but we know little about these spillovers. This paper examines empirically the extent of university-industry informal contacts. Furthermore, it analyses the characteristics of an engineer that acquire knowledge from informal contacts with university researchers. The university-industry contacts are compared with results for interfirm contacts. The research shows that the interfirm informal contacts are more numerous than university informal contacts. Likewise, knowledge is more frequently acquired from other firms than through university-industry contacts. Engineers that have participated in formal projects with university researchers and engineers that are educated at the university have a higher likelihood of acquiring knowledge from informal contacts with university researchers.

Key words: Knowledge flows; informal contacts
Jel codes: D83; O32; I23

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1 Introduction

The diffusion of knowledge between firms through informal social networks has received a lot of attention in the literature on clusters. The existence of knowledge externalities is often argued to be one of the main reasons for clustering of industries (Marshall, 1920; Storper and Walker, 1989; Saxenian, 1994). The main argument is that knowledge and information are flowing more easily between organisations in a cluster than outside and across its borders. The existence and importance of these knowledge flows have been centre of an intense discussion in economics and economics geography (Krugman, 1991; Martin and Sunley, 1996). Critics state that employees will not generally share firm-specific knowledge and only exchange general knowledge of low value that is less disadvantageous for their firm (Breschi and Lissoni, 2001). However, recent studies have shown that knowledge flows through social networks do take place and even firm-specific knowledge is shared (Lissoni, 2001; Dahl and Pedersen, 2004). But, not all agents in a cluster have social contacts with employees in other firms, since social networks are exclusive and are created over time by individuals (Lissoni, 2001; Dahl and Pedersen, 2005).

Universities are often found to be an important part in clusters. The university is seen as a source of new knowledge (Feldman, 1994; Saxenian, 1994; Anselin et al., 1997). University research and knowledge is, somehow, flowing from the university to firms in the cluster. This knowledge diffusion can take place as formal cooperation, through mobility of graduates, and through informal social networks. The university-industry knowledge flows through social networks seem to be less controversial compared to interfirm flows. Subsequently, it has received less attention in the cluster literature. However, the social network between employees in firms and university are also likely to consist of smaller epistemic communities. Furthermore, the evidence is mainly anecdotic or measured by a distance-to-university proxy in regression analysis. In addition, these networks might have a different structure than the interfirm networks. The value of the knowledge shared might be higher and the engineers educated at the local university might have a higher chance of acquiring knowledge compared to non-local engineers.

The purpose of this paper is to study to what extent social networks among engineers are channels for sourcing knowledge between firms and the local university. And what is the relationship between the likelihood of acquiring knowledge and the various characteristics of the engineers. The university-industry contacts are then compared with the interfirm social networks in the cluster. The present analysis is carried out at the micro level, in this case focusing on the engineer, which provides a better picture of the extent of social networks in a cluster.

The following Section 2 presents the theoretical framework on knowledge flows through informal channels. Section 3 describes the case, data and methodology, while the results of the regressions analyses are presented in Section 4. The results are discussed in Section 5 followed by the conclusions in Section 6.

2 Knowledge flows through social networks

The innovation process involves interaction and knowledge sharing between co-workers within the firm to become successful. Innovation studies have found that innovation is an interactive process and the central part of the required knowledge is often difficult to codify. Therefore close interaction among actors is important in the innovation process (Lundvall, 1992; Lundvall and Johnson, 1994). When facing a problem the employee will turn to colleagues, but the many studies of communications patterns in organisations by Allen (1984) have shown that information flows within a company is decreasing sharply over distance. However, no R&D laboratory can be completely self-sustaining. It is necessary to import knowledge from the outside to pursue the external technological developments (Allen and Cohen, 1969). In their analysis of the impact of formal organisational structure on communication structures Allen and Cohen (1969) finds that: "The formal organization is therefore more important, but not the sole determinant of the structure of the technical communication network" Likewise, they identify that the sociometric "stars" in the technical communication network in a laboratory that are used as sources of information for their colleagues, used outside sources to get information more often than others. These stars have rather widespread social networks of informal contacts outside the organisation and acts as technological gatekeepers (Allen and Cohen, 1969).

When the agent decides to share knowledge through informal channels with employees in another firm or university problems can emerge. This relates to the asymmetry in information flows. Firms clearly gain from knowledge spillovers when it receives information, but when its own R&D is being shared it erodes their competitive advantage. Despite knowledge flows initially is a disadvantage for the firm, several studies have shown that firms generally benefit from knowledge spillovers and that informal exchange of information between organisations is frequent in the innovation process (Rogers, 1982; Allen, 1984; von Hippel, 1987; Ingram and Roberts, 2000).

Distance is important for knowledge flows. Several researchers have argued that short geographical distance should increase the sharing of knowledge, while others have stressed the importance of short cognitive distance (see e.g. Storper and Walker, 1989; Saxenian, 1994; Audretsch and Feldman, 1996; Maskell et al., 1998). However, being in a close geographical proximity within the same industry doing similar work does not imply that an agent gains access to knowledge flows. It is necessary to be a part of the epistemic communities that exits in a region. These communities are exclusive and are created over time. Likewise, it is not all agents that have social contacts across firm boundaries within the same industry or with university employees in the region (Lissoni, 2001).

The strength of the ties and the cohesion in the social networks are important for the sharing of knowledge. A high degree of cohesion will provide the agent with redundant information, while agents that spans structural holes i.e. connect two nodes that are not connected, can provide the organisation with new information (Granovetter, 1973; Burt, 2004). In cohesive social networks the agent receive information that is more reliable and firm-specific, while the weak ties increase the total amount of new information, but also increase uncertainty (Ingram and Roberts, 2000). Trust is a key issue in knowledge transfer, since the agent loose control of the information when it is shared and the agent also expects that the receiver reciprocate the favour in the future. Trustworthiness is generated by familiarity and numerous interactions between the agents or it could be created through indirect ties if they have social contacts in common (Piore and Sabel, 1984; Pyke et al., 1990; Maskell et al., 1998; Løvås and Sorenson, 2004).

A wide range of processes and factors influence the possibilities for knowledge flows through social networks in a cluster, but two basic processes are needed: First, the agents must, somehow, be connected to each other and second, they must trust each other to exchange information. The mobility of agents between organisations could potentially be important for knowledge sharing, since it affects the evolution of social network structures

(Almeida and Kogut, 1999). Likewise, Granovetter (1973) argues that job mobility assist the building of social networks by creating new links and bridging the structural holes between organisations. Mobility also generates know-who i.e. who knows what and where do they work. When facing a problem an agent is likely to also think of former colleagues who might know the solution. If the agents previously worked together and shared information when they where colleagues, they might be more likely to exchange information again. The experience of working together could facilitate future knowledge flows, since common coding schemes and trust already exist. These sociological factors should be similar for both interfirm and university-industry networks in a cluster, however, there are also differences.

2.1 Interfirm social networks

The knowledge flows between firms can take different forms, such as knowledge sharing or mobility of employees and use various channels, such as patenting, licensing, cross-licensing, know-how trading, collective invention, and publishing (Appelyard, 1996). These channels of knowledge sharing are more or less formal. Sometimes the diffusion of knowledge between firms takes place through formalised cooperation and other times through social networks. Von Hippel (1987) argues that the knowledge sharing through informal channels is a form of trading know-how, where employees in different firms give advice to technical problems or share information with each other. The receiver of the information is expected reciprocate the favour in the future (Schrader, 1991).

The transfer of knowledge represents a potential cost to the transferring firm, since it might loose possible monopoly rents if the employees decide to share valuable knowledge (Schrader, 1991; Appelyard, 1996). This depends of the redundancy of the information in the network. However, the employees' would not disclosure knowledge that is important to the firm if there are no agency problems. Breschi and Lissoni (2001) are critical of the concept of localised knowledge spillover. They argue that employees will not jeopardise the firm's competitive advantage. Furthermore, they argue that knowledge does not automatically spill over, but is diffused in communities of practitioners through social networks. These networks require social proximity that arises from shared work or study experience and frequent face-to-face interaction and socialising. From studies of social networks between individual employees in the Brescia mechanical industry, Lissoni (2001) adds that the social networks could also arise from successful formal cooperation with suppliers or competitors.

Agents engaging in information trading could benefit from being in contact with agents that offer new non-redundant technical knowledge, but cohesive networks between agents with similar interests improve the quality and depth of the information (Ingram and Roberts, 2000). Thus, not all types of knowledge can be transmitted easily. It takes time and requires usually intermediary cognitive capacities and that the agents have related skills. There are hundreds of routine questions and these can only be answered of agents in similar jobs. Therefore the transfer of tacit knowledge requires a joint understanding for the context in which the knowledge is a part of. If it is embedded in a learning-by-doing context it might be even more difficult. In a cluster where the firms are working within similar technologies there are many agents with similar jobs, but many firms are still working in different part of the value chain. This suggests that even though social networks might be widespread there are limits to the knowledge diffusion, since knowledge might be firm-specific, industry-specific or job-specific.

2.2 University-industry social networks

Universities are often seen as an important source of knowledge in high-tech clusters (see e.g. Feldman, 1994; Saxenian, 1994). Famous examples of prominent clusters with leading universities, such as Stanford in Silicon Valley and MIT in Boston Route 128 have shown that universities often play an important role in clusters. The importance of a university can be very high in terms of star scientists and key actors that attract resources and pull the university research and education in a specific direction and thereby have a large effect on the development of clusters. In addition, the universities have increasingly become a focal point of industrial development for regional and national economies (Etzkowitz, 1998). Anselin et al. (1997) argues that the public nature of the basic research at the university results in positive externalities to the firms through knowledge spillovers. The firms locate close to the universities, often in nearby science parks, and tap into the university research or benefit from knowledge spillovers (Feldman, 1994; Saxenian, 1994; Anselin et al., 1997). These knowledge flows are often measured by patent citations, academic papers, and size of academic staff or university research spending in regression models.

The knowledge flows between a university and firms can take different forms, such as formal research projects (e.g. joint research projects or contract research), mobility of scientists, training, publications, reports, patents, conferences, consultancy, education of highly skilled graduates, university start-ups and informal knowledge flows (Lawson, 1999; Mueller, 2006). The universities have traditionally had two missions: Basic research and training, but recently there have been an increasing focus on the third mission: Commercialisation of knowledge. While some traditional universities have focused mainly on the advancement of knowledge there are many universities, where coorperation with industry has been common (Etzkowitz, 1998).

In their study of cooperation between firms and universities in science-based fields, Meyer-Krahmer and Schmoch (1998) finds that the central linking element is the exchange of knowledge in both directions. They argue that university research in science-based fields is not exclusively basic research, but also applied research. In their survey of German universities they find that academic researchers' rank collaborative research and informal contacts higher than contract research. In addition, the researchers rank knowledge exchange almost as high as additional funds when ranking advantages of interaction with firms, and prefer collaborative research with bi-directional knowledge flows. The highest disadvantage is the short-term orientation of firms. Meyer-Krahmer and Schmoch (1998) argues that university researchers benefit from interaction with firms, since these also conduct R&D and produces new knowledge that the university researchers need to support their own academic career. Thus, the motives for university researchers to participate in knowledge exchange with employees in industry is not that different from the motives of industry employees to participate in interfirm networks.

Breschi and Lissoni (2001) are critical of the idea of automatic knowledge spillovers from universities and local firms. They argue that the research at universities is more basic than applied research and that the knowledge flows through pecuniary channels, such as production of graduates, consultancy, joint research, sponsored research, formal research projects, start-ups and mobility. Furthermore, they argue that the new knowledge from basic research often is tacit, which cannot be transferred through informal contacts, since it is necessary to build a competence to find and understand this specific knowledge. Therefore it can only be recreated and transferred by the researchers through mobility or formal contracts.

2.3 Interfirm vs. university-industry contacts

Knowledge flows from a university to the firms in a cluster can take various forms. However, in a cluster characterised by many firms working within similar technologies, overlaps in the employees' knowledge base and a common labour market, the university is only to a lesser extent a source of knowledge through informal contacts. This is partly caused by the difference between the university's role and aim of the firm. A part can also be explained by tacit knowledge and the specificity of the knowledge with regards to the context it is a part of, such as firm-specific, industry-specific, or related to a particular job function. Therefore the usefulness and value depends on the similarity of the agents' job functions. In addition, there is a pure size difference in number of possible contacts. The larger size of the private employment compared to number of university researchers would make the interfirm contacts more widespread than university-industry contacts.

Hypothesis 1: The interfirm contacts are more frequent than university industry contacts

The sharing of knowledge between firms can be disadvantageous for the transmitting firm which could reduce the extent of knowledge sharing through informal channels compared to the university-industry contacts, however, the greater size of the industry and the difference in types of knowledge and job functions between firms and university would make the frequency of acquiring knowledge higher for interfirm contacts.

Hypothesis 2: The frequency of acquiring useful knowledge through interfirm contacts is higher than university- industry contacts

The characteristics of an engineer that have informal contact with employees in other firms or at the university are likely to have many similarities bound in generic sociological factors. The experience of working together builds trust and job changes facilitates the creation of networks between organisations.

Hypothesis 3: Mobility has a positive effect on the likelihood of having informal contacts and acquiring knowledge through these

From the literature cited above it is clear that formal projects are important in the creation of informal contacts.

Hypothesis 4: Engineers previously involved in formal projects with engineers in other firms in the cluster or university has a higher likelihood of having informal contacts and acquiring knowledge.

The educational background is an important factor in shaping the engineers social networks. The engineers from the local university have former classmates working in the cluster or might have friends in common (indirect ties) or simply know who to contact at the university if they have a problem.

Hypothesis 5: Engineers educated at the local university are more likely to acquire knowledge than non-local engineers from both interfirm and university sources.

3 Survey data

To analyse knowledge flows through informal channels in a cluster a questionnaire was sent to engineers and computer scientists in the wireless communication cluster in North Jutland, Denmark.

The history of the cluster dates back to the 1960s when the first firm in the cluster diversified from production of consumer radios into equipment for maritime radio communications. The company became very successful and a series of firms was founded as spin offs during the 1970s and 1980s. Some of them diversified into mobile communications and the cluster received considerable attention at the Cebit fair in Hanover in 1992, when two companies from North Jutland through a joint research effort presented a GSM mobile phone among only a handful of companies in the world. The cluster experienced a high growth in number of employees and firms during the 1990s and several multinational companies entered the cluster. The profile of the cluster also broadened horizontally, since some firms entered or diversified into various communication technologies and vertically with the entry of service providers, software companies and chip-set R&D companies. For an overview of the history of the cluster see Dahl et al. (2005) and Dalum et al. (2005).

The local Aalborg University (AAU) was founded in 1974 and has today 13,000 students and 1,700 employees in Humanities, Engineering, Natural Sciences and Social Sciences. AAU was until 2000 the one of only two universities in Denmark that offered the MSc in engineering and in the 1990s approximately fifty percent of the Danish MSc's in engineering graduated from AAU. From its establishment AAU has been very active in cooperation with private firms and it participates in many networks and joint research projects. The personnel in various fields of electronics total almost 300 persons. The AAU research within wireless communication was mainly profiled by Centre for Personal Communication (CPK), which from 1993 to 2002 was an important international actor at the research scene in wireless technologies. CPK consisted of 50-60 researchers.

The questionnaire was mailed to the members of the NorCOM association of wireless communication firms in North Jutland. 25 of approximately 35 firms in the cluster were members of NorCOM. To improve the response rate and get the permission of the managers to distribute the questionnaire among their employees we chose to give the respondents full anonymity. 19 managers agreed to approve the questionnaire to engineers, computer scientists and employees with a higher technical education in their company. The questionnaires were sent to 791 employees and 346 responded, which gives a response rate on 44 %. The survey was carried out in November and December 2001. A consultancy report from 2002 indicated that the total number of engineers etc. was approximately 1.000 in 2001 (COWI, 2002).

In the questionnaire an informal contact is defined as a contact with employees from other communication firms in North Jutland or Aalborg University which is not a part of a formal agreement. Furthermore, they were asked if they acquired knowledge through this contact they could use in their own work and the characteristics and value of this knowledge.

Several variables is used in the logistic regression of which most are derived directly from the questionnaire except the control variable for experience, which is calculated as the number of years since graduation, and mobility that is the number of job changes between firms divided by experience. Table 1 shows the distribution of variables for interfirm and university-industry contacts respectively.

Table 1 Distribution of observations across the categorical variables

	Interfirm			University-industry		
Variable	Number of observations	Percentage of observations	Percentage of total	Number of observations	Percentage of observations	Percentage of total
Informal contact			(n=346)			(n=346)
No	86	24.86	24.86	246	71.10	71.10
Yes	260	75.14	75.14	100	28.90	28.90
Knowledge acquisition						
No	153	58.85	69.08	55	55.00	86.99
Yes	107	41.15	30.92	45	45.00	13.01
Value of knowledge acquired						
No knowledge			69.94			87.57
Low	38	35.51	10.98	12	26.67	3.47
Medium	57	53.27	16.47	24	53.33	6.94
High	9	8.41	2.60	7	15.56	2.02
Participated in formal projects						
No	277	80.06	80.06	300	86.71	86.71
Yes	69	19.94	19.94	46	13.29	13.29
Educational institution						
Local university	180	52.02	52.02	180	52.02	52.02
Other institutions	166	47.98	47.98	166	47.98	47.98
R&D as main job function						
No	86	75.14	75.14	86	75.14	75.14
Yes	260	24.86	24.86	260	24.86	24.86
Contact with former colleagues						
No	89	34.23	50.58	77	77.00	93.35
Yes	171	65.77	49.42	23	23.00	6.65
Contact with former classmates						
No	130	50.00	62.43	54	54.00	86.71
Yes	130	50.00	37.57	46	46.00	13.29
Contact with private friends (within local industry/university)						
No	137	52.69	64.45	58	58.00	87.86
Yes	123	47.31	35.55	42	42.00	12.14

4 Results

4.1 Interfirm vs. university-industry knowledge sharing

The demographics of the respondents show that the sample consists mainly of younger men (95%) with an average age of 33 years (standard deviation 6.6 years). 52% of the respondents are graduates from Aalborg University. The largest educational group is the MSc. in engineering (47%) followed by BSc. in engineering (34%), while 3% have a MSc. in computer science and the remaining have another type of higher technical education. The average work experience in the cluster is 5.7 years, while 62% have worked in the cluster for five years or less. They have worked in their current firm on average 3.6 years in their current job. The respondents main job function are primarily in research and development (75.1%) followed by management (16.2%), production (4.9%) and marketing (3.8%).

Approximately 1.000 employees in cluster firms have a higher technical education, while the university employ's 50-60 researchers in wireless communication and 300 in the larger field of electronic engineering. Thus, hypothesis 1 argues that due to the larger size of the industry compared to the specialised university research groups the interfirm informal contacts are more frequent than university-industry contacts. Table 1 shows that 75% of the respondents answered that they had at least one informal contact with employees in other firms in the cluster. Interfirm informal contacts were, as expected, widespread while 29% responded that they had an informal contact with researchers at the local university. However, there are many reasons for having informal contact with employees at the university and other firms. These social networks have various functions and many have mainly a social content.

In the questionnaire the respondents were asked if they acquired knowledge, which could be used in their own job. To investigate whether the engineers are more likely to acquire useful knowledge through informal contacts with employees in other firms compared to researchers from the local university these where compared in Table 1. 31% of the respondents acquire knowledge through interfirm contacts, but only 13% acquire useful knowledge through university contacts. Thus, the university contacts are less frequent than interfirm contacts and the respondents also acquire useful knowledge from university contacts less frequently. This result supports hypothesis 1 and hypothesis 2, but taking the lower frequency of the university contacts into account 41% of the respondents that have interfirm contacts receives knowledge, while 45% of the respondents with university contacts receive knowledge from that source. Thus, a marginal higher share of the engineers that have a university contact acquire knowledge compared to interfirm contacts.

The respondents were also asked to characterise the type of knowledge they receive: General knowledge, technical knowledge on standard equipment, technical knowledge on new products and other. Table 2 shows that the knowledge is mainly characterised as general knowledge (78%-79%) followed by technical knowledge on new products.

Table 2 Types of knowledge acquired through informal contacts

Type of knowledge	Interfirm: Number of observations	Interfirm: Percentage of observations	University-industry: Number of observations	University-industry: Percentage of observations
General knowledge	85	79.4	35	77.8
Technical knowledge on standard equipment	19	17.8	2	4.4
Technical knowledge on new products	33	30.8	7	15.6
Other	8	7.4	8	17.8

Note: The respondents could mention several types

However, Table 1 reveals that only 2.6% of the sample acquires high-value knowledge from interfirm contacts compared to 2% for university contacts. Half of the respondents who acquire knowledge from either interfirm or university contacts characterise this as being of medium value.

Table 1 also reveals whom the respondents are in contact with. For interfirm contacts, almost 66% are in contact with former colleagues (50% of total sample). This indicates that mobility is important for the creation of informal networks. The relationships created by engineers working together seem to last longer than the actual time they work together. However, for university-industry contacts only 23% (7% of total sample) are in contact with former colleagues at the university. This indicates lower university-industry mobility. For the interfirm contacts 65% of the respondents with informal contacts have contact with former classmates, while contact with former classmates account for 46% for university contacts. Thus, many informal contacts are created at the university between students and are kept after graduation. 48% answer that they are in contact with private friends for interfirm contacts and 42% for university–industry contacts.

Lissoni (2001) argues that many informal contacts arise from formal cooperation between firms. Thus, working together creates the base for further interactions in the future. This survey reveals that 20% of the respondents have previously participated in formalised projects with other firms in the cluster. 25% of these have participated in projects with suppliers, 29% with customers and 36% with competitors. For formal projects between university and industry 13% of the respondents had been involved in formal projects with researchers at the local university. The high share of engineers involved in formalised projects with other firms or university could be an important factor in the creation of social networks.

Table 3 shows a correlation matrix and descriptive statistics for the variables used in the regression analysis.

Table 3 Descriptive statistics and correlation matrix

	Interfirm contacts	Mean	S.D.	Min.	Max.	1	2	3	4	5	6	7	8	9	10
1	Informal contact	0.75	0.43	0.00	1.00										
2	Knowledge acquisition	0.31	0.46	0.00	1.00	**0.38**									
3	Value of knowledge	0.52	0.86	0.00	3.00	**0.35**	**0.90**								
4	Participated in formal projects	0.20	0.40	0.00	1.00	**0.14**	**0.20**	**0.21**							
5	Educational institution	0.52	0.50	0.00	1.00	**0.20**	**0.13**	**0.16**	0.09						
6	Experience	8.60	6.38	1.00	34.00	-0.03	0.10	**0.15**	**0.26**	**-0.12**					
7	R&D job	0.75	0.43	0.00	1.00	0.03	**-0.11**	**-0.14**	-0.08	-0.04	**-0.29**				
8	Mobility rate	0.36	0.39	0.05	5.00	**-0.11**	-0.10	**-0.12**	**-0.15**	-0.05	**-0.41**	0.06			
9	Contact with former colleagues	0.49	0.50	0.00	1.00	**0.57**	**0.23**	**0.24**	**0.19**	-0.02	0.26	-0.07	**-0.22**		
10	Contact with former classmates	0.38	0.49	0.00	1.00	**0.45**	**0.17**	**0.12**	0.03	**0.34**	**-0.35**	**0.14**	**0.11**	0.03	
11	Contact with private friends	0.36	0.48	0.00	1.00	**0.43**	**0.20**	**0.16**	0.07	0.04	-0.05	-0.08	0.00	**0.22**	**0.21**
	University-industry contacts	Mean	S.D.	Min.	Max.	1	2	3	4	5	6	7	8	9	10
1	Informal contact	0.29	0.45	0.00	1.00										
2	Knowledge acquisition	0.13	0.34	0.00	1.00	**0.61**									
3	Value of knowledge	0.23	0.66	0.00	3.00	**0.55**	**0.91**								
4	Participated in formal projects	0.13	0.34	0.00	1.00	**0.16**	**0.25**								
5	Educational institution	0.52	0.50	0.00	1.00	**0.34**	**0.25**	**0.28**							
6	Experience	8.60	6.38	1.00	34.00	**-0.16**	0.01	0.06	**0.14**	**-0.12**					
7	R&D job	0.75	0.43	0.00	1.00	0.01	-0.10	**-0.12**	**-0.11**	-0.04	**-0.29**				
8	Mobility rate	0.36	0.39	0.05	5.00	0.10	-0.03	-0.07	**-0.13**	-0.05	**-0.41**	0.06			
9	Contact with former colleagues	0.07	0.25	0.00	1.00	**0.42**	**0.31**	**0.29**	**0.20**	**0.19**	0.02	-0.03	-0.01		
10	Contact with former classmates	0.13	0.34	0.00	1.00	**0.61**	**0.38**	0.31	0.10	**0.31**	**-0.19**	0.03	0.09	**0.20**	
11	Contact with private friends	0.12	0.33	0.00	1.00	**0.58**	**0.33**	**0.31**	**0.12**	**0.14**	0.02	-0.05	0.03	**0.29**	**0.19**

Note: Numbers in bold have associated p-values lower than 0.05

4.2 Characteristics of an engineer that acquire useful knowledge

Two logistic regression models were estimated (Models 1a-b) to analyse the characteristics of a respondent that had informal contacts with employees in other cluster firms and the local university subsequently.

Table 4 Results of the logistic regression for informal contact

	Model 1a: Interfirm			Model 1b: University–industry		
Variables	Parameter Estimate	S.D.	Odds Ratio	Parameter Estimate	S.D.	Odds Ratio
Intercept	1.93***	0.400		-0.54	0.384	
Participated in formal projects (vs. no)	0.46**	0.200	2.51	0.52***	0.181	2.86
Educational institution (AAU vs. other)	0.42***	0.134	2.31	0.82***	0.145	5.16
Experience	-0.03	0.024	0.97	-0.05*	0.027	0.95
R&D job (vs. other)	0.08	0.155	1.18	0.01	0.159	1.03
Mobility rate	-0.68*	0.407	0.50	0.55	0.351	1.73
Observations	346			346		
Concordant	65.6			75.2		
Likelihood ratio	23.96***			59.86***		

Note: *: P<0.1, **: P<0.05, ***: P<0.01.

Table 4 shows that three factors have significant effects on the likelihood of having informal contacts with employees in other firms. Engineers that have participated in formal project with other firms in the cluster or educated from AAU are more than double as likely of having an informal contact, while the mobility rate has a negative and significant effect. Thus, engineers that change jobs more frequently reduce their likelihood of having an informal contact. There are also three significant factors for university-industry contacts. Engineers that have participated in a formal project with researches at Aalborg University have a significant and positive effect on the likelihood of having an informal contact. Educational institution is also positive and significant. The engineers from AAU are five times more likely to have contacts with university researchers (odds ratio 5.16). While mobility was negative and significant for interfirm contacts it proves to be insignificant for university contacts. Thus, it is not possible to confirm hypothesis 3. Work experience was not significant in Model 1a, but had a negative and weak significance in Model 1b. Both models are highly significant and the concordant ratios are 65.6% and 75.2%, indicating that the models are better to predict outcomes than the 50/50 baseline.

The logistic regression Models 2a-d investigates the characteristics of an engineer that acquire knowledge that can be used in his own work. Table 5 shows that the characteristics are quite similar to the previous models. Engineers that have participated in formal projects with other firms in the cluster are more likely to acquire useful knowledge. The participation in formal projects has a significant and positive effect on the likelihood of acquiring knowledge with an odds ratio of 2.3. Being educated at Aalborg University, experience, R&D job and mobility have no significant effect in the regression Models 2a-b. The dummies for whom the engineers are in contact with (former colleagues, former classmates or private friends) are also significant and positive in both models. The likelihood ratio for Models 2a-b is significant and the concordant ratios are 73.1% and 66.4%.

The regression Models 2c-d for university-industry contacts reveals that the contact dummies are significant and positive. Experience, an R&D job function and mobility have no influence on the likelihood of acquiring knowledge. The experience of formally working together with university researchers on projects significantly increases the likelihood of acquiring knowledge in both models. The importance of being educated at the local university seems also to play an important role in establishing informal contacts. These engineers are almost three times as likely to acquire knowledge from university sources compared to their colleagues. The locally educated engineers or engineers previously involved in formal projects seem to maintain their contact at the university. The likelihood ratio is again highly significant and positive, and the predictive power of the models is also high (from 82% to 86%).

The interfirm social networks and the university-industry social networks seem to have many structural similarities. A common sociological feature is the importance of formal projects in the past. During the projects the engineers get to know other engineers working in other firms and the experience of working together seems to increase the likelihood of future exchange of knowledge, especially for university-industry links. This variable is positive and significant for all the regression models, which confirms hypothesis 4. Experience is, surprisingly, not important for having informal contacts or acquiring knowledge, except in Model 1b. The large share of respondents with a relative short work experience could explain this, since these still keep in contact with former classmates. Contact with former colleagues is positive, but mobility only has a significant effect on having interfirm informal contacts. However, there are also differences between these two types of contacts. Approximately half of the sample is educated at the local university. This background is important for acquiring knowledge from the university through informal channels.

Table 5 Results of the logistic regression for acquiring knowledge

Variables	Interfirm					University-industry				
	Model 2a		Model 2b			Model 2c		Model 2d		
	Parameter Estimate	S.D.	Parameter Estimate	S.D.	Odds Ratio	Parameter Estimate	S.D.	Parameter Estimate	S.D.	Odds Ratio
Intercept	-0.48	0.439	-0.49***	0.150		-0.17	0.674	-0.35	0.357	
Participated in formal projects (vs. no)	0.33**	0.153	0.42**	0.146	2.30	0.62***	0.229	0.67**	0.222	3.83
Educational institution (AAU vs. other)	0.18	0.136				0.49**	0.239	0.51**	0.237	2.75
Experience	0.02	0.026				0.00	0.040			
R&D job (vs. other)	-0.20	0.149				-0.23	0.225			
Mobility rate	-0.45	0.510				-0.30	0.763			
Contact with former colleagues (vs. no)	0.35***	0.135	0.40***	0.128	2.24	0.57**	0.283	0.56**	0.278	3.09
Contact with former classmates (vs. no)	0.36**	0.148	0.32**	0.127	1.89	0.90***	0.228	0.85***	0.214	5.49
Contact with private friends (vs. no)	0.30**	0.131	0.29**	0.128	1.79	0.73***	0.228	0.75***	0.223	4.48
Observations	346		346			346		346		
Concordant	73.1		66.4			86.0		82.6		
Likelihood ratio	47.74***		40.24***			79.20***		77.53***		

Note: *: P<0.1, **: P<0.05, ***: P<0.01.

4.3 Characteristics of an engineer that acquire knowledge of high-value

Some of the respondents report that they receive knowledge of high-value from their informal social networks. The likelihood for this is investigated using value-ordered probit regression models. The results of Models 3a-d are shown in Table 6. The results are quite similar to the characteristics of acquiring knowledge in Models 2a-d. Participation in formal projects increases the likelihood of acquiring valuable knowledge for interfirm and university contacts. The contact dummies also remain significant and positive except for university contacts where contact with former colleagues is not significant. Contacts with former colleagues have the highest impact for interfirm contacts, while contact with former classmates is more important for university contacts. Experience and mobility have no significant effects for interfirm networks. Engineers who answer they have R&D as main job function have a significant and negative effect for interfirm contacts. For university-industry contacts, the engineers do not increase the likelihood of obtaining high-value knowledge by increased experience, having an R&D as main function or having higher mobility.

The education institution dummy is significant and positive for both interfirm and university-industry contacts. For the university-industry contacts, this result supports hypothesis 5 and supplements the findings from Models 1c-d and Models 2c-d. The AAU graduates are more likely to benefit from valuable knowledge acquired through informal contacts with university researches. These engineers could have a wider extent of social networks and more easily gain from it. The local educational background also proves to be an advantage when sourcing high-value knowledge through interfirm contacts. This point towards that many informal contacts are created at the university and then continued after graduation. All models are significant and have high concordant ratios.

Table 6 Results of the value-ordered probit regressions for high-value

	Interfirm				**University-industry**			
	Model 3a		Model 3b		Model 3c		Model 3d	
Variables	Parameter Estimate	S.D	Parameter Estimate	S.D	Parameter Estimate	S.D.	Parameter Estimate	S.D.
Intercept 3	-2.02***	0.260	-1.90***	0.162	-1.68***	0.375	-1.70***	0.231
Intercept 2	-0.82***	0.225	-0.71***	0.103	-0.74**	0.350	-0.78***	0.188
Intercept 1	-0.42*	0.223	-0.32***	0.098	-0.46	0.348	-0.51*	0.185
Participated in formal projects (vs. no)	0.16*	0.086	0.20**	0.083	0.34***	0.118	0.38***	0.115
Educational institution (AAU vs. other)	0.18**	0.077	0.18**	0.076	0.41***	0.127	0.42***	0.126
Experience	0.02	0.014			0.01	0.020		
R&D job (vs. other)	-0.14*	0.083	-0.17**	0.080	-0.12	0.113		
Mobility rate	-0.23	0.284			-0.20	0.408		
Contact with former colleagues (vs. no)	0.23***	0.077	0.27***	0.074	0.23	0.149	0.23	0.147
Contact with former classmates (vs. no)	0.18**	0.083	0.13	0.078	0.36***	0.120	0.33***	0.114
Contact with private friends (vs. no)	0.14*	0.074	0.13*	0.074	0.34***	0.122	0.36***	0.119
Observations	346		346		346		346	
Concordant	71.1		69.7		85.6		81.6	
Likelihood ratio	52.91***		49.36***		78.54***		76.21***	

Note: *: P<0.1, **: P<0.05, ***: P<0.01.

5 Discussion

Knowledge does not simply flow between a university and the local industry. This study shows that informal contacts between employees in different firms are more frequent in the wireless communication cluster than university-industry informal contacts. Likewise, 31% of the respondents acquire knowledge from inter-firm contacts and only 13% through university contacts. Thus, it is possible to confirm hypothesis 1 and 2. However, if the results are normalised for the number of respondents that have informal contact, the shares becomes almost equal, since the interfirm networks are more frequent. The analyses of which factors affect the likelihood of having an informal contact and acquiring knowledge revealed differences between the two types of contacts and some unexpected results.

The results of the regressions impose some uncertainty of the role of employee mobility in creating social networks. The dummies on contact with former employees are highly significant in the models on acquiring knowledge, but the mobility rate is insignificant in most of the regressions except for interfirm informal contact where it is significant and negative. Changing jobs is a type of knowledge flow, but the distinction between firm-specific and industry-specific knowledge combined with formal organisational communications structures might explain why old colleagues not necessarily becomes an important informal source of knowledge[1]. Allen's (1984) studies of communication patterns in organisations shows that employment in a company does not automatically create communication between employees and a connection can easily be broken after a job change. It should also be noted that mobility is measured as number of job changes within the cluster firms divided by experience. The respondents and their contacts are anonymous so it is not possible to explore the importance of mobility in depth. Previous joint work experience could potentially be more important in creating social networks that are used for acquiring knowledge than mobility. Then it is not the change of jobs that automatically creates an informal channel for future knowledge flows, but the experience of working together on the same project.

Working together across firm boundaries on formal projects seems to create relationships that last longer than the projects. The logistic regressions in Models 1-3 show a strong effect of formal projects, where engineers previously involved in formal projects with other firms had a higher likelihood of having informal contacts and acquiring useful knowledge through social networks. Lissoni (2001) argues that social networks can be created across firm boundaries as a result of formal cooperation between firms. Participation in formal projects has even a larger effect for university-industry contacts. Likewise, Meyer-Krahmer and Schmoch (1998) argues that university researchers like to keep in contact with firms on the

[1] Other indicators of mobility such as number of job changes, number of different workplaces, and above/under average mobility were also used in regressions but proved to be insignificant

technological forefront to obtain new knowledge. The motives for an engineer to keep in contact with engineers working in another firm or university could also be to keep the contact open for participation in future projects. Formal projects seem to be rather frequent in the cluster, since 20% of the respondents have participated in projects with other firms and 13% have participated in projects with the university. This is also caused by the high-tech character of the cluster and the existence of specialised research competences at the university. Firms in high-tech sectors are well-known to cooperate with universities more often than other firms.

Various types of contact dummies for contact with former colleagues, former classmates or personal friends prove to be important. The contact with former colleagues is more important for interfirm informal contacts, than for university-industry contacts. This could be a result of lower mobility of university researchers to industry and visa versa.

So far, the factors explaining the informal contacts and likelihood of acquiring knowledge have been quite similar for interfirm and university-industry contacts. However, the importance of educational institution differs. Being educated at Aalborg University has a positive and significant effect of having informal contacts, but not for acquiring knowledge through interfirm contacts. However, an educational background from this university was positive and significant in the university-industry regressions. Engineers that are educated from the local university are more likely to have informal contacts with researchers at the university than engineers from other non-local universities. Likewise, the locally educated engineers are more likely to acquire knowledge and also to obtain more valuable knowledge. These might have gained a better knowledge of “who knows what” at the university or have lower barriers for contacting university researchers. Another explanation is that many have formed the social networks when they were students and simply keep in contact with former classmates.

Experience is used as a control variable in the regressions. However, it has no significant impact on the likelihood of having interfirm informal contacts. It has a weak and negative effect on the likelihood of having an informal contact with university researchers with a 5% decrease in the odds for each year of experience. According to the literature, more experienced engineers should have more contacts, and be more able to acquire valuable knowledge than inexperienced engineers. However, work experience is not significant in any of the interfirm or university-industry models for acquiring knowledge and receiving high-value knowledge.

6 Conclusion

The idea of the paper was to go beyond the assumption that university research simply spills over to firms located nearby. The purpose was to investigate the university-industry knowledge flows through informal contacts and compare it to interfirm contacts.

This study shows that most engineers have informal contacts with employees working in other firms and many actually obtain useful knowledge from these sources. Some engineers also acquire knowledge they consider being of high-value in their own job. Many engineers have informal contacts with university researchers and some acquires knowledge from them. However, there are differences between extent and frequencies for the two types of informal contacts. The university-industry informal contacts are less frequent, since only 29% of the engineers have an informal contact with university employees compared to 75% for interfirm contacts. Likewise, a lower share of the engineers acquires knowledge from informal university contacts. This result contrasts the belief that knowledge sharing between firms is more likely to endanger their competitiveness compared to university-industry knowledge sharing.

The social network between employees in firms and university are also likely to consist of smaller epistemic communities that do not include all employees of the local industry. This would imply that the difference in number of employees in the cluster and the number of university researches explain some of the discrepancy in frequencies. Another explanation relates to the difference in job functions and importance of various types of knowledge. When an engineer faces a problem, he is more likely to know and contact an engineer working in a different firm in the industry than a university researcher to get help to solve the particular problem. Questions related to a particular work routine in a company can only be answered by employees with similar work routines and these are more likely to be employed in another firm than at the university.

The profile of an engineer that acquires knowledge through university informal contacts is an engineer, who is educated at the university and has previously participated in formal projects with the university and who is in contact with their former classmates at the university. Some of these sociological factors are also a part of the characteristics of an engineer that acquire knowledge from interfirm informal contacts. However, there are also some differences. The educational background is important for creating informal contacts with the university researchers and obtaining knowledge from them, while it appear to be unimportant for interfirm informal contacts.

Before agents start sharing knowledge they have to know and trust each other. Therefore, one of the common mechanisms in creating informal contacts is joint work experiences, such as working together on formal project across firm boundaries or maintaining relationships with former colleagues or classmates. These long-term relationships are also more likely to be channels of knowledge. However, the missing effects of mobility show that just because people have worked in the same company or studied at the same university, it does not automatically lead to the formation of a network connection between them. Employees obviously do not know all other employees in the firm and it is not certain that the contact between two former employees will persist after a job change.

This study has certain limitations. It shows that social networks and informal communication are diffusing knowledge between firms and between firms and university in a cluster. The respondents are anonymous, which made it impossible to create a social network analysis of informal contacts and to gain a more accurate picture of the extent of the social network. In addition, there is no time dimension that could show how these networks evolve and change over time.

Future studies should address some of these limitations and try an include performance indicators to investigate the effect of knowledge flows through social networks. In addition it is necessary to include both employees in firms and university researchers in studies and also to include questions regarding informal contacts outside the cluster.

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