Formation of research collaborations between universities and firms

Towards an integrated framework of tie formation motives, processes and experiences

by

Taran Thune

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Taran Thune

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Abstract

Recent research and innovation policies put a strong emphasis on interaction between universities and industry. University- Industry (UI) collaboration is in Norwegian policies seen as a key way to strengthening innovation in the economy, by increasing the flow of knowledge across sectors and by stimulating further R&D investments in the private sector. Closer interaction should lead to "more relevant research projects, quicker absorption of scientific knowledge in the private sector and better utilization of scientific knowledge" (NHD 2003). At the same time as a strong belief in the power of interaction is stressed in policy, research has been limited with respect to understanding the preconditions for forming R&D collaboration ties, and how such preconditions shape knowledge exchange.

Review of research on UI interaction highlights that current research has dominantly focused on interaction between firms in a few knowledge intensive industries and technological academic fields in universities where interaction is strong; like biotechnology, ICT or new materials. Based on this particular sector focus, an incentive oriented explanation is posed in the literature, where knowledge intensive firms' strategic needs for new knowledge and universities' need for additional research funding creates a situation of interdependence, which motivates them to collaborate. However, the few comparative studies that have been made suggest that interaction is concentrated in, but is not limited to interaction between R&D intensive economic sectors and technological academic fields. Rather, interaction is spread and does not follow obvious and simple patterns. This observation does not disqualify the assumption that firms' R&D intensity is a precondition for formation of ties, but indicates that there are other factors that are also relevant for understanding tie formation in this context. With this in mind, the purpose of this study is to investigate R&D collaboration in two academic fields that have a high degree of interaction but at the same time are seen as different with respect to relevance for industrial innovation – material science/chemistry and economic/administrative science. Different sources of qualitative data were collected, documents, interviews and field observations, and subjected to analysis utilizing a template analysis framework.

The analysis indicates that tie formation behavior can be understood in terms of two dimensions – interdependence and network embeddedness. The two dimensions are related, but which focus is most central, seems to be specific to particular formation processes. Due to this, a typology categorizing four

different tie formation processes was identified: created, needs driven, opportunity driven and interdependence driven formation processes.

The analysis also indicates that there is a relationship between how collaborative research projects are formed and how interaction in these projects is experienced. Collaborative R&D projects formed based on personal contacts are experienced as more positive and with stronger expectancy of further continuation. How central the R&D collaboration is for the firm, as reflected in its motives and commitment, also seem to have a clear relation to interaction experiences. Collaborative research projects formed based on both previous contact and experienced need, are experienced as more positive overall. Projects that have been established only with previous contact or strategic need are seen as less positive and with less expectation of continuance. Different challenges associated with different formation processes are also outlined.

The central finding in the study is that the interdependence perspective, focusing on strategic needs for resources, cannot fully explain why R&D collaboration between universities and firms emerge. But by also looking at the opportunities available by being embedded in knowledge networks, we can make fuller sense of why universities and firms form ties, how they do it, and the processes and challenges involved. This has implications for research on UI interaction, which largely has overlooked the opportunities and resources involved in tie formation in this context, as well as process perspectives on UI interaction. It also has implications for research and innovation policies that have not taken account of the different resources needed to form ties and carry out knowledge interaction between firms and universities.

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Oslo, October 10th 2006
Taran Thune

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List of abbreviations

EU	European Union
ICT	Information and Communication Technologies
KBM	Kompetanseprosjekter med Brukermedvirkining [Competence projects with user participation]
NFR	Norges Forskningsråd [Norwegian Research Council]
NHD	Nærings- og Handelsdepartementet [Ministry of trade and industry]
NOU	Norsk Offentlig Utredning [Official Norwegian report or 'green paper']
NTH	Norges Tekniske Høyskole [Norwegian Institute of Technology]
NTNU	Norges Teknologiske og Naturvitenskapelige Universitet [Norwegian University of Science and Technology]
OECD	Organization for Economic Co-operation and Development
Ot.Prop	Odelstingsproposisjon [propositions for new laws and law amendments]
R&D	Research and development
SME	Small and Medium sized Enterprises
SSB	Statistisk Sentralbyrå [Statistics Norway]
St.Meld	Stortingsmelding [White paper]
TBL	Teknologibedriftenes Landsforening [Federation of Norwegian Industry]
TTO	Technology Transfer Office
UFD	Utdannings- og Forskningsdepartementet [Ministry of Education and Research]
UI	University-Industry
UIO	Universitetet i Oslo [University of Oslo]

Chapter 1: Introduction

1.1 Research problem and purpose

Strengthening interactions between industry and research institutions like universities, colleges and research institutes have over the last years increasingly been seen as a strategic instrument for regional and national innovation, economic growth and competitiveness. The most recent Norwegian innovation and research policies strongly emphasize interaction and cooperation between firms and universities as a key public policy for fostering innovation in the Norwegian economy. Closer interaction should lead to "more relevant research projects, quicker absorption of scientific knowledge in the private sector and better utilization of scientific knowledge" (NHD 2003, p. 30, trans.). University-industry interaction is emphasized as a tool for stimulating research and development (R&D) capacity building in Norwegian firms, and thereby increasing the investments in R&D, as well as a tool for making higher education and research more relevant and responsive to industry's needs. This policy thrust is in line with the overall policy vision of becoming an internationally leading knowledge nation in the global knowledge-based economy (NHD 2003). This focus is supported through several new policies and laws, a number of programs for increasing cooperation and mobility, as well as financial incentives and tax regulations (St.meld. No. 20, 2004-2005, NHD 2005). But even though interaction between the private sector and research institutions has increased as a result of these initiatives, the government continues to emphasize that there is "too little flow of people and knowledge between universities, colleges and institutes, and the private sector" (St.meld. No. 20 2004-2005, p. 103, trans.) The Norwegian emphasis on cooperation for innovation mirrors international innovation policies, which for the last ten years have focused on stimulating closer interaction between research institutions and industry (Bozeman 2000). Such policies are based on a systems perspective of innovation highlighting interaction between agents and institutions as the driving force of innovation (Remø 2004, Lundvall 1992, Edquist 1997). Like the Norwegian policy, EU innovation policy emphasizes collaboration and creating networks between research institutions and industry, supported by public agencies and initiatives (NHD 2005, p.23). Thus, there seems to be an emerging consensus amongst policy makers that with respect to innovation "networks are good, more networks are better" (Freel 2003, p. 766)

At the same time as a strong belief in the "power of interaction" is stressed in policy, current research has been limited on relevant issues like - what are the preconditions for forming R&D collaboration ties, and do the preconditions shape knowledge interaction and transfer? Answers to questions like these are relevant for understanding if it really is possible, and under what conditions, fostering closer interaction between firms and universities might occur. In light of this, the research problem addressed in this thesis can broadly be defined this way: *How can we understand formation of research collaborations between firms and universities?*

A review of published research on university – industry interaction indicates that research in this area has tended to focus on interaction between a few technological science fields and a few industrial sectors, referred to as science based industries (Pavitt 1984), such as biotechnology, ICT, new materials, chemical and pharmaceutical industries (Meyer-Krahmer & Schmoch 1998, Faulkner & Senker 1995, Rappert, Webster & Charles 1999, Cohen, Nelson & Walsh 2003). In these sectors university – industry interactions are common, and scientific knowledge is seen as core to their development. Based on this particular sector focus, an incentive oriented explanation for tie formation is often posed in the literature (Bonaccorsi & Piccaluga 1994, Geisler 1995). A basic argument in research on university – industry interaction is that firms in industries that are knowledge intensive and require R&D input in production are motivated to interact with universities (and other R&D producing institutions). Tie formation behavior in the form of collaborations with universities is seen as a rational response to their dependence on R&D producing institutions. However, the few comparative studies that have been made suggest that interaction is concentrated in, but is not limited to interaction between knowledge intensive economic sectors and technological knowledge fields. Rather, interaction is spread and do not follow obvious and simple patterns (Meyer-Krahmer & Schmoch 1998, Schartinger et al 2002).

On part of universities, resource dependence due to decreasing public funding for research is often used as an argument in the literature to explain why universities are motivated to interact with industry, as to gain access to additional resources in light of decreasing public funding for science and new public funding mechanisms (Carayol 2003, Mora-Valentin 2000, Bozeman 2000). However, research has shown that resource dependence cannot explain why there is a high degree of concentration of both public and private funding in certain departments and research groups, indicating that the departments and groups that already enjoy most public support also receive the most private funding for research (Slaughter & Leslie 1997). These observations do not disqualify the assumption that dependence is a

precondition for formation of interaction ties, but indicates that there might be other factors that are also relevant for understanding tie formation between universities and industry.

In research on university – industry relations there has been little focus on the process through which formal arrangements emerge and develop, even though this might give new knowledge for understanding knowledge interaction. Schartinger et al (2002) analyze determinants of interaction and find that graduate mobility as a measure of "knowledge proximity" between university departments and firms explain the formation of ties - entailing that knowledge fields/economic sector dyads that have shared human capital also have established links and resources that are needed to form new relationships. Other mobility data point in the same direction (Gulbrandsen & Larsen 2000). This indicates that there is a relationship between informal ties and the formation of formal collaborative arrangements between firms and research institutions. The exploration of the process of forming research collaborations is the main focus in this study.

In light of recent research and innovation policies' strong focus on interaction, and the dominant incentive oriented explanations in current research, this thesis aims at making a contribution to the research literature on university – industry interaction by focusing on formation of knowledge interaction ties. Taking a micro perspective on knowledge interaction, this project explores how formal collaborative relationships between firms and university-based research environments emerge and develop, focusing on the three following research questions:

- How are collaborative R&D projects formed?
- Why are collaborative R&D projects formed?
- How do researchers experience interaction with firms in collaborative R&D projects?

The overall problem statement and the research questions will be addressed by a review of published research on university-industry relationships, knowledge exchange and formation of interorganizational relationships, by analysis of recent research and innovation policies and available statistical data in Norway, and by a qualitative study of university-industry collaboration in two academic fields. Before introducing the theoretical and methodological framework of the study, a presentation of the most central concepts and how they are used in this thesis is provided.

- *University – industry interaction* here means, "all types of direct and indirect, personal and non-personal interactions between organizations and/or individuals from the firm side and the university side, directed

at the exchange of knowledge within innovation processes" (Schartinger et al 2002, p. 304).

- The concepts *university* and *industry* are used throughout the thesis. A more accurate phrasing could be 'universities and colleges', and 'business and industry', as the relationships in question do not only concern traditional universities and industrial firms. The labels university and industry was chosen to simplify and these labels were chosen since they are commonly used in the research literature.

- *Collaborative projects* here entail a particular type of knowledge interactions between universities and industry. The interaction is organized as a joint research and development project, and there is direct interaction between firm and university side during the project period, although the work is usually distributed. The interaction is formal in the sense that a formal contract between the parties exists.

- *Tie formation* here means processes leading up to and activities undertaken by agents (individual or organizational) from the firm side and/or the university side aimed at initiating and establishing a formal R&D collaboration project.

- *Knowledge network* means social and cognitive ties between agents (individual or organizational) from the firm side and the university side established prior to forming a collaborative R&D project. Such ties are seen as both a source of opportunities as well as resources needed to form ties and carry out interaction.

- *Tie formation motive* means some expected benefit assumed to be realized through forming a tie, which acts as a motivation or inducement for firms and universities to enter R&D collaboration projects.

- *Exchange experiences* means how parties involved in a collaboration project experience the activities and processes intended to stimulate exchange of knowledge.

With these conceptual building blocks defined, the conceptual framework and the theoretical perspectives on which it is built will be presented.

1.2 Theoretical perspectives

The purpose of this study is to explore how formal collaborative relations between universities and firms are formed and experienced, and through that, to contribute to broadening the understanding of the preconditions for tie formation in the university-industry context. With this problem definition in mind, a secondary aim of this thesis is to draw together knowledge-, network- and incentive-oriented analyses of knowledge interaction. Based on this, the aim is to develop a conceptual framework that integrates these perspectives.

In interorganizational research, there are two main theoretical arguments that explain tie formation (Ahuja 2000, Gulati 1995, Gulati & Gargiulo 1999). The first concerns an incentive-oriented explanation focusing on the inducements organizations have for forming collaborative relationships (Oliver 1990). The argument states that forces in the external environment of organizations trigger them to seek partnerships. Linkage formation is seen as a way of coping with environmental interdependence. "Interdependence exists whenever one actor does not entirely control all of the conditions necessary for the achievement of an action or for obtaining the outcome desired from the action" (Pfeffer & Salancik 1978, p. 40). Interdependence creates uncertainty, which motivates organizations to form ties with others as a way of manage their dependence and reduce uncertainty (Gulati & Gargiulo 1999).

The other main approach for explaining formation of interorganizational ties focuses on the opportunities and resources agents have for forming collaborative relationships, rather than their incentives for doing so. This approach focuses on the opportunities a focal actor has for forming ties to other organizations in their environment. Rather than asking the question of why organizations want to form relationships, the focus here is on *how* agents form ties and *with whom* they form ties. Tie formation is here explained with reference to the social structure in which the organizations are embedded (Ahuja 2000, Gulati 1995, Gulati & Gargiulo 1999, Uzzi 1997). This perspective focuses on with whom organizations ally, and through that explaining why and how relationships are formed. The structure of the social network and the resources available through that network are central for understanding relationship formation. Such resources are seen as social capital or "the sum of the actual and potential resources embedded within, available through, and derived from the network of relationships possessed by an individual or social unit. Social capital thus comprises both the network and the assets that may be mobilized through that network" (Nahapiet & Ghosal 1998, p. 243).

Prior established relationships form a repository of information, opportunities and resources. Organizations that are successful in establishing new relationships have access to potential partners, information and resources. Those that lack such network resources are in a weaker position to form ties. According to theory, organizations' weak and strong ties to other organizations are a precondition for new relationship formation. The opportunity argument explains the propensity for interaction by reference to the previous direct and indirect ties and the structural, relational and cognitive resources stemming from those relationships.

In addition to these two broad frameworks for explaining tie formation, knowledge-oriented analyses of relationships and exchange are seen as central, since university – industry interactions are intended to transfer and exchange knowledge (Schartinger et al 2002). In terms of the resources needed to form ties between universities and firms with the aim of transferring knowledge, cognitive resources are seen as particularly important (Cohen & Levinthal 1990, Nooteboom 1999, 2002). In recent innovation theory, knowledge is seen as tacit and situated, and transfer requires complex forms of communication and sustained interaction between participants (von Hipple 1994, Zander & Kogut 1995, Simonin 1999, Amesse & Cohendet 2001). If transfer of knowledge requires active interaction between the parties, then the agents' ability to share and absorb knowledge is central. This ability is based on previous experience. This is a basic insight taken from cognitive science: to learn something new you must utilize what you already know to provide interpretation and context for new sensory data. The same basic idea is used on the organizational level of analysis in the absorptive capacity theory (Cohen & Levinthal 1990): Firms' ability to absorb knowledge developed externally depends on their own internal R&D (knowledge generation) capabilities. If this insight is true, then the similarity in knowledge repertoire between participants (homophily) will influence the knowledge transfer process positively (Nooteboom 1999, Hansen 1999). This repertoire, Nooteboom (1999) claims, develops in a shared environment and in mutual interaction.

The principle of homophily, in its several expressions (Rogers & Bhowmik 1970, Granovetter 1973, Cohen & Levinthal 1990, Nooteboom 1999, 2002), underscores the point that transfer of knowledge requires some degree of similarity between participants. But at the same time, since innovation processes concern use of novel knowledge, they require a balance between similarity and difference. Stated differently, they require a cognitive distance small enough to allow for understanding and absorption, but large enough to yield non-redundant knowledge (Nooteboom 1999, Hansen 1999). In terms of formation of ties, this focus suggests that when relationships are entered

into with the purpose of transferring knowledge, some degree of similarity but not overlap in cognitive capacity is a precondition for tie formation and exchange.

The theoretical approaches have different foci in explaining tie formation, focusing on incentives, opportunities and cognitive resources. Ahuja (2000) and Gulati (1995) claim that these perspectives provide insight into linkage formation behavior, but neither provides a complete picture. The strategic needs or incentives perspective assumes that the availability of alliance partners is not constrained, which, according to Ahuja (2000), is a debatable assumption. The opportunity perspective on the other hand, explains linkage formation by reference to participation in prior established networks. This perspective has a limitation with respect to explaining how new actors form ties, since they lack the network resources needed to form relationships. Ahuja (2000) claims that the perspectives can be usefully integrated, focusing on both the actors' inducements to collaborate and their opportunities to do so. In addition, since such ties are intended to transfer knowledge requiring some degree of common understanding and resources, the role of cognitive resources in tie formation and exchange will be explored.

1.3 Conceptual framework

To guide the empirical investigation of tie formation between universities and firms, a conceptual framework was developed indicating the main conceptual foci in the study and assumptions about their relations. Miles and Huberman (1994) claim that a conceptual framework is a formulation of a tentative theory of what the researcher thinks is going on and why. As the study progresses, the conceptual framework gets modified as the researcher learns more about what is going on in the field. "Conceptual frameworks are simply the current version of the researcher's map of the territory being investigated" (Miles & Huberman 1994, p. 20). A detailed presentation and discussion about the conceptual framework is found in the end of chapter 3.

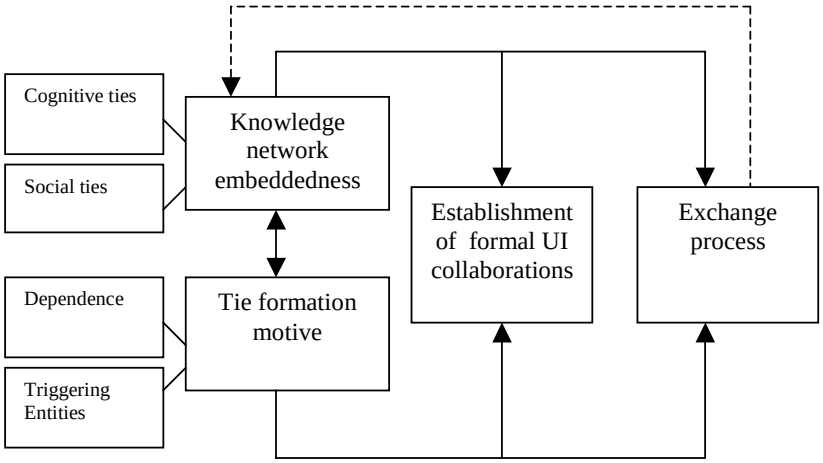

Figure 1: Conceptual framework of study

Knowledge network is the concept developed in this study as a label for the cognitive and social ties between universities and industries, forming a structure in which collaborators are embedded. Access to potential collaborators, relational resources and a common cognitive repertoire are seen as resources for formation of new ties intended to exchange knowledge. A central focus in this thesis is that knowledge networks, in terms of social and cognitive ties between an academic field and an industrial sector, act as a precondition for the formation of formal collaborative arrangements between universities and firms. These links provide both a structure of opportunities and equip potential collaborators with resources needed to create a formal relationship.

Where knowledge networks act as structures of opportunities and resources enabling formation of ties, to enter into formal collaborative arrangements, universities and firms also have motives that act as inducements for tie formation. Dependence on other organizations for resources creates instability, and organizations enter into alliances as a way of coping or managing their interdependence. On the part of industries and firms, a general knowledge intensity argument is a central explanation. Firms and industries that are dependent on scientific knowledge are motivated to form ties to external scientific environments, like universities, governmental R&D labs, etc who have those resources. On the university side, the resource dependence argument is equally widespread. University departments and research groups form ties with firms because it gives them access to more

research money and equipment. In addition, triggering entities or agencies motivating universities and firms to create ties are seen as relevant, as universities and firms alike might be dependent on public agencies.

Further, both knowledge transfer theory and social capital theory assumes that knowledge networks will shape the experiences in collaborating, by providing a new tie with cognitive and social resources needed for knowledge exchange. As will be discussed in chapter three, the participants' ability to exchange knowledge is related to their previous knowledge capability, which is also seen as a product of previous social interaction. The implication of this viewpoint is that participants' who have a common cognitive repertoire are more likely to experience positive knowledge exchange processes. Also, social capital theory suggests that relational social capital resources, such as trust and norms of reciprocity stemming from previous interaction, facilitate positive exchange experiences. The framework assumes that these ties shape the explication of motivations by the agents, leading to the establishment of formal cooperative arrangements, as well as the experiences the partners have in collaborating. Furthermore, positive experiences in the collaboration act to reinforce the network embeddedness between the partners, which increases the likelihood in further cooperation between the participants.

As will be discussed in the methodology chapter, this framework is not a theoretical model and the assumptions built into it do not have the status of hypotheses to be tested. Rather, the framework is intended as a sensitizing tool (Blumer 1954). This framework was developed through the interaction between data and theory, and where the ambition was to develop a theoretically informed and empirically grounded framework for understanding how universities and firms form ties and interact.

1.4 Research strategy and methodological framework

The focus in this thesis was not developed out of an interest in a specific theory or methodology. Rather, a pragmatist perspective on social science has guided the research process, where understanding a particular social problem provided the focus and rationale for the research project, as well as the foundation for the theoretical and methodological choices made. Pragmatist perspectives in social science focus on specific problems as the starting point for research, see the social world as complex and changing, and refute the quest for foundations both objective or subjective (Cresswell 2003, Baert 2005, Tashakkori & Teddlie 1998). As an epistemological position, pragmatism is critical to the representionalist idea of social

research. Rather than seeing research as accurate portrayal of reality, pragmatists believe that researchers' frames of reference influence their representations, and therefore "conceive presuppositions as *sine qua non* to any form of inquiry" (Baert 2005, p. 152). The methodological consequence of these ontological and epistemological views, is that different perspectives and methodologies enriche knowledge construction (Tashakkori & Teddlie 1998, 2003, Cresswell 2003, Patton 2002). Further, pragmatists argue that the question of relevant methodologies must be seen in relation to the purpose of the research.

For the purpose of exploring formation of research collaborations, a qualitative study focusing on how collaborations were formed and experienced by respondents in two different academic fields was chosen as a relevant research strategy.

The reason for this focus is as follows: If dependence stemming from need for resources is the central precondition for tie formation, then it could be assumed that the experiences of forming ties in academic fields that to different degrees are relevant for industrial innovation would be different. With this as a starting point, this project aimed at exploring formation of collaborative ties in academic fields that have some degree of interaction with firms, but could be described as different with respect to relevance for industrial innovation. The idea was to explore tie formation processes in these two different settings, and whether the experiences were similar or different. If they were similar, then it could be further explored if the similar experiences were related to another common precondition relevant for understanding tie formation. This research strategy is inspired by a "most different case" design logic (Andersen 1997, Eisenhardt 1989, Schofield 2002), which focuses on exploring theoretical relationships, and through a theoretical selection of cases aims at maximizing differences in relevant contextual variables.

The concept 'academic field' is used throughout this thesis, rather than subject fields, knowledge fields, disciplines or related words, as a concept for the organization of academic knowledge, or the organization of research, scholarship and education in universities and colleges. An academic field is both a cognitive field and a social structure (Smeby 2001). They concern specialized subject fields but not necessarily 'disciplinary' as knowledge production increasing is inter- and transdisplinary (Gibbons et al 1994). With respect to the organization of scientific knowledge, there are several different taxonomies. A basic division of academic fields categorizes fields as soft and hard, and applied and pure (Biglan 1973, Becher & Trowler 2001). Moreover, academic fields need not be overlapping with institutionalized structures like institutes and departments (Smeby 2001).

In terms of selection, the aim was to select academic field settings that could be described as different with respect to relevance for industrial innovation. The empirical focus is however not on the industry side, but rather on firms' inducements for interacting with research institutions. And there exist statistical data and research publications on what firms report to be the most significant and relevant academic fields in the course of innovation (Faulkner & Senker 1995, Schartinger et al 2002, Cohen, Nelson & Walsh 2003, NFR 2005b). So in order to select academic fields, literature on interaction between universities and industries was reviewed. This was followed by interviews with experts on UI interaction and key informant interviews, as to gain more information about the Norwegian situation. Based on this input, two academic fields – chemistry/material sciences and economics/ administrative sciences were selected for further investigation. Both fields are applied and interdisciplinary, but in Biglan's (1973) classification, one is from the hard sciences and the other from the soft sciences.

The two contexts are selected since there is a, comparatively speaking, high degree of interaction in both fields (Schartinger et al 2002). But where one of the fields is reported as highly relevant for industrial innovation, the relevance of economic/administrative sciences for firm innovation is less clear. This is reflected in both firms' assessment of importance for industrial innovation (Cohen, Nelson & Walsh 2003) and in the type of links used to interact (Schartinger et al 2002). Consequently the two academic fields are interesting as settings for exploring R&D collaborations comparatively.

Based in a pragmatist epistemology, the overall purpose of this study is to improve the understanding of a particular social phenomenon – tie formation between firms and universities. To generate new knowledge intended to improve current conceptualizations, the interplay between theory and observation is central. Approaches that highlight interplay between theories and data as the core process of constructing representations and explanations of social phenomena, is by Ragin (1994) referred to as "retroductive". The interplay or dialogue between ideas and evidence is carried out through the development of "analytical frames" based on theories and "images" based on empirical evidence. In terms of developing images from empirical data, theoretical sampling, systematic coding, and constant comparison are tools from the grounded theory approach (Glaser & Strauss 1967, Strauss & Corbin 1998), which enable a systematic collection and analysis of empirical data.

In this study, different types of data were collected; documents, available statistical data, interviews and field observations. The two first types of data were mainly collected in the early phase of the research process. Semi-

structured interviews were used in the focused phase of the data collection, where researchers and R&D managers that had concrete experiences with UI interaction through involvement in concrete collaborative R&D projects were interviewed. In addition, field observation of meetings between academic researchers and representatives of firms was carried out.

Focusing on the retroductive logic of developing representations of social phenomena, a template analysis approach was implemented (Crabtree & Miller 1999; King 2004, 2005), which utilizes coding procedures from grounded theory, but where the interplay between theory and data is made an explicit part of the analysis process. Template analysis focuses on interplay between the researcher and the data, and sees the creation of a preliminary coding template as a way of making explicit the frames that the researcher approaches data analysis with, and that this should be done prior to indexing and coding segments of data. The qualitative data analysis software QSR N6 (Nu*dist) was utilized in the data analysis process. Several retroductive loops occurred during the analysis process. The coding of text and revising of coding template process unfolded through several rounds of interfacing. The initial assumptions were used as a basis for coding but the empirical data substantially refined the coding and re-conceptualization process. After many rounds of data reduction, display and comparisons, a coherent and refined image, both grounded in the data and consistent with the analytic frame, was developed. The main result in the study – a matrix showing tie formation processes by combinations of preconditions (a typology of four types of tie formation processes and interaction experiences associated with different types of formation processes) – can only be described as the result of a continuous dialogue between data and theory, through which the representation of tie formation behavior has developed.

1.5 Contributions and limitations

The purpose of this study is to improve present conceptualizations and suggest new perspectives of relevance to understanding collaborative relationships in the UI context, and to suggest new areas where further research is needed. This study seeks to make some contributions to the research literature on UI interaction, and it is within this particular research context the contributions and limitations of this thesis are discussed.

The research literature that has addressed university – industry interaction[1] has been fragmented and data driven (Slaughter & Rhoads 2004), and there

[1] As will be reviewed in chapter two

have been few integrating analytical frameworks that characterize central dimensions of university-industry interaction as a social phenomenon. Thus, in terms of theoretical contributions, the ambition of this study is to sort out and discuss relevant theoretical dimensions, through the combination of theoretical analysis and empirical investigation. As such, the study aims at contributing to the research literature on UI relations by clarifying central theoretical dimensions and by connecting this topic to the broader literature on interorganizational relationships and exchange of knowledge.

In general, there is a lack of micro level data on university-industry interaction (Gulbrandsen 2003). Specifically, there is a lack of knowledge about how interaction between firms and universities is actually carried out – that is, the processes of forming, developing and carrying out knowledge interaction. Due to this, more micro level data on knowledge interaction is required, and qualitative data might be particularly suitable, because the present understanding of the "micro cosmos" of knowledge interaction is poorly understood. In light of this, a second contribution of this study this study is to generate micro-level data about interaction processes with collaborative R&D projects as an analytical focus. Mora-Valentin, Montoro-Sanches & Guerras-Martin (2004) highlight this as a promising approach for further investigation of UI relationships.

In terms of methodological contributions, this study seeks to explore similarities by focusing on formal R&D collaboration projects in two academic fields that were assumed to be different in terms of relevance for industrial innovation. Since this has not been done in previous research, a contribution of this thesis is to focus on similarities through theoretical sampling and exploration of different cases. Focusing of what is similar across diverse contexts can improve conceptualizations because it enables a clearer focus on key properties. In addition to a theoretically informed research strategy, it has been a deliberate attempt in this study to make transparent many elements of the qualitative research process, with the purpose of increasing reflexivity and auditability. The template analysis framework as developed here is seen as a contribution towards making qualitative analysis strategies more transparent.

On the other hand, this study has several limitations, reflecting the choices made during the course of investigation both in terms of empirical focus, theoretical perspectives as well as methodological choices. First of all, this study focuses on exploring project formation processes as experienced mainly by researchers. This represents a limited perspective on interaction processes in two ways – it targets only one phase in the UI interaction process and has mainly emphasized the experiences and perceptions of one group of actors. To ensure more stakeholders' perspectives, field

observations and informal interviews with industrial actors were carried out. However, this represents a weakness and this is particularly visible in chapter 6 focusing on firm incentives and motives *as perceived* by the researchers. Also, this study has not been able to follow collaborative projects over time.

Qualitative exploration, utilizing different sources of data that are systematically analyzed, is time and resource demanding. And since a theoretically informed comparison was a central focus, going in depth in all cases was not feasible. Due to this necessary trade-off, the focus here is on understanding similarities, whilst downplaying the unique and not providing a lot of richness and detail in descriptions of the sites and observations. Consequently, some might question why a qualitative and exploratory approach was chosen. But since the motivation in this study is to understand micro-dynamism in knowledge interaction processes, a qualitative study was seen as highly relevant, as it enabled exploration of the largely informal nature of knowledge interaction.

This study is a small empirical study of collaboration projects in two academic fields, in three institutions, in one small country. Consequently, the question of whether the results from this study is relevant for understanding tie formation in other academic fields, institutions and countries can be posed. But this is not the aim of this study as such. This thesis is primarily a discussion of some propositions, with the aim of suggesting a conceptual framework on the connections between motives, resources and experiences related to tie formation between firms and universities. The framework, which is an outcome of theoretical and empirical exploration, needs to be investigated and subjected to testing in further research. Due to this, several avenues of further research is suggested in the last chapter of the thesis.

1.6 Thesis outline

As a point of departure and further introduction to university – industry interaction as a field of investigation, the second chapter in this thesis presents a systematic review of the research literature on university – industry ties focusing on agents and their characteristics, interaction forms, interaction processes and performance. The review forms a baseline and a context of justification for the theoretical and empirical foci chosen in this study. In chapter 3, the theoretical framework is presented, in which three perspectives on tie formation is explored. In the last section of this chapter, the analytical framework, based on an integration of the theoretical perspectives, is presented and discussed.

Chapter 4 presents the methodological framework of the study, providing description and discussion of the epistemological perspective, the research strategy and methodology, the methods of data collection and analysis, and the quality measures implemented in this study.

Chapters 5 to 9 are the data description and analysis part of the thesis. Chapter 5 presents documentary material and statistical data on university – industry interaction in the Norwegian context. Chapters 6 to 8 present data mainly from an interview study with respondents involved in collaborative R&D projects as well as some field observation and documentary data. Chapter 6 explores the perceived motivations and inducements for forming ties. Chapter 7 explores the process of forming ties and chapter 8 investigates researchers' interaction experiences. Chapter 9 provides a comparison of the two academic field contexts on the conceptual focus areas developed in the analysis, as well as a synthesis highlighting relationships between central concepts.

In chapter 10, the findings are discussed in light of the analytical framework, the documentary and statistical data, and in light of related research literature. A discussion of contributions made in the study, as well as the implications that can be drawn from the study, in terms of policy implications and issues for further research, are addressed in chapter 11.

Chapter 2: University – industry interaction – a review of literature

2.1 Introduction

For the last years interaction between research institutions, like universities, and firms has become a significant area of policy, as governments have sought to strengthen the degree of innovation in constituent economies, and where universities have been regarded as sources of economically useful knowledge. Policy makers, such as national governments, the OECD and EU, increasingly see knowledge as the core resource of modern economies and central for global competitiveness. The knowledge economy thesis, central in today's policies, states that the main source of productivity and competitiveness in modern economies is knowledge, both as an input, but increasingly as production itself (Castells 1996). This is seen related to the growth of the service sector over industrial production and in the efforts to restructure industrial production to become more innovative. The restructuring of production and work, have led several social scientists to conceptualize contemporary western countries as knowledge societies (Stehr 1994) or post-industrial societies (Bell 1976). Regardless of the configurations knowledge societies take, knowledge-based economic growth is seen as dependent upon production, dissemination, reconfiguring and use of knowledge. Knowledge in this regard is seen as both scientific knowledge as well as know-how, or competence vested in nations' and firms' human capital (Gibbons et al 1994). To strengthen both scientific knowledge and general competence, policy makers are increasingly redefining higher education and research policies to cater for knowledge based economic growth. Thus within the knowledge economy, the university takes center stage in economic and industrial policy. In the words of Castells (1994, p.16): "If knowledge is the electricity of the new informational-international economy, then the institutions of higher education are the power sources on which the new development process must rely".

The triple helix model of university – industry – government relations (Etzkowitz & Leydesdorrf 1997; 2000) is a model that attempts to explain dynamics in knowledge-based economies, focusing on the expanded role of knowledge in society and the role of the university. Focus is put on the increasingly interwoven relations between universities, industry and governments in the knowledge economy. According to Leydesdorff and Etzkowitz, the knowledge economy spurs this development, as it becomes a

common goal for government, industry and the university to promote innovation, in which science based knowledge is central. To promote developments of knowledge infrastructures and innovation systems, all institutional sectors are involved in stimulating creation and dissemination of new knowledge. With such a common goal, the three spheres are beginning to take the role of the other (Leydesdorff & Etzkowitz 2001). Thus, universities are beginning to act like firms by capitalizing knowledge and starting up new commercial entities; firms are beginning to act like universities by investing in research laboratories and corporate universities; and the government is assuming a role as industry in supporting development of industry relevant research, and technology transfer to industry.

University-industry interaction has also during last years become an increasing area of attention for researchers. Studies range from descriptive to explanatory, focusing on a number of different variables and analytic frameworks to account for university - industry interaction as an empirical and theoretical phenomenon. University-industry collaboration as a topic of research has been investigated using a number of theoretical and methodological approaches and from various academic fields; particularly science policy, science and technology studies, innovation studies, technology management studies as well as inter-organizational and network approaches. But also higher education studies and education policy research have focused on university-industry interaction. Most published research is found within science policy studies (published in international journals like *Science and Public Policy* and *Research Policy*). According to Slaughter & Rhoades (2004), due to the interdisciplinary treatment of the topic the literature is fragmented, as the different approaches do not necessarily 'communicate'. Also a part of the research on UI collaboration focuses on these relationships as such. Others see these relationships as cases of theoretical relationships that have generality outside this specific context. In terms of the latter, UI relations have been studied empirically for development and testing of theories of inter-organizational relations, inter-organizational learning, knowledge diffusion, innovation and economic growth. This is not the focus in this literature review. Rather, the ambition here is to review published literature that focuses on describing, exploring and explaining collaborative relationships between firms and universities.

Searching, collecting and reviewing research literature in a systematic and comprehensive manner was a complex task due to two factors. First, because of the interdisciplinary treatment of the topic, there is not one common indexing of journal articles on this topic. There is a high degree of complexity in the literature, and several labels for the phenomenon university – industry relationships are used. This meant that literature search

strategies utilizing database searches did not yield a complete overview of the research field[2]. So in addition to database search, a review of titles and abstracts of all articles published the last years in selected journals[3] was carried out.

The aim of this chapter is to provide a review of research on university – industry interaction, to provide a backdrop for the specific research focus in this study. The aim is to describe main trends in the literature, and emphasis is given to analytical frameworks and variables, rather than research results in themselves. This will be followed by a discussion of potential deficiencies in the existing body of knowledge of university- industry relations, and in light of these, to propose new research questions. The literature will be systematized thematically by using the conceptualization of UI interaction as introduced in the introductory chapter: Activities where agents (individual or organizational) from the firm side and the university side interact (directly or indirectly, personal and non-personal) and where the aim is to exchange knowledge (Schartinger et al 2002). The three following questions structure the review:

- Who is engaging in university – industry interaction, and what are their characteristics and motivations to interact?
- How do universities and firms interact in terms of activities and exchange processes?
- How has outcomes and performance been conceptualized in the UI literature?

[2] The databases ERIC, ISI Web of science and ECO First Search were accessed and searched for all articles utilizing the following strings: Industry AND university, Industry AND university AND relations, collaboration AND industry AND university, collaboration AND firms AND universities.

[3] Titles and abstracts of all numbers of following journals were searched from 1995 to 2002: Research Policy, Science, Technology and Human Values, Technological Forecasting and Social Change, Technovation, R&D management, Industrial and Corporate Change, International Journal of Technology Management, Science and Public Policy, Journal of Higher Education, the Review of higher education and Minerva. The majority of this review was carried out whilst visiting Stanford University, which gave me access to four separate research libraries: the social science library, and the libraries at the school of education and business school and the engineering library. Due to this access, a broad interdisplinary review was possible. The journals Research Policy, Science and Public Policy, and Industry & Higher Education were also reviewed from 2002 to 2006. The selection of journals was made based on primary database searches that indicated the journals that most frequently had published on the topic, but the selction was also supported by reading previous literature reviews (Mora-Valentin 2002).

Most of the published research focuses on the first of these questions, with a second cluster around describing interaction activities. In proportion, little research has been carried out on interaction processes, and literature focusing on performance is relatively scarce. In this chapter, the focus is on systematizing and analyzing what has been seen as central foci in previous research on UI relations. In the last section of the chapter, this will be discussed as a context for the choice of research focus and research questions made in this study.

2.2 Agents in university – industry interaction

Research on who the agents are, or who interacts in UI collaborations, reflects the varied levels of analysis in research on university industry interaction. Literature on university – industry relations has focused on individuals (Etzkowitz 2000, Owen-Smith and Powell 2001, Gulbrandsen & Larsen 2000), organizations (Vedovello 1997, Bonaccorsi & Piccaluga 1994, Waagø 2001) and on national and sectoral systems of interaction (Etzkowitz & Leydesdorrf 1997, Schartinger et al 2002; Meyer-Krahmer & Schmoch 1998; Rappert, Webster & Charles 1999; Faulkner & Senker 1995). Due to this multi-level mode of analysis, the question of agents and their characteristics will be addressed reflecting these different levels.

Since university – industry interaction has been seen in terms of science-technology dynamics in specific fields, the propensity for interaction and explanations for why university – industry collaborations emerge, frequently centers on characteristics of the agents themselves. However, this is particularly so when explaining why firms interact with universities, referred to as the "propensity for interaction" (Faulkner & Senker 1995; Vedovello 1997). Moreover, characteristics of the agents are also used to explain variety in the intensity of interaction and channels used for interaction (Schartinger et al 2002; Faulkner & Senker 1995; Rappert, Webster & Charles1999; Santoro & Chakrabarti 2002). What factors have been suggested for explaining the propensity for interaction? Again, the literature explains this at varying levels of analysis (Faulkner & Senker 1995). One can distinguish between industrial and firm characteristics on the "firm side", and institutional, disciplinary and individual characteristics on the "university side". In addition, and related to these levels, technology related factors are seen as explanatory variables, that interact with these characteristics. The following table presents the review of variables that are seen as affecting propensity for interaction.

Table 1: Variables for propensity for university – industry interaction

Levels of analysis	Concepts/variables
Industrial sector	Knowledge intensity Knowledge proximity Size Maturity
Firm	Knowledge intensity Size Technology centrality Geographic proximity
University	Resource dependency Policy regime Entrepreneurial norms
Discipline	Prestige Market potential Size Visibility Knowledge proximity

Details about the variables and concepts seen to affect the propensity for interaction is addressed in the in the text below, first focusing on the industry and firm side, and then on the university side.

2.2.1 Industry characteristics

Empirical research on university – industry interaction by and large focuses on interaction in a few industrial sectors, usually referred to as science-based industries (Faulkner & Senker 1995; Rappert, Webster & Charles1999; Meyer-Krahmer & Schmoch 1998), such as biotechnology, information and communication technologies, chemicals, pharmaceuticals, and new materials. Most studies focus on one specific sector, where as other compare two to four sectors (Faulkner & Senker 1995; Rappert, Webster & Charles1999; Meyer-Krahmer & Schmoch 1998). In these areas university-industry interactions are common, and are or have been core to the development of these fields. Consequently, these sectors are seen as science-industry (technological) constellations, and the focus is set upon the interaction, rather on the originating spheres. To capture this communal level of analysis, the concept of technological communities or technological-scientific communities has been proposed (Meyer-Krahmer & Schmoch 1998). This approach is related to research that focuses on technological regimes (Breschi, Malerba & Orsenigo 2000) or technological systems (Carlsson & Stankiewicz 1991).

With respect to university-industry knowledge interaction, focus has been put on properties of the knowledge used in innovative activities, and particularly on identifying science-based technologies (Pavitt 1984, Meyer-Krahmer & Schmoch 1998). A science-based technology refers to the extent to which scientific knowledge has been central in developing that technology, usually measured by reference to scientific publications in patents. Thus it is related to the linkage between a science field and a developing technological field of application.

Although literature on university – industry interaction focuses on specific science-based sectors of the economy, knowledge interaction is not something that only occurs in such fields. "The mutual exchange of knowledge in techno-scientific communities is obviously a broad phenomenon that is not limited to some exceptional cases, but applies to whole disciplines and subdisciplines" (Meyer-Krahmer & Schmoch 1998, p. 848). However, since there are more interactions in some sectors than in others, specific industrial characteristics are considered to explain the propensity for interaction, as well as the level and type of interaction (Schartinger et al 2002, Meyer-Krahmer & Schmoch 1998). Three variables are frequently used in analyzing sectoral differences: knowledge intensity, size of sector and maturity of technological sectors. An alternative explanation, knowledge proximity, has also been tentatively explored. The explanatory variables for propensity for interaction are seen to represent different dimensions of interdependence between industrial sectors and universities (Geisler 1995).

The first variable, knowledge intensity, is commonly used (Schartinger et al 2002, Meyer-Krahmer & Schmoch 1998). The variable is a composite of different measures, such as the degree to which sectors depend on scientific knowledge inputs in production as well as sectoral R&D capabilities. According to Schartinger et al (2002) and Faulkner & Senker (1995), this is associated with different types of innovation processes in different sectors. Sectors that are oriented on radical innovations have greater demand for knowledge inputs, than sectors that focus on incremental innovations. Radical innovations, high knowledge inputs and high R&D intensity are characteristics associated with so-called science-based industries (Meyer-Krahmer & Schmoch 1998). Schartinger et al (2002) also associates high employment dynamics with knowledge intensity, as the above characteristics are assumed to reflect growing labor demands, and therefore inclined to interact with universities as main producers of highly trained workers.

Sectoral R&D capability is another dimension to knowledge intensity, usually measured in terms of R&D expenditure and share of R&D personnel (Meyer-Krahmer & Schmoch 1998, Schartinger et al 2002). As have been

identified at the firm level, experiences in R&D, is associated with the potential for absorbing knowledge produced outside the firm.

Knowledge proximity is a variable used by Schartinger et al (2002) to explain sectoral differences in linkage activity and it refers to "degrees of technological proximity between a certain field of science and sectors of economic activities" (Schartinger et al 2002, p. 307) measured in human resource terms. They investigated knowledge interaction in a large number of sectors, and consequently found that knowledge proximity to a large extent explain variance in propensity to linkage across sectors. This variable, though not explicitly recognized in other studies, is usually implied in the selection of sectors for investigation, science based fields, which probably will have a close human resource ties with universities.

The maturity of sectors is a variable that, according to Rappert, Webster & Charles (1999), has been introduced as an alternative explanation to the knowledge intensity arguments in accounting for variance between sectors in terms of linkage activity. Maturity, according to them, refers both to the phase of technology development that the sector is currently in, as well as the age of the firms. The variable suggests that the propensity to interact is higher in the early phases of technology development, and when firms are young and relatively inexperienced. These assumptions have been tested and confirmed, particularly in research on the biotechnology sector (Faulkner & Senker 1995).

Size of sectors is a common variable, entailing whether the sector is populated by small or large firms (Faulkner & Senker 1995; Meyer-Krahmer & Schmoch 1998; Schartinger et al 2002). Industries populated with larger firms have more absorptive capacity as well as larger R&D budgets and more slack resources, and as such, should interact more with universities. However, evidence on size related to propensity to linkage is ambiguous, as will be discussed in the next section.

2.2.2 Firm characteristics

At the firm level, variables that explain variances in the propensity for interaction are rather similar to the variables that explain variance at the aggregate level. Central variables are R&D intensity (Vedovello 1997) and size (Santoro & Chakrabarti 2002), as well technology centrality (Santoro & Chakrabarti 2002; Faulkner & Senker 1995) and geographical proximity (Vedovello 1997, Schartinger et al 2002).

As at the aggregate level, knowledge intensity (demand and capability) is seen as the central variable explaining the propensity by firms to interact with universities. As such the level of R&D activity of a firm is seen as an explanatory variable of interaction (Mansfield 1991, Arora & Gambardella 1990; Vedovello 1997). Cohen & Levinthal's (1990) notion of "absorptive capacity" refers to a firm's ability to identify and assess knowledge and information produced externally, assimilate it and exploit it for economic ends, and claim that this is a critical ability for innovation. The theory of absorptive capacity, drawing upon information processing and cognitive learning theory, states that "the ability to evaluate and utilize outside knowledge is largely a function of the level of prior related knowledge" (Cohen & Levinthal 1990, p. 128). It is a function of experience and the capabilities that the organization already possesses. A firm's ability to utilize external knowledge is seen as a product of internal research and development activities, training and production operations. In terms of university industry interaction, this theory implies that firms interacting with universities have internal R&D capabilities and some degree of complimentarity in knowledge resources (Santoro 2000).

The size of the firm is seen a central variable, and is also related to the absorptive capacity of the firm, as seen above. Santoro & Chakrabarti (2002) extend this analysis by looking at the relationship between size and technology centrality (core versus non-core technology) in explaining the propensity for, and mode, of linkage. They claim that larger firms interact with university predominantly in non-core technologies (scouting the scientific frontier for windows of opportunity), and smaller firms interact with universities in core technologies (problem solving), and that different linkage mechanisms are used for these purposes. These propositions might, in this way, also account for the ambiguous findings on impact of size on propensity for linkage, and correspond to the main motivations behind firm interaction with universities, as identified by literature (Bonaccorsi & Piccaluga 1994).

Geographical proximity is a central variable in regional studies of innovation, which identify local knowledge spillovers as central for innovation (Almeida & Kogut 1999). Within the research on university – industry interaction it is a frequently included variable (Schartinger et al 2002; Waagø 2001, Santoro & Gopalakrishnan 2000), but findings are ambiguous and seems to have limited strength as a stand-alone explanation, in the sense that it interacts with other variables.

2.2.3 University and disciplinary characteristics

Where as studies attempting to explain why firms interact with universities point to various factors, studies explaining why universities interact with firms have a more narrow scope. It is largely explained by decreasing public funding of science, and increasing reliance on non-governmental sources, as well as new science and technology policies (Carayol 2003, Nimtz, Coscarelli & Blair 1995, Mora-Valentin 2000, Bozeman 2000). Consequently, a more reactive explanatory model is formed.

The resource dependence argument for explaining propensity for interaction on part of the university is usually only alluded to. The argument is taken at face value: Less public money triggers behavior to seek external money. Less frequently in the literature has this behavior been investigated explicitly. Slaughter & Leslie (1997) have however investigated the relationship between resource dependence and entrepreneurial behavior in their book on "academic capitalism", defined as "market and marketlike behavior on parts of universities and faculty" (p. 11). Slaughter & Leslie offer detailed empirical investigations on how institutions and faculty have changed their behavior in response to changes in the environment. They put emphasis on one variable for explaining the emergence of entrepreneurial universities – resource dependency, brought about by declining public funding and new patterns of financing. Decline and redistribution of funds triggered institutional and faculty responses along the lines of academic capitalism to secure external funding, particularly for research. Specific responses also vary between countries, institutions, departments and faculty. Thus, differentiation rather than convergence is a central finding in Slaughter & Leslie's study.

The most important form of differentiation is taking place between different academic fields. According to Slaughter & Leslie (1997) academic capitalism is largely focused on techno-science fields, like biotechnology, material science, computer science, and other fields close to the market, like business administration and economics. These subject fields have closer ties to economic sectors, and in addition they are likely to gain more public funding, as they are seen as strategic to national and regional economic development. In these areas, institutions and faculty are able to develop research-related market relations. These findings are also corroborated by Schartinger et al (2002). The basic natural sciences, social science and humanities do not have the 'market potential' that these areas have, and in these areas engagement in academic capitalism is likely to focus more on education and service than research (Slaughter & Leslie 1997; Schartinger et al 2002). As such, the resource dependency argument alone does not explain propensity for linkage. Discipline level variables, such as knowledge

proximity and market potential, further explain the variance in responses to decline of public funding.

Schartinger et al (2002) investigate five structural variables at the disciplinary level that explain the propensity for university - industry interaction: size, experience, reputation, employment dynamics and public awareness. The size structure of a field of science is considered to affect the propensity to linkage. Larger disciplines (measured in size of departments) have more resources and consequently more available to use on projects aside from day to day tasks (predominately teaching). Support for this has been found in the level of patenting relating to size of a discipline (Meyer-Krahmer & Schmoch 1998), as well as in surveys of university – industry interactions (Schartinger et al 2002).

Growth of a field of science is also seen as relevant for explaining university – industry interaction. Expanding fields are the fields that politicians see as strategic for economic development (Schartinger et al 2002). This has been seen in the development of biotechnology (Faulkner & Senker 1995), which increased whilst other academic fields stagnated. Previous experience in external R&D collaboration is also seen as central for explaining propensity for interaction, as it will alleviate barriers as well as have established a contact network that furthers the propensity for interaction.

The reputation of a field of science (measured by publications in international journals) is seen as a precondition for interaction, according to Schartinger et al (2002), as firms will interact with renowned departments to reduce risks and costs, thus reinforcing the "Matthew effect" in science (Merton 1968). This is also found relevant at the individual level. Faculty that interact with industry and receive support for industry are tenured professors with a high reputation (Etzkowitz 2000, Owen-Smith and Powell 2001, Mansfield & Lee 1996). In relation to reputation, public awareness of a field of science is seen relevant, and consequently, that firms tend to collaborate with departments that are visible in the public eye (measured by media coverage).

2.2.4 Motivations and expected benefits

The propensity for interaction is affected by many factors associated with characteristics of the agents. Another way of looking at the propensity for interaction is looking at the expectations firms and universities have for interacting with each other, which induces them to collaborate. Motivation (the concept used in the research literature) in this context means goals or perceived benefits expected to be realized through interacting (Mora-

Valentin 2000). Motivations for interaction are frequently presented as "benefits" of university – industry interaction (Rappert, Webster & Charles1999, Nimtz, Coscarelli & Blair 1995, Mora-Valentin 2000, Carayol 2003). The expectations are also seen to affect the expected performance of university – industry interaction (Bonaccorsi & Piccaluga 1994) as well as the linkage mechanisms used (Rappert, Webster & Charles1999; Faulkner & Senker 1995).

Access to the research frontier and "keeping an eye on" new knowledge and opportunities, are regarded as general motivations for firms (Nimtz, Coscarelli & Blair 1995, Faulkner & Senker 1995, Bonaccorsi & Piccaluga 1994; Rappert, Webster & Charles1999; Santoro & Gopalakrishnan 2000). Several studies emphasize that firms' expectations with regards to university science, is that it should contribute to the general pool of knowledge. Problem solving (Bonaccorsi & Piccaluga 1994; Rappert, Webster & Charles1999; Santoro & Gopalakrishnan 2000) or assistance with general and specific problems is another motivation for firms to interact with universities. However, as Santoro & Gopalakrishnan (2000) have showed, expectations can interact with firms' size and technology centrality. They claim that larger firms primarily interact with universities to keeping abreast on university research in ancillary technologies, whereas smaller firms interact with universities for problem solving in their core technologies.

Delegating R&D activities, risk reduction, cost sharing and access to public research money are motivations that are also mentioned, though not as frequently (Bonaccorsi & Piccaluga 1994). Some authors mention a trend of outsourcing in R&D, particularly in non-core technologies or in specific phases of technology development, such as testing of prototypes or drug testing. In terms of cost sharing and access to public research money, some have highlighted this particularly for smaller firms, which have limited capability and resources for internal R&D. This forms a rationale behind several new policy measures that emphasize user interaction as a condition for funding.

Access to research infrastructure and access to expertise (Santoro & Gopalakrishnan 2000; Rappert, Webster & Charles1999; OECD 1999) are motivations that firms frequently cite. However, these more specific goals are naturally related to the above goals as well.

Recruitment is seen as a central motivation for firms (Santoro & Gopalakrishnan 2000; Rappert, Webster & Charles1999; OECD 1999; Faulkner & Senker 1995). In some studies it is referred to as the most important reason for why firms interact with universities (Gulbrandsen & Larsen 2000). Thus, access to highly trained manpower is important for

firms. Moreover, Rappert, Webster & Charles (1999) point at increasing goodwill and visibility of the firm among the university graduates as central motivations, particularly in the IT industry. Thus it is related to the goal of improving corporate image (Santoro & Gopalakrishnan 2000; Bonaccorsi & Piccaluga 1994; Nimtz, Coscarelli & Blair 1995), but it is not explicated how university –industry collaboration enhances the corporate image of a firm.

There might be other motivations as well, and several authors, with varying degrees of evidence and explanations, present extensive lists. The main university motivations described are (Waagø 2001, Santoro & Gopalakrishnan 2000, OECD 1999, Nimtz, Coscarelli & Blair 1995, Meyer-Krahmer & Schmoch 1998, Mora-Valentin 2000, Carayol 2003):

- Securing additional funding for research. This motivation pertains to the resource dependence argument presented above.
- Access to R&D equipment
- Access to relevant industrial research and research problems. Sectors of high knowledge proximity and where substantial R&D is carried out in industry, access to industrial research is relevant.
- Increasing relevance of education and provide employment opportunities for students
- Increase the political legitimacy by showing that the institutions contribute to economic development, and to fulfill the "service mission" of universities

The universities' motives are generally not investigated to the same extent, and are usually equated with lack of resources. Studies that focus on the individual academic within specific disciplines, highlight motivations at the individual level, and ask the question of why some academics interact with industry and not others. The answers tend to focus on the characteristics and behavior of academic entrepreneurs (Etzkowitz et al 2000; Owen-Smith & Powell 2001), where status and age are two variables that have been used to explain differences in faculty behavior. At this level, and also at the university level, the resource dependence argument is criticized due to the empirical evidence that shows that academics and universities that mostly interact with industry are those that are already favored in terms of public funding of research, and as such should be less resource dependent. This has also been seen in patenting and licensing behavior (Mowrey et al 2001). This means that resource dependence in itself does not alone explain university behavior for interacting with industry or seeking to commercialize scientific knowledge. They need opportunities to do so. But integrating incentive oriented and structural arguments have not been common in research on UI relations.

2.3 Linking activities

The second main topic addressed in research on UI relations concern describing and classifying university – industry knowledge interaction in terms of the activities that are carried out (Faulkner & Senker 1995, Schartinger et al 2002; Vedovello 1997; Santoro 2000; Bonaccorsi & Piccaluga 1994; Waagø 2001, Geisler 2001). Some papers mainly list various types of activities in descriptive categories, but others provide tentative analytical frameworks for analyzing observed differences. The categories are usually empirically derived. It is not one common definition of what constitutes university-industry interaction and what is not. As a consequence, a variety of phenomena are included, and few attempts are made to demarcate the concept. The definitions that are used are, symptomatically, broad (Schartinger et al 2002). Many articles present extensive lists of different types of university – industry interactions. These are some of the interaction types that are frequently mentioned (Bonaccorsi & Piccaluga 1994; Waagø 2001; Santoro 2000; Vedovello 1997; Bozeman 2000; Geisler 2001; Faulkner & Senker 1995; Schartinger et al 2002):

- Consultancy
- Studentships
- Employment of graduates by firms
- Sponsored university positions
- Use of university facilities and equipment
- R&D contracts
- R&D consortia and cooperative research
- Joint ventures
- Part-time teaching
- Academic spin-off firms
- Co-authoring of papers
- Informal networking
- Technology transfer schemes
- Patenting and technology licensing agreements
- Employee exchanges, sabbaticals/secondments
- Publications
- Establishment of campus laboratories in research parks
- Conferences
- Joint supervision of Master and Ph.D. students

But these descriptive categories do not say much about the nature of university - industry interaction, although they are used extensively in empirical research to measure the extent of and types of linkage between universities and industry. According to Blackman & Segal (1991), creating a typology of university –industry interactions have proved difficult, as universities and firms interact is such a variety of ways. Not having a

working definition of what to include in such a typology, doesn't ease the analytical job either. As such, it can be interesting to see what analytical dimensions have been used to discern between types of knowledge interactions. Not many authors provide insights into how they discern between categories. In consequence, the three dimensions discerned below are a result of analysis of literature. The following table provides a summary of the dimensions that will be described further below.

Table 2: Summary of variables for linking activities

Dimensions	Variable/concept	Properties
Domain	Area of activity	Research, education, service or similar
Institutional arrangement	Formalization Resource involvement Length Scope (goal specificity)	formal – informal ties large – small resources long term – short term targeted – open
Content	Knowledge flow Personal interaction Char. of knowledge	one vs bi-directional face to face vs distant codified vs tacit

2.3.1 Area of activity

Area of activity typologies (Mora-Valentin 2002; Anderson 2001) basically point to domain of activity where the interaction is taking place, particularly with reference to the university's domains of activity, such as research links, educational links, and service and consultancy links. The literature is generally preoccupied with research links, and in some instances with the intersections of research and consultancy links. However, these typologies do most often go any deeper into whether domain of activity influences type of interaction.

2.3.2 Institutional arrangements and formalization

Another commonly used dimension is degree of formalization, or the dichotomy formal versus informal links, pointing to the nature of the agreement between the partners in a collaborative relationship. According to Vedovello (1997), a formal tie has an established agreement specifying the commitments and payment of fees by the involved agents. Formality is hence seen as related to resource involvement and extent of commitment. According to Faulkner & Senker (1995), most research on university – industry interaction has focused on the institutionalization of these relationships or on different institutional arrangements. Examples here

include the taxonomies made by Bonaccorsi and Piccaluga (1994) and Vedovello (1997).

Informal linkage activities are regarded as the most common form of university – industry interaction, and can be seen as "non-contractual barter arrangements" (Faulkner & Senker 1995). The emphasis on bartering entails that social exchange is seen as central in university – industry interaction, in which academic and industrial scientists exchange knowledge, but also equipment, research materials, and even students (Slaughter et al 2002, Bouty 2000). Moreover, many authors emphasize that the relation between formal and informal interactions is one of sequence rather than excluding alternatives, by emphasizing that formal agreements almost always grow out of existing informal relationships (Faulkner & Senker 1995, Gulbrandsen & Larsen 2000).

Degree of resource involvement is related to formalization (Bonaccorsi & Piccaluga 1994). Resource involvement means the extent of resources (monetary or other) the parties have committed to the link. However, one can have links to which no resources are committed, for instance where industrial scientists read academic papers. In general however, the parties must commit some resources for interaction to occur. Resource involvement is considered to interact with formalization, since greater resource involvement is associated with a demand for formal contract. Low cost linkage would be activities like consulting or student fellowships. An example of a high cost linkage is a collaborative research centers, to which considerable resources are committed.

The length of an agreement or the "extent of sponsor commitment" (Bonaccorsi & Piccaluga 1994, Fujisue 1998) is a dimension also considered to interact with formalization, ranging from short- to long-term commitment of resources. Long-term commitment is associated with greater formalization, as for instance building up specific structures for collaborative work, for instance in collaborative research centers. But one can easily imagine long-term partnerships that are informal in nature, for instance networking between academic and industrial scientists.

A dimension that interacts with length of agreement, is goal specificity, raging from targeted, to non-targeted to open relations (Bonaccorsi & Piccaluga 1994, Vedovello 1997). Sponsoring can be considered as open in scope of the relation and informal gatherings likewise, where as contract research or use of university facilities are more targeted links. Long-term commitments, such as collaborative centers, are not likely to have one specific goal; rather multiple goals will be pursued. And, as such, they can be seen as non-targeted arrangements (Bonaccorsi & Piccaluga 1994). As

seen above, firm size was associated with different motivations, where larger firms were more prone to emphasizing broader goals (such as access to scientific frontier) and smaller firms emphasized problem solving. Seen in this manner, the motivations are associated with different scopes of arrangements, seen in the degree of goal specificity.

The above dimensions, excluding for the purpose of analysis the area of activity, essentially focus on the form that university-industry interaction can take, particularly focusing on the nature of the agreement as a distinguishing variable between different interaction forms. One can therefore say that these variables are used to measure the extent of institutionalization of university – industry relations associated with the degree of formalization, and related variables commitment of resources, length, contractual arrangement, and goal specificity.

2.3.3 Content and knowledge flow

Characteristics of knowledge are also used to discern between different types of university – industry interactions. These concern conceptualizations of the direction of the flow of knowledge as well as characteristics of knowledge. As such, one can argue that these dimensions target the content of the university – industry interaction more than the form of the interaction.

The first content dimension concerns the knowledge flow or whether the link can be seen as a one or bi-directional flow of knowledge (Meyer-Krahmer & Schmoch 1999, Harmon et al 1998). As noted, several authors now emphasize the bi-directional flow of knowledge in university – industry interactions. With reference to variety in links, one-way relations exist is reading of papers and patents, as well as in the traditional concept of technology transfer and licensing agreements. Joint ventures, collaborative research projects are examples of two-way links.

Associated, the level of personal interaction is a common content dimension (Schartinger et al 2002, Rappert, Webster & Charles1999, Faulkner & Senker 1995, Vedovello 1997, Bonaccorsi & Piccaluga 1995), varying between face-to-face interactions and links that do not entail any form of personal interaction, such as papers and patents. Face to face interactions include informal networking, chance meetings, academic consulting, collaborative research and all forms of human resource links.

Quite a few authors associate personal interaction with characteristics of knowledge in university –industry interactions. As properties of knowledge are associated with characteristics of communicating, characteristics of

knowledge is considered relevant for discerning university – industry interactions. As such, it is argued, certain links are more suitable for transferring tacit knowledge than others. According to Schartinger et al (2002), channels that have face to face properties are suitable for transferring tacit knowledge: "Personal interactions are associated with the exchange of tacit knowledge through activities such as talking and listening or demonstrating or copying" (p.305).

The literature on interaction activities, seen in terms of institutional arrangements and characteristics of knowledge transfer, treat knowledge interaction between firms and universities in a fairly superficial and static manner.

2.4 Interaction processes and performance in UI collaboration

The literature review indicates that empirical studies of how interaction is carried out and coordinated in R&D collaborations are not as common as research focusing on why universities and firms interact and the institutional arrangements for such relationships. Much research in this area is cross-sectional and quantitative, and describe in broad strokes how interaction is carried out by identifying categories of links. There are few in-depth studies of interaction, and micro level data is generally scarce (Gulbrandsen 2003). Likewise, research focusing on processes of forming, developing and coordinating UI collaboration is fairly absent. Although some papers touch on some of these issues when identifying barriers and enablers of successful interaction (Carayannis, Alexander & Ioannidis 2000, Geisler 2001, Cyert & Goodman 1997, Mora-Valentin, Montoro-Sanches & Guerras-Martin 2004, Barnes, Pashby & Gibbons 2002), there has been little systematic effort to explore interaction processes and performance in the UI context.

Within the literature on scientific alliances more general, there have been attempts at exploring the micro-dynamics of knowledge interaction (Allen 1977, Bouty 2000, Porac et al 2004, Schrum et al 2001). These studies focus on interaction between scientists, either only industrial or only academic, in different organizations. Focusing on this level of analysis, the social mechanisms involved in exchanging knowledge becomes apparent, such as familiarity and trust. Bouty (2000) shows that social capital resources impacts on both the researchers expectations (benefits expected to be obtained by interacting) and the types of knowledge resources exchanged between scientists in industry. Bouty also shows that exchange relationships between industrial scientists develop gradually. Initially scientists engage in low-risk exchanges and try each other out. Through repeated interactions

relationships can grow into equitable exchanges governed by norms of reciprocity and deep trust. According to her, social capital is central factor of success in interorganizational knowledge exchange, because it facilitates exchange processes. Porac et al (2004), on the other hand, investigated the dynamics of R&D collaboration in a university-based scientific alliance. They also depart from the premise that strong relational ties is favorable for knowledge exchange in alliances and investigated how collaborative work is coordinated and carried out in practice, as well as the performance of the collaboration. They find that R&D collaboration is carried out through loose collaboration within a distributed work environment. Periodic meetings along with interpersonal interaction achieve coordination of work across the distributed entities. They also find that although previous interaction and common disciplinary backgrounds are associated with positive assessment of performance, these factors do not seem to affect research output, as measured by publication data. Likewise, Schrum et al (2001) investigated the relationship between trust stemming from previous relationships and performance in scientific alliances, and find that it is not directly associated with performance but that it is associated with lower levels of conflict in the interaction process. Both these papers suggest that previous interaction, and thereby social capital resources, facilitates interaction process and coordination of interaction, but that the direct impact on performance is more questionable.

University – industry interactions are complex phenomena, involving a diversity of agents, expectations and linkage activities. According to Bonaccorsi & Piccaluga (1994), UI collaborations can serve at least three purposes related to generation of new knowledge, transfer of knowledge, and absorption of knowledge. The expectations behind establishing the collaboration will influence the performance related to these dimensions. As such, certain interactions can be set up with the intention to generate new knowledge, others to transfer knowledge over organizational boundaries, and others again to disseminate knowledge more broadly. In addition, the impact in terms of firms' use of knowledge in innovative activities has been emphasized as an outcome of university – industry interaction (Faulkner & Senker 1995). Thus, there is several output measures from UI relations, such as publications (Porac et al 2004), co-publications (Gulbrandsen 2003), or reported use in firm innovations (Faulkner & Senker 1995, Hervik, Bræin & Bergem 2004, Cohen, Nelson & Walsh 2003).

In addition to studies linking performance to R&D output measures and attempts at measuring impact, there are several studies on success of UI collaboration based on subjective measures of performance (Mora-Valentin, Montoro-Sanches & Guerras-Martin 2004, Barnes, Pashby & Gibbons 2002, Geisler 2001). Subjective performance measures include "global

satisfaction" or level of satisfaction as reported by the respondents (Mora-Valentin, Montoro-Sanches & Guerras-Martin 2004, Geisler 2001) and "performance talk" (Shrum, Chompalov & Genuth 2001, Barnes, Pashby & Gibbons 2002). Another success measures is continuity and evolution of the collaboration over time (Mora-Valentin, Montoro-Sanches & Guerras-Martin 2004, Bouty 2000, Geisler 2001), which can be measured both subjectively and objectively. Since UI collaborations are voluntary arrangements, persistence over time is considered a good outcome measure of successful interaction.

However, what is seen as central for enabling successful collaboration when measuring collaboration subjectively is not emphasized to the same extent in studies emphasizing objective outcome measures. Mora-Valentin, Montoro-Sanches & Guerras-Martin (2004) find that previous collaboration experience, trust, reputation, organizational commitment and definition of objectives are associated with successful collaboration. Barnes, Pashby & Gibbons (2002) find several factors related to partner selection, project management and general factors, such as trust and commitment, are associated with successful UI collaboration projects. Porac et al (2004) find that trust, commitment and resources stemming from previous interaction are associated with success in terms of subjectively perceived performance, but not with research output. This could indicate that social relationships, and resources stemming from such relations, are central for agents' experience of the interaction process, but not necessarily for explaining research output.

2.5 Research on UI interaction and questions for further research

The literature on UI interaction reviewed in this chapter focuses dominantly on agents and activities. Characteristics of agents at various levels of analysis are used to explain the propensity for interaction; knowledge intensity, R&D capability, knowledge proximity, maturity and size are variables that explain differences in interaction at the level of industrial sectors. R&D intensity, size and technology centrality are also used to explain differences in firms' interaction behavior. All of these variables are seen as dimensions of interdependence between industry and universities. In terms of universities, resource dependence is used to explain why universities are interested in interacting with industry to secure external money. However, research has shown that resource dependence cannot explain why there is much differentiation between institutions and departments with respect to interaction with firms. Structural variables, like knowledge proximity, experience and reputation are seen as important, and

are also used for explaining behavior at the level of individual faculty members.

In terms of activities, the most common approach to discerning between different activities is by looking at the institutional arrangement for linkage. Contractual arrangements, resources, scope and length of agreement are important institutional dimensions for categorizing different types of linkage. However, since research to a large extent targets the formal arrangements, they might emphasis too little the role of informal links. Also, there has been very little exploration of micro dynamics of knowledge exchange in UI collaborations. Research into knowledge exchange in scientific alliances has to some extent looked into this, and this research finds that social resources emanating from previous relations are central for exchange of knowledge. This research also finds that relationships develop iteratively over time, and that formal agreements are embedded in informal networks and relationships. Although recognized within research on UI relations, systematic research into formation and development of collaboration has not been carried out.

Although research has explored different sides of university – industry relationships, we still do not know with any degree of certainty how university-industry collaboration is able to transfer knowledge over organizational and sectoral boundaries or to contribute to innovation. This is partly due to research in this area, which has focused on experiences of a few industries in which the science-technology link is particularly strong. This has lead to a belief that scientific knowledge is important for economic growth, which again has led to increasing policy emphasis on university – industry relations. This "best case" empirical focus has lead to a strong emphasis on university-industry ties in the first place, as well as certain types of interactions. Very few studies have investigated knowledge interactions across several sectors. Schartinger at al's (2002) comparative study of knowledge interactions in forty-six fields of science indicate that the type of interaction used is significantly different between sectors. They claim that "a restriction of the analysis of industry- university relations to only a few types of channels may produce misleading results as there are significant differences in the orientation on certain types of interaction by industrial sectors and fields of science" (Schartinger et al 2002, p. 326). A central finding is that sectors relying on informal and interpersonal interactions are frequently unaccounted for, and that this type of interaction is not explored enough.

Research on UI relations has focused on understanding who the agents are, and how characteristics of agents explain their propensity for interaction in a very static manner. One dominant focus is on why interactions vary across

sectors, firms, universities and disciplines. There is little focus on the process through which formal arrangements emerge and develop, even though this might give new knowledge for understanding preconditions for knowledge interaction. Likewise, research tends to target either preconditions for interaction or exploring empirically types of knowledge interaction activities. Process oriented research that integrate preconditions and interaction processes, is lacking.

With this as a backdrop, this thesis aims at contributing to the research literature on university – industry interaction by focusing on how ties are formed and how the involved participants experience them. Taking a micro level perspective on knowledge interaction, this project explores how formal collaborative relationships emerge and develop. The aim is to make a contribution to the literature on UI relations primarily by exploring the process of tie formation, and link this to how the interaction process is experienced. To do this, this thesis propose that social and cognitive ties between firms and academic fields are relevant for understanding how ties are formed as well as how participants experience the interaction process. The theoretical arguments underpinning this interpretation is presented and discussed in the next chapter.

Chapter 3: Knowledge exchange and formation of collaborative ties – perspectives for exploring UI relationships

3.1 Introduction

The purpose of this chapter is to present and discuss concepts and theories of relevance for understanding why and how firms and university environments form collaborations. Collaboration between firms and universities was above conceptualized as knowledge interaction, defined as "all types of direct or indirect, personal and non-personal interactions between organizations and/or individuals from the firm side and the university side, directed at the exchange of knowledge…" (Schartinger et al 2002, p. 304). Consequently, collaboration between firms and universities are here seen as knowledge exchange relationships. With this in mind, this chapter seeks to develop an understanding of knowledge exchange and how exchange ties emerge and develop, and to utilize this to generate a sensitizing analytic frame for this study.

Since knowledge interaction as defined concern interorganizational and interpersonal arrangements entered into with the purpose of exchanging knowledge, an analysis of the characteristics of knowledge exchange is seen as relevant. This is addressed in the first main section of this chapter, which starts by analyzing central perspectives on knowledge exchange in terms of ideas of knowledge and distribution. This analysis is carried out as a foundation for understanding knowledge interaction as a particular type of collaborative relationships. Further, recent knowledge transfer and innovation perspectives highlight that a linear 'information-dissemination' model of knowledge transfer is flawed, and that knowledge transfer should rather be understood as interaction between agents aimed at exchange of knowledge and mutual learning. This again poses requirements for the relationships intended to fostering knowledge exchange. Consequently, an analysis of social relationships and knowledge exchange follows, looking into concepts of similarities and differences between exchange partners in relation to characteristics of knowledge. This analysis indicates that characteristics of social relationships, particularly the relative similarity in cognitive capacity between interaction partners is central for knowledge exchange – particularly for exchange of tacit and complex knowledge.

The second main section of the chapter further extends this perspective by looking into conceptualizations of tie formation, emphasizing both social capital explanations, interdependence explanations and an integrated process perspective on tie formation. The third main section of the chapter provides a synthesis of the different elements, seen in relation to the specific exchange ties investigated here. This is achieved by developing a conceptual framework that indicates the main conceptual foci and their assumed relationships.

3.2 Knowledge exchange

There are two basic conceptualizations of knowledge exchange found in literature that deals with the transfer of knowledge in and between organizations (Cowan, David & Foray 2000, Dasgupta & David 1994). The two conceptualizations can be referred to as the 'information distribution model' and the 'social learning model'. In the information distribution perspective, knowledge transfer is seen as a relatively straightforward dissemination of information (a message) from a sender to a receiver by the use of some medium. The signaling metaphor is the basic communication model behind this model: Information is produced by the sender or source, communicated, and absorbed by the receiver and put to use. The transfer of information is instantaneous, easy and costless. This is particularly so within economics that has treated the transfer of information as costless (Cowan, David & Foray 2000). Although this model has been criticized for decades, it has still informed policy and literature on knowledge transfer.

But evidence from empirical research showed that knowledge transfer is not easy; it is difficult, time consuming and costly (von Hipple 1994, Simonin 1999). This led to analyses of the difficulties inherent in transferring knowledge, and the dominant point of criticism was the idea of knowledge that the above model was based on. The conceptualization of knowledge above is flawed, according to critics, as knowledge is reduced to information or data that can easily be transferred. Knowledge is something different that information, Cowan, David & Foray (2000) claim. They define information as structured data coded into a message. "A message containing structured data, the receipt of which causes some action by the recipient agent – without implying that the nature of the action is determined solely and uniquely by the message itself" (Cowan, David & Foray 2000, p. 216). Knowledge on the other hand is a concept that covers the cognitive repertoires humans has for making sense of information. Although it is obvious that information and knowledge is related, they are not the same.

> Two agents endowed with the same information may well end up doing different things because the cognitive structures of different individuals or groups are likely to be developed through experience, exposure to particular problems, etc, and hence their cognitive understanding of the information is different (Malerba & Orsenigo 2000, p. 291).

If we see knowledge as a capacity for interpreting and acting upon information resting with agents, is it meaningful to talk about knowledge transfer? According to its critics, the flaw of the 'information-dissemination' model is that it "implies the absence of any meaningful distinction between information and knowledge" (Cowan, David & Foray 2000 p 216). Information can be transferred easily, but what about knowledge? Knowledge used in problem solving cannot be reduced to data and it is not easy to communicate it. Rather knowledge is relatively inert or "sticky" (von Hipple 1994; Szulanski 2000) and does not 'travel light'. In the economics of knowledge literature this problem is recognized and discussed in terms of the characteristics of knowledge that enables or resists transfer (Rogers 2003/1980, Winter 1987, Simonin 1999, Zander & Kogut 1995). Although this perspective has an understanding of the difficulties inherent in knowledge transfer since some of its properties make it sticky and inert, it's still basically an information perspective. It's possible to decontextualize and code knowledge into information and transfer it. Thus, knowledge can exist outside the human experience. Some have a different viewpoint, and claim that the diffusion of knowledge cannot be reduced to the transmission of information (Cowan, David & Foray 2000). In their view, there is a qualitative difference between knowledge and information. The implication is that if knowledge cannot be reduced to information and transferred, it is not meaningful to talk about the transfer of knowledge as above.

3.2.1 Conceptualizations of knowledge

An important conceptual distinction underlying the discussion of knowledge transfer is between articulated or codified knowledge and what is known as tacit knowledge, or the tacit dimension to knowledge (Polanyi, 1983) has been influential in research on knowledge and learning in organizations. Polanyi's starting point was "the fact that we can know more than we can tell" (1983, p 4). We are able to recognize a person's face amongst hundreds of others on a street, but cannot say why we recognize a face. A swimmer is able to keep herself afloat without being aware of how she does it. This tacit dimension of knowledge is complementary to conscious cognitive processes. Polanyi explains this with reference to findings of Gestalt psychology about human perception. Human knowledge consists of holistic understandings,

which cannot always be reduced to its parts without losing the whole. Moreover, humans can be aware of objects without being focused on them. The cognitive context provides meaning to the interpretations of perceptions, although we are not aware of it. Thus, we know more than we can tell. This tacit dimension to knowing entails that knowledge is partly unarticulated or difficult to communicate in symbolic representation. But this does not mean that tacitness is the same as 'inarticulability'. The context will determine if knowledge remains tacit rather than articulated. What is tacit knowledge to some might be articulated to others. So, there is no clear-cut distinction between tacit and explicit knowledge in Polanyi's view. "These two are not sharply divided. While tacit knowledge can be possessed by itself, explicit knowledge must rely on being tacitly understood and applied." (Polanyi 1969, p. 144)

If it is so that knowledge of any kind (and Polanyi provides numerous examples from different domains) has a tacit dimension that is a central part of knowing, what implications does this have for how humans acquire knowledge and how knowledge is transmitted? Articulated or 'explicit knowledge' can be transmitted through systems of symbolic representation such as language, for instance by writing it down, creating manuals and blueprints, etc. Tacit knowledge on the other hand can be learned through observation of skillful performance, practical examples, experience and practice. Learning, for Polanyi, is experience based.

> But the characteristic features of the situation are seen more clearly if we consider the way one man comes to understand the skillful performance of another man. He must try to combine mentally the movements which the performer combines practically and he must combine them in a pattern similar to the performer's pattern of movements. Two kinds of indwelling meet here. The performer co-ordinates his moves by dwelling in them as parts of his body, while the watcher tries to correlate these moves by seeking to dwell in them from outside. He dwells in these moves by interiorizing them (Polanyi 1983, p 30)

With respect to the knowledge transfer question, the basic argument is (as seen above) that explicit knowledge is easy to transfer whilst tacit knowledge is hard or impossible to transfer. It requires 'indwelling'. But some claim that this is too hasty a conclusion. Malerba & Orsenigo provides examples on situations where highly explicit knowledge is impossible to access although it is publicly available, and where tacit knowledge easily can be codified or situations where things are easy to use even when they are not codified. They claim: "the comparison between tacit and codified knowledge in terms of ease of transmission might be profoundly misleading and sometimes unwarranted, because one is comparing totally different things"

(Malerba & Orsenigo 2000, p 293). Johnson, Lorenz & Lundvall (2002) make the same criticism of the tacit/codified distinction in transfer of knowledge, and raises the point that there are different categories of knowledge.

The question of different forms of knowledge, runs through the history of philosophy: From Aristotle's concepts 'episteme' and 'techne' to Gilbert Ryle's concepts 'knowing that' and 'knowing how', and cognitive psychologists' concepts of 'procedural' and 'declarative' knowledge. The distinction relates to knowledge about facts, things and principles on one side and practice-related knowledge on the other. With respect to procedural/"knowing how" type knowledge; there is a difference in interpretations of the concept between knowledge of how to do something and knowledge that manifests itself in doing something (Nickols 2000). The latter aspect entails that a perspective that resembles Polanyi's tacit dimension: that "we cannot reduce to mere words that which we obviously know or know how to do" (Nickols 2000). These distinctions have given rise to a taxonomy of knowledge types (Johnson, Lorenz & Lundvall 2002).

- *Know-what:* knowledge about 'facts' is relatively easy to codify and transfer.
- *Know-why*: theoretical and principal knowledge, like principles and laws in nature and society, or what we usually think of a scientific knowledge. This type of knowledge is usually considered to be codified, but as has been demonstrated in the sociology of science tradition, science involves to a large extent tacit know-how as well. Scientific knowledge is codified and published in papers etc, but at the same time, one can usually not read from the paper how the discovery was made and replicate it. The knowledge in doing science is not codified, but is experience based.
- *Know-how*: knowledge of how to do something and knowledge-in-doing, or expertise. Know how is not necessarily only practical (procedural) but as stated above can involve theoretical knowledge as well. Know-how is usually seen as tacit, although it might be possible to codify know-how. "…but there will always remain irreducible differences between the skills of a hart surgeon and the code-book she uses" (ibid, p. 251). The know-how is experience based; transfer is seen as participation and experience.
- *Know-who*: related to knowing who knows what and who knows what to do, including social and communicative skills in interacting with others. Know-who is naturally context dependent, and is considered to be hard to codify.

The argument is that different categories of knowledge to varying degrees have a tacit dimension and that making knowledge explicit involves different types of codification or articulation processes. Know-what and know-why can in these authors view be easily reduced to information and disseminated. Polanyi on the other hand claims that even knowledge such as declarative statement requires active interpretation by relating new information to experience. According to some authors, know-how can never be codified. Others point to the fact that knowledge, which cannot be expressed by being written down, can still be articulated and taught, or codification can be made incompletely by codifying the rules of conduct, steps and procedures of a performance. Some authors discuss how knowledge can be transferred embodied in artifacts or technologies (Malerba & Orsenigo 2000). Sahal (1981) claims that a technology is not a stand-alone artifact, but relies on a set of processes and products that specifies its use and application. It's the configuration of objects and the knowledge of how to use the artifact (its knowledge base), which together form the technology. This is important with respect to knowledge transfer. "It is not merely the technology that is transferred but also knowledge of its use and application" (Bozeman 2000, p. 629). As such conceptualizations of knowledge are relevant for understanding the processes through which knowledge is distributed or transferred from one agent or site to another.

3.2.2 Conceptualizations of distribution

How knowledge is conceptualized is very important for understanding how knowledge can be distributed. In the literature there are three main perspectives on transfer – diffusion, transaction and learning.

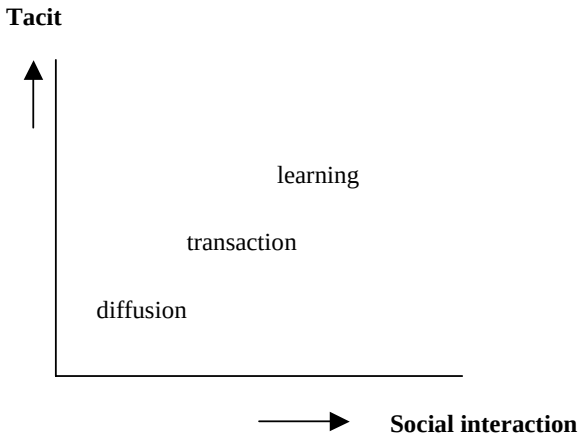

Figure 2: Perspectives on knowledge transfer

In the diffusion perspective, transfer entails a spontaneous and self-controlled process of spreading. The virus metaphor is sometimes used to describe this logic. There is no control over who the senders and receivers are, and the process is not coordinated. When the knowledge is made public anyone interested can access it. This model is based on an information perspective. Knowledge is equated with information and dissemination requires little interaction between senders and receivers.

The transaction perspective sees knowledge transfer as a coordinated transaction between defined agents. It is a defined sender and receiver and a knowledge product that is to be transferred between them. The deal is like any other transaction, regulated by a contract, which specifies the product/services that are to be transferred, the deadline and payment. The knowledge product is developed and built in one place and is transferred to the receiver in finished form or at a given stage of the technology development process. This logic is central in a traditional technology transfer perspective (Harmon et al 1998).

The third perspective perceives the transfer process as a learning process. It is based on an interactive logic with mutual learning between the agents involved (Harmon et al 1998). The roles of the senders and receivers are not clearly delineated. The transfer is two-way in a dyad or multilateral in a network, and is interactive. The learning process is social in the sense that participating in and observing practice or "knowledge in doing" is seen as way of transferring knowledge. This resembles Polanyi's concept

"indwelling". Knowledge is seen as complex and tacit, and transfer of knowledge requires sustained interaction and participation in a community of practitioners. The transfer of knowledge also requires adaptation by the receiver. Absorptive capacity is needed for transfer of knowledge, since the ability to learn from others is grounded in prior knowledge. This distribution model then brings the receiver of knowledge into the picture and breaks down the linear sender-receiver approach to knowledge transfer.

How do these three logics relate to the conceptualizations of knowledge as above? The models of transfer entail different foci with respect to what kind of content they carry. The diffusion model is based on an information perspective, in the sense that the content must be articulated for instance in publications. This form of transfer does not require interaction between the senders and receivers of the information. The focus of the transaction model is on embodied knowledge or technology, at least traditionally speaking. So knowledge is to some extent articulated and embedded in technology and scripts of how to use a particular tool. The transaction model requires clear roles and some form of social interaction between the parties. The learning model based on interaction between participants enables the exchange of tacit and know-how knowledge.

The interactive learning perspective on knowledge transfer is emphasized in recent interactive and systems perspectives on innovation. These theories emphasize mutual learning between different agents as the core driver of innovation (Lundvall 1992, Edquist 1997, Zander & Kogut 1995, Liebeskind et al 1996, Powell, Koput & Smith-Doerr 1996). In this perspective, knowledge is constructed as tacit and complex, and thus it is hard to transfer but can be shared through social interaction. Complex knowledge requires complex and flexible exchange mechanisms. Such mechanisms are developed through interaction between agents over time. This perspective on knowledge transfer poses important requirements for how relationships are formed and how they develop over time.

In the following sections, the interactive learning perspective will be emphasized, in which social relationships is seen as the foundation for knowledge exchange and innovation. This perspective is emphasized because it is fundamental to current research and innovation policies (Remø 2004). First, focus is put on approaches that highlight that characteristics of social relationships, particularly similarities in cognitive capacity, are relevant for understanding knowledge exchange. Following this, focus is put on how and why relationships are formed.

3.2.3 Social relationships and knowledge exchange

The fundamental problem of knowledge exchange is difference – between countries and cultures, institutions and organizations and between individuals. "Strategies for negotiating these differences are always based on an assumption of difference-reduction, the lessening of perceptual gaps among communicative participants" (Dearing 1993, p. 78). As seen in the previous section, analyses of the knowledge conceptualizations illuminated that knowledge, as opposed to information and to some extent technology, requires complex and interactive sharing between participants to be transferred. Thus knowledge exchange is seen as an interactive learning process. But if transfer of knowledge requires active interaction between the parties, then the participants' ability to share and absorb knowledge is central. This ability is based on previous experience (Nooteboom 1999). This assumption is based on a basic insight from cognitive science: to learn something new you must utilize what you already know to provide interpretation and context for new sensory data. The same principle is used on the organizational level of analysis in the absorptive capacity theory (Cohen & Levinthal 1990): Firms' ability to use knowledge developed externally depend on their own internal R&D (knowledge generation) capabilities. If this insight is true, then the similarity in knowledge capability between participants will influence the knowledge transfer process positively. And opposite, the more different participants are the less likelihood for successful knowledge transfer. Thus, Dearing's argument above: the fundamental problem is difference.

Within communication and diffusion research, the conceptual pair homophily and hetrophily is important for understanding how information is transferred between senders and receivers. According to Rogers & Bhowmik (1970) a fundamental principle of human communication is that "exchange of messages most frequently occurs between a source and a receiver who are alike, similar, homophilous" (p. 526). Homophily is the concept used to say something about the likeness or similarity between participants in a communication act and other forms of social interactions, with respect to variables like education, social status and values. Hetrophily then is a measure of difference between parties on such variables.

Why is it so that communication occurs more frequent between similar communicative partners? Communication is more effective between homophilous agents since they in advance share knowledge, information, language, codes and opinions. Communication is more rewarding for the sender and receiver, which again leads to a higher rate of interaction. Homophily and effective communication forms an interdependent relationship. Homophily increases the likelihood of effective

communication. Effective communication leads to repeated interaction, which again leads to increasing homophily (Rogers & Bhowmik 1970; Rogers 2003). Homophily then fosters communication.

However, there is a paradox between homophily and diffusion of new knowledge. On one side homophily enables easier communication, which is beneficial for the transfer of knowledge. On the other, the likelihood of obtaining new knowledge from a similar agent is smaller than from a heterophile one. This is the basic assumption of the "strength of weak ties" theory by Granovetter (1973). Weak ties or distant and infrequent relationships are positive for innovation by providing access to novel information. Weak ties then have important information benefits. "Those to whom we are weakly tied are more likely to move in circles different from our own and will thus have access to information different from that which we receive" (Granovetter 1973, p. 1371). Strong ties, marked by close and frequent interaction, carry less non-redundant knowledge but communication is more efficient.

Homophily acts as a barrier to diffusion of knowledge, but at the same time facilitates transfer of knowledge. Particularly when knowledge is novel, a high degree of homophily will hinder the diffusion process. "Ultimately, the diffusion process can only occur through communication links that are at least somewhat heterophilous" (Rogers 2003, p. 306). Thus, it requires a balancing act. Nooteboom refers to the balance between homophily and hetrophily in transfer of knowledge as the principle of "external economy of cognitive scope" (1999; 2002)

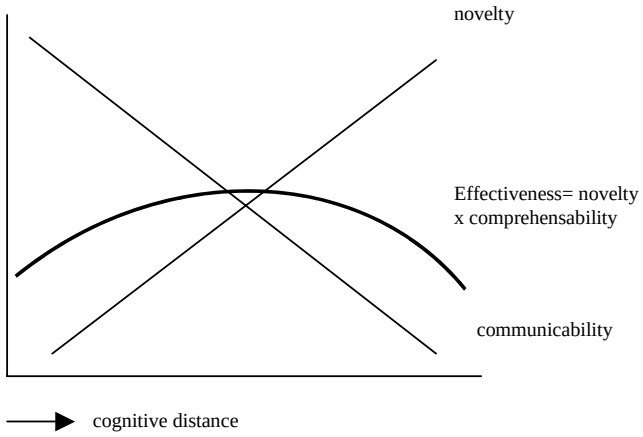

Figure 3 External economy of cognitive scope (Nooteboom 1999)

By this he means that knowledge is contingent upon the social environment, and therefore path-dependent. But to learn new things one also needs complementary, external sources of knowledge. The outside source of complementary knowledge requires a cognitive distance small enough to allow for understanding, but large enough to yield non-redundant knowledge. This principle, Nooteboom claims, explains the absorptive capacity argument - that in order to utilize external knowledge, firms need to invest in internal R&D capability (Cohen & Levinthal 1990). Or in other words, to ease communication of novel knowledge, the receiver needs sufficient knowledge to understand the external source. This can be achieved in two, interrelated ways. Carrying out internal R&D to achieve competencies in that area is a central way of achieving absorptive capacity, particularly if knowledge is codified (relying on weak ties). Interacting with the source of the novel knowledge is another form of achieving absorptive capacity, and is important when the knowledge involved is dominantly tacit and new (relying on stronger ties).

Some authors do however claim that the benefits of different ties (homophile strong ties and heterophile weak ties) for sharing of knowledge also depend upon the different types of knowledge dissemination activities used (Hansen 1999). Hansen discerns between search and transfer activities and his argument is that the benefits of tie strength are relative to the kind of learning activity carried out. Weak ties with novelty benefits are superior for search activities; that is when an individual or group is scanning for and

identifying knowledge from external sources. Strong ties with comprehensibility benefits are more important for transfer activities; when the knowledge identified is to be is transferred and accommodated in a new context. Thus, different ties are important in different stages of the knowledge transfer process.

This distinction also relates to properties of knowledge as discussed in the previous section. The strength of weak ties argument is built upon an information perspective where transfer of knowledge is easy, costless and instantaneous. Focus is put on how weak links provide access to novel information, but does not say anything about how knowledge flows from the source to the recipient. But when knowledge is seen as tacit, complex and hard to "move", strong ties enabling frequent two-way interactions are beneficial for transfer (Hansen 1999). Thus, Hansen argues, that the benefits of different ties are relative to type of knowledge to be transferred, as well as types of learning activities.

KNOWLEDGE	TIE STRENGHT	
	Strong	*Weak*
Noncodified, dependent	Low search benefits, Moderate transfer problems	Search benefits, Severe transfer problems
Codified, independent	Low search benefits, Few transfer problems	Search benefits Few transfer problems

Figure 4 Search and transfer effects, knowledge complexity and tie strength (Hansen 1999)

Innovation requires some degree of novel knowledge or ideas acquired from a heterophilous other, and at the same time this knowledge is hard to communicate and absorb due to "perceptual gaps". If this theory is true, then we assume that collaboration in innovation processes requires a balance between homophily and hetrophily. Partners need to be sufficiently different to carry some novel knowledge, but also sufficiently similar to be able to communicate efficiently. Since this is a question of balance, the relationship between agents will be henceforth discussed in terms of proximity, as a concept for closeness but not overlap between somewhat heterophile agents.

As seen above, transfer and absorption of knowledge in interorganizational and interpersonal relations requires a balance between distance leading to the access to novel knowledge and ideas, and familiarity which enables

communication and absorption of knowledge. The theory proposes that this balance of concerns is at the root of the knowledge transfer problem, and explains why proximity is seen as important for innovation. “Technological innovation is a process that is based on relationships of proximity, the forms, modes and combinations of which might be quite varied” (Kirat & Lung 1999, p.29). Kirat & Lung (1999) claim that there are two dominant views on the sources of proximity – one geographical and the other technological.

Geographic proximity is the most intuitive meaning of proximity, and indicates that agents are positioned within a determined space. Simply put that agents are located at the same place, territorially defined. Geographical proximity is not the same as physical proximity, which is the outcome of natural constraints or natural borders like mountains or fjords. Geographical proximity can also be a social construction, in the sense that communication networks, transportation, etc create space and regions. Many studies have linked geographical proximity and its positive effect on transfer of knowledge (Almeida & Kogut 1999, Vedovello 1997). This is the central focus in research on local and regional innovation systems (Saxenian 1994). A central argument is that spatial proximity leads to increasing interaction between agents, in the form of informal social interaction, networks, and mobility. From these largely informal contacts, knowledge spills over organizational boundaries (Almeida & Kogut 1999), which is beneficial for diffusing knowledge and ideas. Informal contacts are also seen as a seedbed of formal cooperative relations (Larson 1992).

According to Kirat & Lung (1999), the other dominant view emphasizes technology as a source of proximity. Technological proximity is by them defined as “interdependencies woven between the various activities within the scope of ‘production relationships’” (p. 29). Interdependencies can be defined both horizontally and vertically, interdependencies between organizations in R&D-production relationships, and similarities in production. Essentially, technological proximity concerns the extent to which organizations are similar in what they produce and how they produce it. But underlying this is also similarity in the technological knowledge base, the technological and scientific knowledge underlying the use of technology. It is in this latter sense that we can talk about technological proximity between science and industry.

The technological proximity perspective is related to research that focuses on technological systems or regimes (Breschi, Malerba & Orsenigo 2000, Carlsson & Stankiewicz 1991). Breschi, Malerba & Orsenigo (2000) defines a technological regime as “a specific combination of technological opportunities, appropriability of innovations, cumulativeness of technical advances and properties of the knowledge base” (p. 391). They further claim

that these factors affect how innovative activities are organized in different technological sectors. With respect to university-industry knowledge interaction, focus has been put on properties of the knowledge used in innovative activities, and particularly on identifying science-based technologies (Pavitt 1984, Meyer-Krahmer & Schmoch 1998). A science-based technology refers to the extent to which scientific knowledge has been central in developing that technology. This has usually measured by reference to scientific publications in patents, and as such can be seen as related to the proximity between a science field and a developing technology or technological sector.

This latter point reflects a more general aspect of technological proximity, which relates to the question of cognitive proximity or closeness in cognitive repertoires. "If knowledge is contingent upon categories of thought, and these develop in interaction with the physical and social environment, then cognition is path-dependent and idiosyncratic. People will be able to understand each other only to the extent that they have developed their categories in a shared environment and in mutual interaction" (Nooteboom 1999, p.140). Formal education is an important source of common cognitive repertoire of highly educated employees in both industry and universities. Porac et al (2004) investigated productivity of scientific alliances, and found that that:

> (…) knowledge sharing and collaboration in alliances will be easier when the partners involved have prior experience collaborating with each other, deep experience in the relevant knowledge domains, are similar in their disciplinary backgrounds and professional qualifications, and are working in disciplinary programs with codified methodological and theoretical paradigms that cross-cut organizational boundaries (Porac et al 2004, p. 644)

Having a joint cognitive repertoire stemming from education, experience and previous interactions, is seen to enable exchange of knowledge in collaborative relationships. An implication of this analysis is that relationship between agents in collaborative relationships will matter a lot for knowledge exchange processes. According to Hansen (1999) there is a strong relationship between the type of knowledge to be transferred, and the quality of social relationships intended to transfer knowledge. The strength of ties argument proposes that when the knowledge is complex and tacit, strong ties are needed to transfer knowledge. The homophily concept (Rogers & Bhowmik (1970) and the absorptive capacity argument by Cohen & Levinthal (1990) propose that transfer of knowledge requires some degree of similarity, for the transfer to have any effect, but allowing for difference to include novelty, a principle that Nooteboom (1999) refers to as "external

economy of cognitive scope". Both of these perspectives argue for an interactive or exchange perspective on knowledge transfer based on analyses of properties of knowledge, in which the relationship between agents is the central knowledge transfer tool. In the next section, the relationship perspective will be further explored by looking into how exchange ties are formed and hoe they develop. Here focus is not on knowledge exchange ties particularly, and tie formation is investigated at the interorganizational level. The central question addressed here is: If exchange of knowledge depends on the relationship between agents, then how are such ties formed, why are ties formed, and with whom are ties formed?

3.3 Formation of ties

Within the literature that deals with the formation of relationships between organizations there are two dominant perspectives (Gulati 1995; Gulati & Gargiulo 1999, Ahuja 2000). One approach focuses on explaining why relationships emerge, emphasizing the inducements agents have for establishing ties. Several theoretical frameworks are used as explanations for the formation of interorganizational relationships, including resource dependence, imitative behavior and learning (Oliver 1990, Gulati 1995, Ahuja 2000). Such frameworks differ in the explanations of why organizations enter into alliances, but have in common the focus on the inducements organizations have, seen as determinants of interorganizational relationships (Oliver 1990). Questions of with whom organizations form alliances, is not explored. This is however a focus in social network approaches, which explain tie formation with reference to prior relationships and the social structure in which an organization is embedded (Ahuja 2000, Gulati 1995, Uzzi 1997). This perspective focuses on with whom organizations ally, and through that, explaining why and how relationships are formed. Where as the first perspective focuses on the inducements, the second targets the opportunities organizations have for linkage (Ahuja 2000).

Ahuja (2000) and Gulati (1995) claim that both of these perspectives provide insight into linkage formation behavior, but neither provides a complete picture. The inducement perspective assumes that the availability of alliance partners is not constrained, which, according to Ahuja (2000) is a debatable assumption. The opportunity perspective, on the other hand, explains linkage formation by reference to participation in prior established networks. This perspective has a limitation with respect to explaining how new actors form ties, since they lack the network resources needed to form relationships. Ahuja (2000) claims that the two perspectives can be usefully integrated,

focusing on both the actors' inducements to collaborate and their opportunities to do so. Due to this, first opportunity theory of tie formation is presented, followed by incentive theory of tie formation, and drawing upon both perspectives in a process framework of tie formation.

3.3.1 Social capital and formation of ties

The structure of relationships, and the resources that stems from these, can be seen as resources available for an agent to utilize in the course of action. Resources available through social relationships are in research literature usually defined as "social capital" (Bourdieu 1986, Portes 1998, Coleman 1990, Ahuja 2000, Nahapiet & Ghosal, 1998). Several definitions of social capital exist (Adler & Kwon 2000). Some researchers focuses on social capital as a resource for the individual actor, where as other strands of social capital research focuses on describing social capital as a characteristic of collectives or social systems (Sandefur and Lauman 1988). Focusing on social capital as a characteristic of social systems, Nahapiet & Ghosal (1998, p. 243) defines it as:

> The sum of the actual and potential resources embedded within, available through, and derived from the network of relationships possessed by an individual or social unit. Social capital thus comprises both the network and the assets that may be mobilized through that network.

Social capital is seen as a form of capital, in the sense that it can be invested in for future benefits and can be used for productive purposes (Coleman 1990). Like human capital it requires maintenance to remain productive and does not loose value when it is used. Social capital rests in the relationships between people, not in the actors themselves. As such, social capital can never be individually owned, as it is dependent on the interaction of individuals (Lesser 2000). Neither can social capital be traded, but it can be shared. This makes social capital different than other forms of capital. Mutual obligations, trust, access to information and opportunities, status and reputation are examples of resources that are available through membership in social networks. And since social capital is a set of actual and potential resources, it has many attributes. Nahapiet & Ghosal (1998) identifies three dimensions of social capital – structural, relational and cognitive dimensions.

The structural dimension of social capital concerns the "impersonal configurations of linkages between people and units" (Granovetter 1992) – who you reach and how you reach them (Nahapiet & Ghosal 1998). Focusing on the structure of connections between actors means identifying

the existence or absence of links between actors, the density and connectivity of ties in a network. The character of the links and the structure of the network give the actors in the network access to resources and opportunities.

In social capital theory, network ties are seen as instrumental resources for action. A network can be defined as a set of direct and indirect social relationships centered around a given person, object or event (Meyerson 2000). Ties between nodes in a network can be described as strong or weak, and network structures can be described as dense or sparse. Both weak and strong ties in a network provide organizations with information about potential partners and opportunities to form new linkages. The conceptual pair strong and weak ties (Granovetter 1973) are central in both alliance formation studies (e.g. Uzzi 1996) as well as knowledge transfer research (e.g. Hansen 1999). According to Granovetter (1973, p. 1361), "the strength of a tie is a (probably linear) combination of the amount of time, the emotional intensity, the intimacy (mutual confidence), and the reciprocal services that characterize the tie". Strong ties are relationships characterized by close and frequent interaction, where a lot of time and emotions are invested in the relationships. Typical examples include friendships and familial relationships. Weak ties on the other hand are relationships where contact is less frequent and with less investments of time and emotions, for instance social acquaintances. Lazzarini & Zenger (2002, p. 4) have modified the definition of tie strength to interorganizational relationships and define it as "the degree of commitment that supports an exchange relationship for the transfer of goods, services, or information". But instead of treating tie strength as a static characteristic of relationships, Lazzarini & Zenger (2002) argue that tie strength is dynamic: over time weak ties might grow strong and strong ties might weaken.

Relational embeddedness "describes the kind of personal relationships people have developed with each other through a history of interaction" (Granovetter 1992 in Nahapiet & Ghosal 1998, p. 244). The relational side of social capital focuses on how the social relations such as respect and friendship between people influences their behavior. Thus this concept focuses more on the content and effect of the connections rather than their structure. Trust, norms and sanctions, obligations and expectations, identity and identification, status and reputation are examples of relational social capital resources.

In addition to structural and relational aspects of social capital, Nahapiet & Ghosal (1998) also include a cognitive dimension, but add that these resources have not been discussed much in the literature on social capital. By the cognitive dimension they mean resources that provide "shared

representations, interpretations and systems of meaning among parties" (ibid, p. 244). Examples of cognitive social resources are common language, codes and shared narratives.

These resources are quite different in character, but have in common that they are properties of a social system of interaction and that they facilitate the actions of actors in the network (Coleman 1990). The resources are not necessarily positive, in the sense that they are always benefits. Social capital can also have negative effects. Being in a densely connected network also constrains the information and opportunities available to the actor (Adler & Kwon 2000).

Social capital research has investigated a large number of questions relating to social structure and action. For the sake of this analysis, emphasis is here put on one question: how are ties formed? Social capital research explains the formation of ties endogenously. That is, that the formation of relationships rises out of the social network in which an organization is embedded (Gulati 1995). Prior strong and weak ties form a repository of resources and opportunities for the focal organization about potential partners. Such structures can explain with whom organizations ally and how they form ties (Gulati 1995, Gulati & Gargiulo 1999).

In terms of structural resources, being embedded in a network of ties facilitates the formation of new ties (Ahuja 2000, Granovetter 1985, Gulati 1995, Gulati & Gargiulo 1999). Information stemming from strong ties is regarded as trustworthy and reliable, but less non-redundant information is available through strong ties (Granovetter 1985). Weak ties are central for access to new information and new opportunities (Granovetter 1973), and third party referrals are central for the formation of new ties (Uzzi 1996). "Better than the statement that someone is known to be reliable is information from a trusted informant that he has dealt with that individual and found him so. Even better is information from one's own dealings with that person" (Granovetter 1985, p. 490). The latter point to that previous interaction between organizations or people leads to the development of trust and through that reputation in being a trustworthy collaborator - two network resources that can lead to the formation of further ties.

Relational social capital like trust and reputation develop from direct social interaction, especially in strong interpersonal ties (Gulati 1995, Uzzi 1996). This highlights the role of interpersonal relations for the formation of interorganizational ties. "Personal reputations, as well as histories and individual friendships, were important factors in explaining the formation of ties" (Larson 1992, p. 84). Strong ties in addition to developing trust, also has a cognitive aspect. Through previous interactions the partners learn

about each other's needs, capabilities and competences, and might also lead to internal capabilities of how to manage the relationship in the organizations. This knowledge forms the basis for development of further ties between the organizations.

This framework explains how ties are formed with the basis in prior relationships. But are there any social capital explanations for how completely new relationships are formed? If formation of ties depends upon having prior ties and resources such as trust, reputation and information, how can new organizations ever enter networks? Uzzi's (1996) concept of referral networks sheds some light on how new ties emerge in social capital terms. Referrals create new ties by connecting previously unconnected actors and at the same time "equip the new exchange with resources from preexisting embedded ties" (Uzzi 1996, p. 679). The connector establishes trustworthiness between the new actors through using her common link to both of them, thus transferring the behavioral expectations from one link to another. Being referred a new tie through a previously established strong tie increases the reputation and trust in the new relationship.

By focusing on with whom organizations ally, social capital researchers are able to explore the preconditions for tie formation. Tie formation in this perspective is a result of previous indirect and direct ties and the resources stemming from these ties. These resources gives organizations opportunities for collaboration, information about potential partners and equips the collaborators with social and cognitive "start capital" which enables them to form ties. The extent to which they do form ties can also be seen as related to the inducements to form ties, which will be discussed below.

3.3.2 Interdependence and inducements for tie formation

Tie formation is also explained by reference to the incentives organizations have for entering into alliances (Oliver 1990, Gulati 1995, Gulati & Gargiulo 1999, Ahuja 2000, Doz, Olk & Ring 2000). Such explanations focus on *why* organizations link with others by reference to factors in the external environment of the organization that triggers them to seek partnerships. Tie formation is then seen as a strategy for coping with environmental interdependence. "Interdependence exists whenever one actor does not entirely control all of the conditions necessary for the achievement of an action or for obtaining the outcome desired from the action" (Pfeffer & Salancik 1978, p. 40). Organizations are rarely self-sufficient, and its interdependence on the environment impacts on its ability to achieve its desired outcomes. Since organizations are not self-sufficient, they must rely on the environment to provide support and engage in exchanges with other

groups or organizations for needed resources. Through forming ties to other organizations in the environment, the focal organization is able to procure resources and reduce uncertainty. “Interorganizational cooperation is thus a means by which organizations manage their dependence on other organizations in their environment and attempt to mitigate the uncertainty generated by that dependence” (Gulati & Gargiulo 1999, p. 1443).

In addition to the general environmental interdependence perspective, particular contingencies that motivate organizations to form interorganizational ties have been identified. Oliver (1990) provides an overview of six contingencies: necessity, asymmetry, stability, legitimacy, reciprocity and efficiency. By grouping them together, three broad perspectives on environmental contingencies that motivate formation of ties are identified. The contingencies asymmetry, stability and legitimacy all focus on that organizations establish linkages or exchanges with others as a way of coping with uncertainty stemming from dependence on the environment for resources of various kinds. Forming ties with organizations is a way for organizations to attempt to manage this uncertainty by procuring needed resources, create stability and/or gain power. Within the literature on interorganizational ties between firms, resources like specific competences, financial resources, power and legitimacy are mentioned as resources obtainable through forming ties to others (Eisenhardt & Schoonhoven 1996).

As discussed in the introduction and in chapter 2, resource dependence is a general framework used for explaining why firms and universities form ties, where knowledge intensive firms enter into ties with universities to get access to specialized competences, and where tie formation on part of the university is explained in terms of need for research funding. In terms of the competence resources, Teece’s (1986) framework of core and complementary assets in innovation is of relevance for understanding strategic competence needs in the innovation context. His argument is that in addition to the firm’s core technological know-how, a large number of complementary resources are needed for a successful innovation. He further argues that there are different degrees of dependence between core and complementary resources in different innovations. The specificity of the dependence between core and complementary resources in an innovation impacts on firms’ decisions of how to procure resources. The criticality of specific complementary resources and extent of investment needed to access the resource determine firm strategy.

The contingency reciprocity concerns that organizations might share common goals or interests and this commonality motivates them to form ties (Oliver 1990). But whether having common interests in itself is a motivation for forming ties, probably depends on what kind of goals or interests in

question. This perspective is similar to the social capital theory of tie formation, since it presupposes the existence of previous relationships.

Necessity points to the perspective that there might be other organizations in the environment that influence the formation of a tie beyond the immediate collaborators. According to Oliver (1990) most literature on interorganizational alliances assumes that alliances are voluntary arrangements entered into by equal partners. There is however good reasons to believe that organizations might form ties because an external agent triggers them to do so. Broadening the perspective of necessity, leads to the question of the role of triggering agencies in alliance formation processes (Doz, Olk & Ring 2000). Governmental agencies, individual "champions", industry organizations or specific firms can in some formation processes act as a trigger or champion who acts to facilitate the formation on an interorganizational relationship. Triggers are relevant in situations with less environmental interdependence and similar interests between organizations. Ties are formed because "champions create the perception of the need for the collaboration" (Doz, Olk & Ring 2000, p. 251). This latter perspective indicates that preconditions and motivations are integrated in tie formation processes, an issue that is discussed below.

3.3.3 A process perspective on tie formation

The two perspectives presented above shed light upon the formation of interorganizational ties by focusing on two separate questions. The inducement perspective focuses on why organizations enter into relationships; the conditions that lead to relationship formation and the organizations' inducements. The opportunity perspective on the other hand focuses on who organizations form ties with, looking into the social structure in which the organization is embedded as an explanation for how, why and with whom ties are formed. Several authors emphasize that these are equally valid perspectives, and aim at developing integrative frameworks that recognizes the duality of tie formation (Gulati 1995, Gulati & Gargiulo 1999, Ahuja 2000). Ahuja (2000, p. 318) integrates the perspectives by focusing on that links are formed "only when actors with inducements to form linkages are successful in finding collaboration opportunities". But this explicit recognition does not resolve the issue of how the two foci, inducement and opportunity, fit together. Is it so that organizations develop a motivation for tie formation and then use the social structure to find partners, as Ahuja suggests? Or can it be that opportunities give rise to inducements? To gain some further clarification on this issue, this section will look into process frameworks on tie formation.

Larson (1992) developed a phase model of network dyad formation based on an exploratory ethnographic study of entrepreneurial firms. Her data suggest that the formation process of network dyads has three phases. In the first phase the preconditions for the exchange are developed. Central here are prior personal relationships, and personal and firm reputations, which become the source of mutual trust on which the new relationship is based. These factors reduce uncertainty and establish the expectations that enhance early cooperation. According to her, the "social context provides the environment within which economic exchange can be initiated" (ibid, p. 84).

After this informal phase of the relationship, the transformation into a stable and formal exchange relationship might progress. The conditions to move from an informal to a formal relationship involve both considerations of economic advantage by both parties, but also the further development of trust and norms of reciprocity during a "trial period". Larson claims: "The ties undeniably required conditions of mutual economic advantage, but the data strongly suggest that these were necessary but not sufficient rationales" (ibid, p. 87). An incremental development process through which the organizations get to know each other and how to work together are important steps in the establishment of a new dyad. The trial phase leads to an institutionalization of rules and procedures, as well as the development of clear expectations, which together form the initial structure for exchange.

In the last phase the relationship solidifies through integration between partners. Operational integration, strategic integration and integration and control through social relations become important forms of coordination as the relationships mature. Ring & Van de Ven (1994) highlight the institutionalization process of interorganizational relationships, through which informal coordination processes, personal relationships and psychological contracts gradually supplant formal contracts and formal processes of coordination.

Larson's ethnographic account of tie formation processes reveals that both incentives and social structure are important factors for tie formation. She does however suggest that resources available through the social structure in which the organization is embedded, like personal friendships, reputations and trust are important preconditions for exchange even before the motivation for forming a tie has been made explicit.

After Larson developed her framework, more refined process models of tie and network formation have been developed, identifying both more phases and activities in the formation process, but also variances in formation processes. Doz, Olk & Ring (2000) identify nine phases of collaboration development, but claim that not all phases are equally important in all

formation processes due to the initial conditions that spurred the decision to form ties. They relate the initial conditions to two different formation processes: emergent and engineered. Ring, Olk & Doz (2005) later added a third formation process that they called embedded. Their argument is that different initial conditions lead to different formation processes. When environmental interdependence and similar interest motivate organizations to cooperate, the formation process follows an emergent pattern. But when a triggering entity initiates the cooperation, the formation process follows an engineered pattern. When the potential collaborators from the onset enjoy strong social relationships, formation processes follow an embedded pattern. In the first, organizations experience common environmental threats or face a common need for resources, which lead them to form a tie. Their common interests generate a consensus on the domain of their cooperation, and establish a strong expectation of continuity of interaction. This expectation leads them to develop a formal structure for their relationship. In the engineered pattern of tie formation, an intervention of a triggering entity is a necessary condition for tie formation. The organizations do not experience strong external stimuli to cooperate, like a common threat or need of resources, and do not have an apparent common motivation. The champion creates "a perception of the need for the collaboration" (p. 251). With this as the starting point, the formation process follows a "hub and spoke" approach, where the nodes in the network cooperate with the triggering agent, but only indirectly with each other. Since the organizations at the start do not recognize similar interest, their expectations to the relationship are likely less, and the relationships tend to have an explorative orientation. However, with increasing cooperation the organizations develop similar interest, and in time, Doz, Olk & Ring (2000) argues, engineered alliances will lead to networks governed by emergent processes.

In terms of the explanatory frameworks of tie formation, the two alliance formation processes have interesting input. Doz, Olk & Rings (2000) data suggest that in some instances organizations have an explicit motivation to cooperate, which leads them to search for alliance partners using a snowball process. However, Doz, Olk & Ring claim (ibid), the partners are likely to be from the same industry, and are embedded in a social network already. The engineered process on the other hand is about creating new relationships between organizations that do not have an explicit motivation to cooperate when the tie is formed. This formation process requires a triggering entity. Over time the experience in cooperation leads to common interest, which forms a motivation to continue the cooperation.

Although the two processes look quite different, it seems to be the same dynamic that drive the formation process: Opportunities for cooperation leads to development of motivation for cooperation which again strengthens

opportunities for cooperation. This seems to be a particularly apt description of the formation of new ties. Organizations that are not embedded in a social structure and that do not share common interest, form ties when a triggering entity is able to create a perception of the need of cooperation. Over time, cooperation leads to common interest, expectations of continuation and trust between participants that further embed the organizations in a social structure on which new ties are formed.

This section has discussed two general perspectives on tie formation and a framework that integrates the two perspectives. Social capital research indicates that formation of ties is related to the network in which a focal agent is embedded, which gives the agent opportunities for forming ties. Incentive oriented explanations focuses on the motivations organizations have for forming ties, seen largely in terms of interdependence with other organizations in the environment for important resources. The two perspectives form an integrated process framework for exploring tie formation processes. In the next section, the aim is to integrate the perspectives developed above, for the purpose of establishing a conceptual framework for exploring tie formation processes in the university – industry setting.

3.4 Towards a conceptual framework for exploring formation of university – industry collaborations

In the theoretical framework three perspectives were presented to shed light upon knowledge interaction as a social phenomenon. First knowledge interaction was analyzed from a knowledge perspective, focusing on communicative characteristics of knowledge and relationships intended to transfer or exchange knowledge. An insight taken from this analysis was that knowledge might be hard or impossible to transfer as information. When knowledge is tacit and complex knowledge transfer takes the form of sustained social interaction. This puts requirements on the relationship between the sender and receiver in terms of some degree of similarity in knowledge capacity. In innovation processes, the transfer of novel knowledge is central, posing additional problems for knowledge transfer through social relationships. The balance between homophily and novelty was discussed as a relationship of proximity. Literature suggests that proximity can have different sources and take on different forms, and focus was put on the role of knowledge proximity.

The second perspective emphasized in the theoretical framework extends this idea by looking into knowledge interaction from a social exchange

perspective. In this perspective, the character of the relationships intended to foster knowledge exchange is central. And due to this, who collaborates and how ties are formed is seen as relevant for understanding knowledge interaction. The social network in which organizations are embedded, and the resources available through the network, are seen as central for understanding tie formation and interaction in collaborative relationships. However, the organizations' tie formation motives are also seen as relevant.

Below these analyses will be used to conceptualize knowledge networks as a precondition for formation of knowledge exchange ties. With the theories presented above as a guiding framework, knowledge networks are conceptualized along two main dimensions - a cognitive and a social dimension. Following this, a framework is suggested that integrates preconditions, tie formation and exchange experiences.

3.4.1 The knowledge network concept

Since university – industry interaction as defined in this study concerns interaction with the purpose of exchanging knowledge over organizational boundaries, the process will be influenced by the communicative properties of knowledge and characteristics of the participants. Theory of knowledge transfer suggests that if knowledge is tacit and novel, sustained social interaction is needed for transfer. To communicate knowledge in such ways, puts requirements on the relationship between participants. To transfer knowledge requires that participants are to some extent homophile in terms of cognitive repertoires. This repertoire, Nooteboom (1999) claims, develops in a shared environment and in mutual interaction. Formal education is a dominant site for the development of the cognitive repertoire of scientist and engineers and other highly educated employees. From a knowledge perspective, some degree of similarity in cognitive repertoire stemming in part from university education is likely a precondition for the exchange of knowledge between firms and universities. For instance, firms or industrial sectors that employ university graduates from a particular science field are cognitively proximate with that field of knowledge (Schartinger et al 2002). They are able to share knowledge with the university because they share educational backgrounds, and through that cognitive categories, codes and language (Nahapiet & Ghosal 1998).

An interrelated point concerns the existence of a cross-organizational codified body of knowledge for facilitating knowledge exchange. Porac et al (2004) investigated knowledge exchange in scientific alliances and found that collaborative research teams working within traditional areas of research characterized by a well established disciplinary paradigm are more

productive than teams working in emerging disciplines. When there is established a codified body of theoretical and methodological knowledge that crosses organizational boundaries and which participants share, knowledge exchange is easier.

In terms of a social dimension to the concept knowledge network, the structure of relations and the resources available through those structures are relevant dimensions. As seen above Granovetter (1992) and Nahapiet & Ghosal (1998) discern structural and relational dimensions of social capital. Structural embeddedness points to the system of direct and indirect linkages between agents and units, which give access to information and opportunities. Relational embeddedness, on the other hand, points to the personal relationships people have developed as a result of previous interactions, and the resources stemming from previous interactions such as trust, reputation, obligations, status and identity.

Bearing in mind these two aspects, knowledge network embeddedness can be seen as a source of both a network of links between agents and units (structural), and resources stemming from previous direct personal interaction (relational). Long-term human capital relations between industry and universities can be seen as network of direct and indirect ties giving the agents access to opportunities for forming ties and information about potential collaborators. Human capital relations can also be seen as a source of relational embeddedness between firms and university departments, as some agents during formal education or later have engaged in previous direct interaction. Through those interactions, mutual trust, norms of reciprocity and reputation have developed which in turn impacts on who firms and universities collaborate with. The relational ties lubricate social exchange, promote cooperation and facilitate communication.

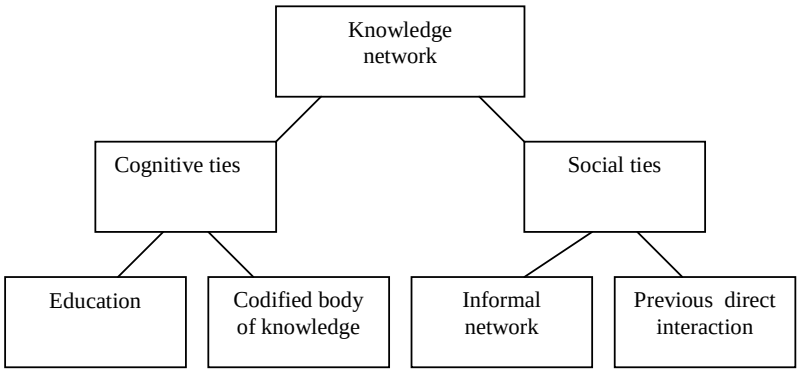

Figure 5: Knowledge network concept

The knowledge network concept attempts to capture the existence and density of ties between industrial sectors and academic fields (and between firms and university departments). These ties are both of a cognitive and social nature. Cognitive ties or a joint cognitive repertoire stemming from a common educational background and a codified body of theoretical and methodological knowledge, impacts on the ability to share knowledge over organizational boundaries, since cognitive categories are developed in a joint environment. As such it has a direct impact on the knowledge exchange process. Social ties, both the structure of ties and resources stemming from previous direct interaction, furnish potential collaborators with opportunities for linkage and resources needed to form and succeed with collaboration. Social ties impact on the knowledge exchange process indirectly by influencing the tie formation process and directly on the knowledge exchange process through providing social capital that positively influences the exchange process.

3.4.2 Towards an integrated framework

As described above, there are two general perspectives on tie formation. One perspective targets the motives organizations have that induces them to form ties. Here tie formation is seen as a strategy for dealing with uncertainty and dependence. The second perspective emphasizes the opportunities organizations have for forming ties, rising out of the networks in which they are embedded. A third and integrated perspective, empirically observing the tie formation process, highlights that motivation and opportunity are related issues in tie formation.

Doz, Olk & Ring (2000) have investigated variance in tie formation processes, which they see related to different initial conditions. The social structure and resources available through the structure such as trust, reputation and information give organizations opportunities to cooperate, but also leads to recognition of a common interest and explicates motivations for cooperating. When organizations lack a common structure, a triggering entity function as a reserve structure for connecting previously unconnected organizations and create a perception of a need to cooperate. In time, however, cooperation leads to common interests and embeds the organizations further in a social structure from which further ties form.

Thus both opportunities and resources for forming ties and inducements are seen as preconditions for entering into formal collaborative arrangements. Larson (1992) describes an informal, preconditions phase in tie formation, followed by the formal establishment of the collaborative arrangement. Larson argues that in the informal phase, the preconditions for entering into formal collaborations develop through gaining opportunities through informal relations and developing social capital resources like trust and reputation. On this basis, the organizations develop or make explicit the strategic inducements for creating an alliance. The formation is followed by an implementation phase where integration between the organizations in terms of routines, tasks and strategies is central. The exchange experiences itself further embed the organizations in a social structure and create social resources from which further ties form.

Focusing on this process framework, the following figure describes the conceptual framework in the study. Below its constituent parts will be described and the theoretical assumptions on which it is built will be outlined. The framework is not a theoretical model and conceptual foci are intended as sensitizing concepts and as tools for interpretation[4].

[4] This approach is explained further in chapter 4.

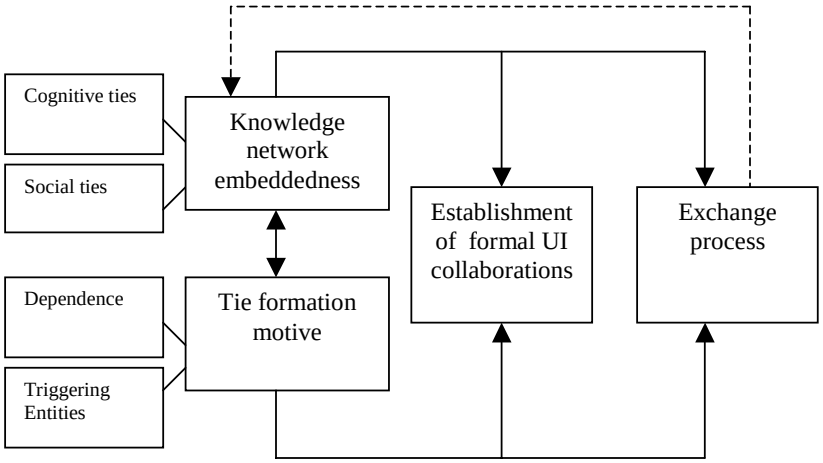

Figure 6: Conceptual framework of study

In this study, the focus is on exploring the relationship between informal ties between academic fields and industries – which is conceptualized as knowledge networks - and the development of formal collaborative ties between firms and universities. The interest lies in exploring the formation of knowledge exchange ties, and the relationship between preconditions, formation and interaction experience.

Knowledge network is the concept developed in this study as a label for the cognitive and social ties between universities and industries, forming a social and cognitive structure in which potential collaborators are embedded. Access to potential collaborators, social resources and a joint cognitive repertoire stemming from a common educational background, a body of codified knowledge, prior interaction experiences and informal relationships are seen as preconditions for formation of ties intended to exchange knowledge.

Where knowledge networks act as a structure of opportunities and resources enabling formation of ties, to enter into formal collaborative arrangements inducements for forming ties are also relevant. Above, a general framework of environmental interdependence as an explanation of why organizations enter into alliances was discussed (Oliver 1990). Interdependence on other organizations for resources creates instability, and organizations enter into

alliances as a way of coping or managing their interdependence. In university – industry relations, the resource dependence argument is well established but has several facets, as discussed in chapter two. On the part of industrial sectors or firms, a general knowledge intensity argument is a central explanation. Industrial sectors that rely on scientific knowledge input in production, which are oriented towards radical innovation processes, and have internal R&D capability, are seen as knowledge intensive. They are seen as dependent on scientific knowledge and are thus motivated to form ties to research environments, like universities and governmental R&D labs, who have those resources. As argued by Teece (1986) dependence is stronger when there is dependence between a firm's core competence and external complementary assets. On the university side, the resource dependence argument is equally widespread. Universities form ties with firms because it gives them access to more research money and equipment. Universities are motivated to form such ties because public funding of academic research has decreased. To reduce the uncertainty due to environmental change, universities are motivated to seek external funding and commercialize research (Slaughter & Leslie 1997).

In addition, the question of triggering entities, motivating universities and firms to create ties, is seen as highly relevant in cases where interdependence is not experienced (Doz, Olk & Ring 2000). And as will be discussed in chapter 5, several agencies and programs are intended to trigger the formation of ties between firms and universities in Norway, by providing funding for cooperative research projects between firms and universities.

Further, both knowledge transfer theory and social capital theory assume that cognitive proximity will shape the experiences in collaborating, by providing a new tie with cognitive and social resources needed for knowledge exchange. As discussed above, the ability to exchange knowledge is related cognitive repertoires, which is also seen as a product of previous social interaction. The implication of this viewpoint is that agents who share a common cognitive repertoire are more likely to experience a positive knowledge exchange process. Also, social capital theory suggests that relational social capital resources such as trust and norms of reciprocity stemming from previous interaction facilitate positive exchange experiences.

As will be presented in the next chapter, this framework was developed through interplay between data and theory, and where the ambition was to develop a theoretically informed and empirically grounded framework for understanding how ties are formed in the university-industry context and how knowledge is exchanged in such arrangements. The empirical part of the study is an exploratory study of formation of formal collaborative R&D projects in two academic fields. The methodological framework for the study is outlined in the next chapter.

Chapter 4: Methodological framework of study

4.1 Purpose and research strategy

This aim of this chapter is to outline a methodological framework for the study, taking as a point of departure the research problem and the objectives of this study. Secondly, a description and analysis of the epistemological perspective embedded in the focus and methodology chosen in this research project is carried out. With the reflections about the purpose and epistemological perspective in this research project as a basis, specific questions concerning the methodological perspective are addressed. This will be followed by a description of the methods of data collection and analysis utilized in the study. The question of quality criteria for qualitative research is finally discussed and descriptions of the tools for ensuring quality and relevance in this research project are provided.

As seen in the introductory chapter the overall purpose of this study is to investigate formation of collaborative R&D relationships between firms and universities. The reason behind choosing this focus was that research on university-industry interaction traditionally has focused on interaction between technological academic fields in universities and firms in knowledge intensive sectors. The basic argument in most research on UI interaction is that firms or industries that are knowledge intensive and dependent on scientific knowledge are motivated to interact with universities and other R&D institutions, which on their side are seen as dependent of firms for resources. Tie formation behavior is a rational response to their interdependence. So it is a dominant incentive oriented explanation model for tie formation in UI relations, as seen in chapter 2. However, the few comparative studies that have been made suggest that interaction is concentrated in, but is not limited to knowledge intensive economic sectors and technological knowledge fields. Interaction is spread and do not follow obvious and simple patterns (Schartinger et al 2002). This observation does not disqualify the assumption that knowledge intensity is a precondition for formation of interaction ties, but indicates that there might be other factors that are also relevant for understanding tie formation processes and behavior in this context. The opportunities and resources agents have for forming ties stemming from their embeddedness in a social structure can be seen as an additional explanation to incentive oriented explanations. Based on this, the

investigation of the formation of research collaboration projects is one of the main purposes of this study. As seen in chapter 2, this is an area where little research has been carried out. However, one observation is interesting since it gives insight into how ties are formed. Schartinger et al (2002) claim that graduate mobility is a measure of "knowledge proximity" between university departments and firms explain the formation of ties. Entailing that academic fields/industry dyads that have shared human capital also have established links and resources that are needed to form new relationships. Other mobility data point in the same direction (Gulbrandsen & Larsen 2000). Thus, it seems to be a relationship between informal ties and the formation of formal collaborative ties between firms and research institutions. Taking this observation as a starting point, the aim for new knowledge in this project is to contribute to conceptual clarification. Through this, can we further develop conceptual frameworks for understanding the process of tie formation in the UI context. Thus, the purpose of this research project is neither to create nor to test theory, but to clarify and refine conceptual models, by focusing on the process through which collaborative relationships emerge and develop in the UI context.

With this purpose in mind, a qualitative study of how R&D collaborations were formed and experienced by researchers in two different academic contexts was chosen as a suitable research strategy. Qualitative research encompasses a variety of different approaches and methods that share an interpretative approach to its subject matter and that focuses on understanding social phenomena by "interpreting phenomena in terms of the meanings people bring to them" (Denzin & Lincoln 1994, p. 2). According to Strauss & Corbin (1998), Creswell (1993) and Denzin & Lincoln (1994) qualitative research is suitable for improving the understanding of phenomena about which little is currently known or for exploring new perspectives or concepts.

In this research project, focus is put on exploring research collaborations between firms and university based research groups in two academic fields. The reason for this focus is theoretical. Simply put, the argument is that if interdependence as a precondition for tie formation is a valid interpretation, then we could assume that the experiences of forming ties in academic fields that are different in relevance for industrial innovation would be different in respect to how and why collaborative projects were formed and how they were experienced. At the same time, empirical observations indicate that patterns of interaction are not simple and that other structural variables also account for tie formation behavior. With this as a starting point, this project aimed at selecting two academic fields that could be seen as different with respect to relevance for industrial innovation, whilst having a high degree of interaction with industry. The idea was to explore what contributed to the tie

formation process in these two different contexts, and whether the experiences were similar or different. If they were similar, then it could be further explored if the similar experiences could be understood in light of another common precondition that is relevant for tie formation. This research strategy focuses on exploring theoretical relationships, but selection of cases aims at maximizing differences in relevant contextual variables (Andersen 1997, Eisenhardt 1989, Schofield 2002). Before going further into the methodology chosen, key epistemological assumptions embedded in this research project's focus and methodological choices will be analyzed.

4.2 Epistemological assumptions

According to Morgan & Smircich (1980) methodologies embody "assumptions regarding the nature of knowledge and the methods through which that knowledge can be obtained, as well as a set of root assumptions about the nature of the phenomena to be investigated" (p. 491). Justifications for the methodological choices researchers make reach into these assumptions. "It reaches into the understanding you and I have of what human knowledge is, what it entails, and what status can be ascribed to it. What kind of knowledge do we believe will be attained by our research? What characteristic do we believe that knowledge to have?" (Crotty 1998, p. 2) These are questions of epistemology, which can be defined as sets of assumptions about what is entailed in knowing or "how we know what we know" (ibid. p. 8). Ontologies are defined as assumptions about *what is*, or about the nature of reality. Ontology, epistemology and methodology are closely related (Burrell & Morgan 1992). Assumptions about the nature of social reality are intrinsically related to assumptions about how we can come to know anything about reality.

Table 3: Epistemological and ontological assumptions

Ontology	Reality is external to human consciousness (realist ontology)	Reality is constructed by humans (relativist ontology)
Epistemology	Knowledge is observations of this external reality (objectivist epistemology)	Knowledge is interpretations of peoples' experiences and how they make sense of their experiences (constructivist epistemology)

This duality is a simplified picture of "root" assumptions in social science (Easterby-Smith, Thorpe & Lowe 2002, Crotty 1998). And between these poles different social science perspectives can be placed, reflecting nuances in perspectives about ontology, human nature, epistemology and methodology (Morgan & Smircich 1980, Burrell & Morgan 1992). Many texts on philosophy of social science present overviews on different social science approaches grounded in analyses of their epistemological foundations, and tend to contrast positivist (and post-positivists) from interpretative/constructivist epistemologies (Easterby-Smith, Thorpe & Lowe 2002, Gephart 1999, Lincoln & Guba 2000). This polarization is by Mjøset (2005) referred to as "the standard dualism" and Tashakkori & Teddlie (1998) as "the great either-or". But according to Easterby-Smith, Thorpe & Lowe (2002) distinctions between paradigms that are clearly distinguishable in theory, start to break down in the practical process of designing research, choosing methodologies and carrying out research.

The focus in this thesis was not developed out of an interest in a specific theory or methodology. Rather, a pragmatist perspective on social science guided the research process, where understanding a particular social problem provided the focus and rationale for the research project, as well as the foundation for the theoretical and methodological choices made. The following table displays the pragmatist perspective as compared to two central social science paradigms - positivism and constructivism (Tashakkori & Teddlie 1998). The key elements will be described further below, along with a reflection of how they are reflected in this study.

Table 4: Comparison of three paradigms in the social sciences

Paradigm	**Positivism**	**Pragmatism**	**Constructivism**
Methods	Quantitative	Quantitative + qualitative	Qualitative
Logic	Deductive	Deductive + inductive	Inductive
Epistemology	Objective Knower and known dualism	Objective + subjective	Subjective Knower and known inseparable
Axiology	Inquiry is value free	Values play a large role in interpreting results	Inquiry is value bound
Ontology	Realism	Accepts external reality. Choose explanations that best produce desired outcomes	Relativism
Causal linkages	There are causal relationships but these may be known imperfectly	There may be causal relationships but we will never be able to pin them down	Impossible to distinguish cause and effects

Pragmatist perspectives in social science focus on specific problems as the starting point for research. Pragmatist perspectives see the social world as complex and changing, and refute the quest for foundationalism whether they are objective or subjective (Cresswell 2003, Baert 2005). As an epistemological position pragmatism is critical to the representionalist idea of social research, where theories are seen as mirroring the external world. Rather than seeing research as accurate portrayal of external reality, pragmatists believe that researchers' frames of reference influence their representations, and therefore "conceive presuppositions as *sine qua non* to any form of inquiry" (Baert 2005, p. 152). The methodological consequence of these ontological and epistemological views is that the process of knowing is enriched by different perspectives and methodologies (Tashakkori & Teddlie 1998, 2003, Cresswell 2003, Patton 2002). Further, pragmatists argue that the issue of methodology must be seen in relation to the purposes of the research. Baert (2005, p.154) claims: "No reference to the ontology of the social can ever be sufficient to settle matters of social methodology; there is nothing essential about the social that compels the use of a particular method." Pragmatist epistemology consequently becomes a rationale for the use of mixed methodologies and perspectives, either during the course of one investigation or in sequences of studies (Tashakoori & Teddlie 1998, 2003, Cresswell 2003).

As a brief reflection before discussing the methodology of the research project more detailed, the following points represent the epistemological perspective embedded in this study. As will be discussed below, in this study the idea of social research as a 'dialogue' between theory and observation is taken as a methodological point of departure. Constructing representations about social phenomena involve both developing analytic frameworks based on theory and generating images from empirical data. The use of conceptual frameworks was seen as sensitizing, in the meaning that they act as lenses that enables the researcher to observe and interpret. Theories are not seen as neatly corresponding to empirical data, but as tools for interpretation (Blumer 1954). Utilizing different analytical tools and data gathered through different methodological tools enable development of nuanced representations of complex social problems. Images generated by empirical data are seen as interpretations, and not as accurate representations of either an external reality or the subjective experiences of individuals. Since representation is not seen as theory-free, reflexivity on the researchers role as an interpreter is seen as central (Alvesson & Skjöldberg 2000). A valid representation is not seen as a correspondence with external reality or emphatic understanding of subjective experiences. Rather, since theory and observation are seen as interrelated, and the researcher interprets and constructs representations by developing analytic frames and images grounded in the data, making transparent and engaging in critical reflexivity is seen as central tools for increasing quality the representation of social phenomena.

With the purpose of the research presented and these epistemological reflections in mind, the next sections of this chapter will outline the research methodology and the specific methods used for collecting and analyzing data in this research project.

4.3 Research methodology

The aim of this section is to present and reflect on the methodological perspective in this thesis. Based in a pragmatist epistemology, the overall purpose of this study is to improve the understanding of a particular social phenomenon – tie formation between firms and universities. Further that the interplay between theory and observation is central in developing improved understandings. With this in mind, the idea of retroduction and the dialogue model of social research (Ragin 1994) will be presented. After this, key methodological tools for developing images from empirical data will be described. Theoretical sampling, systematic coding, and constant comparison are tools from the grounded theory approach (Glaser & Strauss

1967, Strauss & Corbin 1998), which enables a systematic collection and analysis of empirical data. However, the approach taken here emphasizes the interplay between data and theory, or retroduction, to a larger extent than what has been emphasized in the traditional grounded theory literature (Glaser & Strauss 1967). Focusing on the retroductive logic of developing representations of social phenomena a template analysis approach (Crabtree & Miller 1999; King 2004, 2005) was implemented, which utilizes core coding and analysis procedures from grounded theory, but where the interplay between theory and data is made an explicit part of the analysis process. These elements will be discussed below and in the next sections in this chapter.

4.3.1 Social research as a dialogue

> Social research, in simplest terms, involves a dialogue between ideas and evidence. Ideas help social researchers make sense of evidence, and researchers use evidence to extend, revise and test ideas. The end result of this dialogue is a representation of social life – evidence that has been shaped by ideas, presented along with the thinking that guided the construction of the representation (Ragin 1994, p. 55).

In contemporary epistemological discussions, there is by and large an agreement that all "facts are theory laden" and that observation never is independent of the cognitive and theoretical frames of the observer (Chalmers 1982). According to Alvesson & Skjöldberg (2000): "data never come in the shape of pure drops from an original virgin source; they are always merged with theory at the very moment of their genesis" (ibid, p.17). Approaches that highlight the interplay of theories and data as the core process of constructing representations and explanations of social phenomena is by Ragin (1994) referred to as "retroductive". The dialogue between ideas and evidence is carried out through the development of "analytical frames" based on theories and images based on "empirical evidence". Ragin (1994, p. 56) claims that it is important to investigate the ideas/evidence dialogue "because the character of the representation of social life that results from different ways of practicing social research are strongly influenced by the nature of this dialogue". The following figure illustrates the dialogue figuratively, and highlights three core analytical processes in social research.

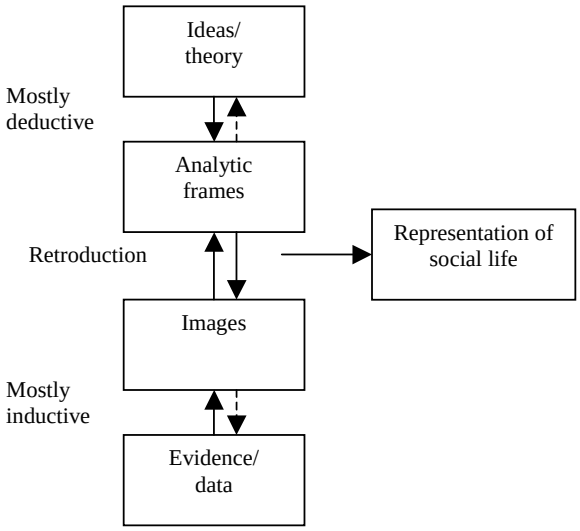

Figure 7: A simple model of social research (Ragin 1994)

In this figure, generating a representation of some phenomenon is carried out through three retroduction loops. The first loop (idea – analytic framework) concerns the development of a conceptual framework. An analytic frame is an articulated idea about the phenomenon under study and is made up of concepts and their relations. According to Ragin (1994) analytic frames are developed mainly in a deductive fashion, but not entirely as data collection and analysis also guide the development of conceptual frameworks. Analytic frames, in this perspective, work as sensitizing frameworks – as developing theoretical lenses for exploring data. According to Blumer (1954) sensitizing concepts suggest directions in what to look for and under what conditions different types of interaction are likely to occur. In this way "sensitizing concepts act as theoretical lenses to help the researcher find examples as well as patterns in the meanings represented in data, using theoretical sampling rather than random sampling to identify examples of research interest" (Gephart 1999). This sensitizing perspective on conceptual frameworks is stressed in this thesis.

The bottom loop (data – image loop) concerns data collection, condensation and integration (imaging). According to Ragin (1994) this process is mainly inductive, focusing on the emerging representation (image) and how it is developed through interplay between data and image. Images are developed through synthesizing data "by linking bits of evidence in a meaningful way" (Ragin 1994, p. 68). The methodological tools for building images from

empirical data will be further described below. However, the process of constructing images (through data condensation and display) also has deductive elements, especially in coding processes, as will be discussed below when presenting the data analysis approach.

But the main retroduction loop occurs through interaction between analytic frames and images in the interpretation process. Thus the process of constructing and refining images of evidence occurs simultaneously with using analytical frames to analyze evidence. This retroduction loop progressively generates and refines the representation (and explanation) of social phenomena through the interaction of analytic frames and images.

What is different in qualitative data analysis as opposed to quantitative analysis is that the three loops are carried out at the same time and that they are integrated. In quantitative studies, the ideas – evidence dialogue is carried out in separated sequences of review of theory, hypotheses development, data collection and analysis. In qualitative studies these processes tend to overlap and take the form of a flexible learning process, and moving back and forth between problem statement, theory and data, and a continuous adjustment of all elements (Olaisen 1991).

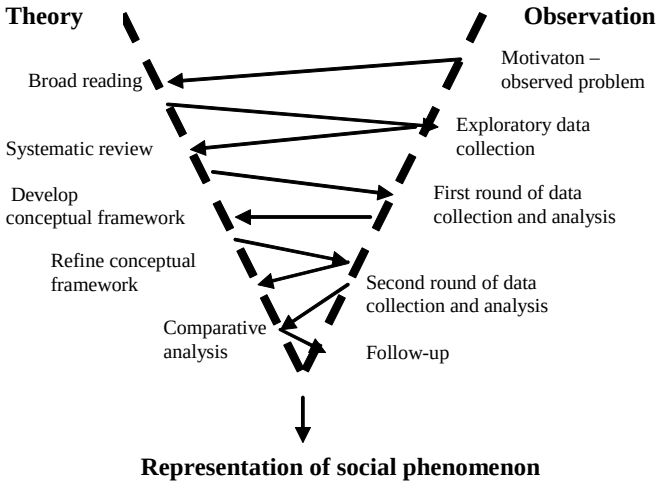

Figure 8: The research process as a dialogue between theory and observation

The figure illustrates that moving between observation and theory has been a dominant activity in this research process. The narrowing of the gap between

theory and observation indicates that focus both empirically and theoretically has narrowed through the process, has moved from broader descriptions towards focusing on exploring limited relationships. The arrows going back and forth indicate that the process has both inductive and deductive elements. This is by Ragin referred to as "retroduction". The end product, the representation of social phenomena, is constructed by both evidence shaped by ideas and ideas shaped by evidence.

4.3.2 Generating images from empirical data

As seen above, in the dialogue model, one of the main loops concerned developing images of a given phenomenon by integrating bits of evidence. This process is mainly inductive, according to Ragin (1994), and is carried out through data collection and reduction. The grounded theory approach (Glaser & Strauss 1967, Strauss & Corbin 1998) is a method for generating images from data through a set of procedures for systematically collecting and analyzing data. The basic idea is that concepts and theories should emerge from data, rather than collecting data to test fully developed theories. At the same time, Strauss & Corbin highlight that at the hart of qualitative data analysis is the interplay between the researchers and the data (Strauss and Corbin 1998). As seen above, the dialogue perspective criticizes naïve induction, and highlights retroduction in theory development. However the methodological tools developed in grounded theory methodology, theoretical sampling, systematic coding and constant comparative analysis, are seen as central tools for data collection, reduction and analysis within the retroduction perspective (Ragin 1994). These tools provide a systematic approach to handling qualitative data, and will be presented below.

The process of generating theory from qualitative data involves systematic use of coding procedures through which the concepts, conceptual categories and dimensions are specified, refined and related. In Glaser & Strauss' words, theorizing involves a "constant comparative analysis". The idea behind constant comparison is to systematically look at similarities and differences between incidents to guide the development of conceptual categories and conceptual dimensions – the building blocks of theory. To do this the investigator jointly collects and analyzes data, by using explicit coding and analysis procedures and theoretical sampling (Glaser & Strauss 1967).

Constant comparison of incidents focusing on similarities and differences between an incident and other similar observations is carried out through coding procedures. Coding is Strauss & Corbin's (1998) name for "the analytical process through which data are fractured, conceptualized, and

integrated to form theory" (p. 3). Strauss & Corbin discern between open, axial and selective coding. Open coding is about labeling and categorizing phenomena through close examination of data in terms of similarities and differences. The purpose is to generate categories, and to specify properties and dimensions of the categories as to characterize the phenomenon and indicate how it varies. Categories in this context mean "concepts, derived from the data, that stand for phenomena" (ibid, p. 114). Axial coding concerns analyzing how categories relate to subcategories (creating coding trees or hierarchies), and selective coding concerns coding for the purpose of integrating categories through relational statements as to form theoretical (or conceptual) frameworks. The purpose of axial and selective coding is to integrate categories and their properties, and comparison is carried out between incidents and conceptual properties.

Theoretical sampling is the key data collection strategy in grounded theory approaches. "Theoretical sampling is the process of data collection for generating theory whereby the analyst jointly collects, codes and analyzes his data and decides what data to collect next and where to find them, in order to develop his theory as it emerges" (Glaser & Strauss 1967, p. 45). Along with the general comparative approach, sampling for minimizing and maximizing differences is recommended, with the purpose of characterizing categories and understanding how categories vary. So the emerging theory controls the data collection process, which stops when theoretical saturation is reached – when concepts are well developed and new data no not refine the concepts in terms of properties and dimensions.

In theoretical sampling and constant comparison, characterizing categories and relations to other categories is a core activity. Thus, the method concerns both creating images (maximizing similarities as to establish patterns in the data) and to seek out evidence that does not fit the emerging theory (through maximizing differences). This latter aspect is highlighted by Ragin (1994), Miles & Huberman (1994) and Seale (1999) as a key method in qualitative data analysis. Deliberately looking for negative instances is in line with a fallabilistic strategy, where negative instances are seen as opportunities to refute or refine the emerging theory. This perspective was not stressed in the original version of grounded theory. However, maximizing difference and systematically investigating negative instances and outliers are here seen as central tools for refining conceptualizations and/or specifications of scope conditions for the emerging representation.

To sum up, the motivation behind this research project was to understand a given social problem and a pragmatist perspective guided the focus and methodological choices made. Also in line with a pragmatist epistemology, the great "either-or" (Baert 2005) is rejected, focusing on the inductive and

deductive logic of generating representations of social phenomena. The image of dialogue between theory and observation was chosen as a methodological focus, and the processes through which representations are developed through different analytical loops, was outlined. Focusing on the image building process of generating images from empirical data, the tools of theoretical sampling, systematic coding and constant comparison was emphasized. In the following sections, how this methodological perspective was implemented in the chosen methods of data collection and analysis will be outlined.

4.4 Methods of data collection and analysis

4.4.1 Theoretical sampling

In qualitative research, selection of units of observations or cases to investigate tends to be purposeful, theory driven and evolves with the fieldwork rather than being completely specified at the beginning (Miles & Huberman 1994). Also, in the logic of theoretical sampling, cases are seen as constructions made by the researcher based on analytic frames and developing conceptualizations (Ragin 1992, Strauss & Corbin 1998). What the case is a case of is a basic question in qualitative research; one that directly addresses the relationship between data and theory (Ragin 1994). According to Walton (1992) “cases are always hypotheses”. In this way, theoretical sampling is crucial design step when one seeks to build or refine theory (Eisenhardt 1989, Glaser & Strauss 1967, Walton 1992). The idea behind theoretical sampling is not that the cases should be representative of a larger population to control for extraneous variation, but that the cases are theoretically representative. According to Andersen (1997), the logic is to draw new implications from theoretical insights and try them out on new data. Eisenhardt (1989) further claims that in selecting cases it makes sense to choose “extreme cases or polar types, in which the process of interest is transparently observable”. By sampling cases for maximizing and minimizing differences, Glaser & Strauss (1967) claim that concepts and categories become progressively refined.

Many phenomena that social scientists study are multilevel, for instance countries, organizations, communities or groups. This means that there is not always overlap between the level on which data are collected, and the level of analysis where the explanation is formed. One might for instance collect data from individuals to explain group or organization level phenomena, or from institutions to explain national or system level phenomena. Due to this, Ragin (1987) claims that it is useful to distinguish between two meanings of unit of analysis: unit of observation and unit of explanation. “Observational

units refer to the unit used in data collection and data analysis; explanatory unit refers to the unit that is used to account for the pattern of results obtained" (ibid p. 8). With this distinction in mind, the units of analysis to be investigated in this study can be seen as formal collaborative R&D projects in the context of two academic fields, where key informants are the central units of observation. Due to this, the theoretical sampling has been carried out in two main steps.

In terms of academic fields, the intention was to select academic fields that could be seen as different with respect to assumed relevance for industrial innovation. The focus is not on the firms as such, but on the rationales for interacting with research environments in universities and colleges. And there exists statistical data (NFR 2005b) and research publications (Faulkner & Senker 1995, Schartinger et al 2002, Cohen, Nelson & Walsh 2003) on what firms report to be the most significant and relevant academic fields for them in the course of innovation. To select academic fields, the approach taken was first to systematically review literature on interaction between universities and industries and discuss with senior researchers on the topic, and carry out five key informant interviews to get more specific information about the Norwegian situation. Based on this input, two academic fields – chemistry/material sciences and economic/administrative sciences were selected for further exploration.

Table 5: The two academic fields as contexts for UI linkage

Chemistry/materials	**Economic/administrative**
Highly relevant for industrial innovation as reported by firms Highly relevant for innovation in selected industries	Less directly relevant for industrial innovation. Generally relevant for many industrial sectors and firms
High propensity for interaction with business/industry	High propensity for interaction with business/industry
Interacts mainly through R&D collaboration	Interacts mainly through education/training links

The table summarizes the characteristics of the two chosen academic fields as contexts for UI linkage. These are not standardized selection criteria, but emerged as a result of reading research literature and interviewing key stakeholders in Norway.

Within the academic field of chemistry and material science, respondents from two institutions were interviewed. At the University of Oslo this academic field is organized both at the departmental level (in the Department

of Chemistry) and at the Center for Material Science and Nanotechnology. At the Norwegian University for Natural and Technical sciences (NTNU) research is carried out in two separate institutes – department of chemical engineering and department of material science. Due to this difference in organizational affiliation, this academic field is labeled chemistry/materials. The respondents interviewed work in areas like catalysis and petrochemistry, polymers, functional inorganic chemistry and separation technology. And they interact with firms in chemical industry, pharmaceutical industry, metal industry, oil/gas and energy industries. This academic field is seen as highly relevant for industrial innovation as reported by firms (Cohen, Nelson & Walsh 2003, NFR 2005b), show a relatively high propensity for interaction with firms, and interaction is carried out in the form of R&D collaboration (Schartinger et al 2002).

The second academic field is economic/administrative sciences. The respondents interviewed are all from the same institution, The Norwegian School of Management, but affiliated to different departments. They work on areas like economics, marketing, strategy, leadership and organization science, and interact with firms in many different industries, for instance oil/gas industry, telecom, banking and business consulting. This academic field has a high propensity for interaction with firms comparatively speaking (Schartinger et al 2002, Gulbrandsen & Larsen 2000), but does not to the same extent engage in R&D collaboration. Rather interaction with industry is mainly focused on education/training ties (Schartinger et al 2002). It is also seen as less specifically relevant for industrial R&D and innovation, but it is of general relevance to many industries and firms (Schartinger et al 2002).

The two contexts are selected since there is a, comparatively speaking, high degree of interaction in both fields, but that only one of the fields is seen as directly relevant for industrial innovation. The dependence on business/economics for firm innovation is much less clear, as reflected in both firms' assessment of its importance and in the type of links used to interact. Consequently it is an interesting context for exploring formation of R&D collaborations.

4.4.2 Sources of data

The following table presents an overview of the types of data collected during the course of investigation.

Table 6: Sources of data

Method	Data sources	Purpose
Documentary analysis	National policy documents Institutional strategies/policy Auxiliary documentary material (websites, yearly reports, etc)	Acquire knowledge about UI interaction in Norway
Statistics	Norwegian R&D system statistics Employment of recently graduated statistics Higher education system statistics	Acquire knowledge about UI interaction in Norway
Key informant interviews	5 thematic interviews with key informants	Exploring ways of understanding UI interaction Develop conceptual frame
Topical interviews	24 semi structured interviews with researchers and R&D managers involved in collaborative R&D projects	Describe and compare experiences in forming ties between firms and universities
Field observation	11 hours of field observation of three collaboration initiation meetings between academics and firm representatives	Describe and compare experiences in forming ties between firms and universities

In the early phase of the research project different sources of data were collected; documents, statistical materials and interviews with key informants. The aim at this stage was to learn more about what was going on with UI interaction in Norway and what were central ways of understanding this phenomenon, including what was seen as key questions and issues for further research. Secondary aims were to learn more about interesting cases for further investigation and to explore "in situ" the developing conceptual framework. Collection of data in this stage was systematic but not very focused; rather the aim was to collect many-faceted data as to gain a fuller understanding of the research problem in its context.

The documentary and statistical materials were collected in a broad manner aiming at comprehensiveness in the understanding of UI interaction in the Norwegian context[5]. In addition to collecting secondary material, five key informant interviews were carried out, purposefully selecting respondents to represent different stakeholder viewpoints: government, universities and

[5] Detailed information about these sources and the presentation of the Norwegian context is found in chapter 5.

industry. The aim was not to identify different stakeholder perspectives, but rather to explore key informants understanding of UI interaction in the Norwegian setting and to discuss the projects developing research focus and framework with key people in the field. Input from these interviews informed the development of the research focus.

In the course of this exploratory phase, the decision to carry out a comparative study of formation of R&D collaboration was made. In this stage a more focused form of data collection proceeded, utilizing topical interviews with respondents that had concrete experiences in UI interaction through involvement in collaborative R&D projects. Topical interviews are a form of qualitative interviewing that focuses on "particular events or processes, and are concerned with what happened, when and why (Rubin & Rubin 1995, p. 28). Topical interviews focuses on gaining relatively detailed descriptions of processes and events, as well as the respondents' reflections about such events. The interviews are focused and the interviewer structures the conversation and most often deal with precisely defined subjects or a target group. "Often topical interviews trace a process or how a particular decision was made" (Rubin & Rubin 1995, p. 29). Here, the interviews focused on how the collaborative R&D projects emerged and how interaction was carried out and experienced.

The decision to collect data in two academic fields was made early in the project, but within the two science field cases sampling was an iterative process occurring throughout the fieldwork along the lines of a theoretical sampling strategy (Strauss & Corbin 1998). Respondents were first recruited through contacting department heads in two universities[6] and from an official project database in a business school. The aim was to create a list of people who were in charge of, or involved in, ongoing or recently ended collaborative R&D projects in the departments. The persons listed were afterwards contacted by e-mail[7].

In the two academic fields, interviews with 24 respondents were carried out. The interviews were with respondents that that had been or were currently involved in one or several identified collaborative R&D projects between industry and universities. They all had personal experiences from R&D collaboration, and the interviews focused on what their experiences were, not on general opinions about UI interaction. What these people have in common and the reason for why they were selected is direct interaction

[6] A copy of the letter to department heads asking for information about potential respondents can be found in appendix A.
[7] A copy of the information letter to respondents can be found in appendix A

experience[8]. By interviewing respondents that had direct experiences from one or more collaborative projects, the intention was to look for respondents' accounts of what happened in the course of forming a collaborative R&D project, and how this process was understood and experienced by the respondents. Due to time and resources constraints, it was not possible to carry out interviews with all respondents that were suggested during the interviews. And in the group of respondents, the firm side is not equally represented as the academic side. This is a weakness of the research and it limits the perspective. But at the same time the respondents that were interviewed are all highly knowledgeable about the collaborative projects and the interaction processes, and there is also a high consistency in their experiences. Also the issues discussed were not controversial or problematic for the respondents. Due to this, there is no reason to suggest that other respondents would have dramatically different experiences and assessments. However, this is a qualitative study with a small number of respondents, and does not aim at generalizing to a broader population of collaborative research projects.

The interviews focused on the following themes: Background information about the project, the background for forming the R&D collaboration project, the formation process, the experience of interacting and how the respondents assess the collaboration. A short interview guide was developed in advance[9]. Detailed sub-questions and probes were used to follow up the respondents' answers. The respondents were allowed to tell the story of the collaboration projects if they were motivated to do so, and the interviewer followed up with questions along the way. The questions were not always put in a given order, but all interviews focused on all the themes in the guide. Each interview took about one hour, and was conducted in the respondents' offices or another place of the respondents' choosing. Most of the interviews were tape recorded and transcribed. In the remaining interviews detailed notes were taken and an interview report was written down immediately after the interview.

As a supplement to the interviews, one full day meeting where industrial representatives from several firms interacted with university scientists in material science and two half-day meetings with economic/administrative researchers and several representatives from collaborating firms were observed. The meetings were held as part of a process to initiate new collaborative R&D projects, and as such they offered an opportunity to observe a small step in collaboration formation processes. In these meetings,

[8] The respondents are both both senior and junior faculty as well as non-academic staff (se appendix B for a description of the respondents).
[9] See appendix C

field notes were written and copies of all presentation and other written materials were collected. Interviews with the organizers and participants after the meetings to get their assessment of the events were also carried out. The interview transcripts, documents and field notes were subjected to systematic qualitative data analysis following a template analysis approach, which will be described below.

4.4.3 A template analysis approach to data analysis

In terms of the data analysis, an approach to qualitative data analysis that can be used to take account of retroduction processes is template analysis (King 2004, King 2005, Crabtree & Miller 1999). Template analysis is an approach to coding and analysis of qualitative data, that emphasizes that the analyst always approaches data with expectations or "frames" that influences coding and interpretation of data (Alvesson & Skjöldberg 2000). As opposed to grounded theory that stresses that the analyst should let codes emerge from the data (Glaser & Strauss 1967), template analysis stress that the analyst should start by creating a preliminary set of codes – a template of themes that the researcher expects will be relevant in the analysis of the data. According to King (2005): "It is important to recognize that themes in qualitative research are not hiding in the data, waiting to be "discovered" by the researcher. Rather, they arise from the engagement of a particular researcher with the text, as he or she attempts to address a particular research question". So just like grounded theory, template analysis focuses on interplay between the researcher and the data, but template analysis sees the creation of a preliminary coding template as a way of making explicit the frames the researcher approaches the data with, and that this should be done prior to indexing and coding segments of data. If such pre-understandings are made explicit, only then it can be addressed and used critically in the interpretation process.

A template is a preliminary set of codes that is created based on the study's main research questions, conceptual framework, literature reviews, and interview guide, case protocols or other data collection instruments. The initial template embodies what the researcher assumes will be central themes in the data material, but is used as a heuristic tool, not as a fixed standard by which all data is to be coded. It is a way of making explicit the researcher's pre-understanding of the topic – but it is meant to be confronted with data. The initial template is tentative, and should be changed, refined, restructured as the analysis progresses. The initial template is used to code a subset of the data; adding, changing, and potentially restructuring (by changing the order of themes) codes by detailed line-by-line analysis of data. By extending the material for analysis, and through several analytical loops of template – data

interactions, the template is revised several times over to produce more comprehensive and refined templates of categories and sub-categories. The process covers open and axial coding as defined by Strauss & Corbin (1998). "This iterative process of coding, modifying the template, and re-coding could in theory go on indefinitely" (King 2005). But like in grounded theory, theoretical saturation is used as a principle for when to stop revising and coding – that is when revisions produce limited improvements.

A saturated template is not a model or theory. Rather it is a tool to guide further interpretation of evidence by integration of categories. Template analysis is a way to reduce data by breaking data apart and code data segments, just like other coding tools. Building images and exploring relationships between categories are not achieved by template analysis, but like in grounded theory the use of memos and sampling and coding for emerging relationships is possible extensions of template analysis. Selective sampling and coding around a core category to develop conceptual frameworks are usable procedures also in template approaches, as well as the use of data displays like matrices and networks (Miles & Huberman 1994). The basic difference between the two coding techniques is that template analysis utilizes a priori codes, and that iterations of the template are core to theory development. According to King (2004, 2005), the value of template analysis is that it makes the process of coding more transparent, and that based on continuous revisions of templates (which are saved and "memoed" for significant changes), the technique makes it easier both to create audit trials to increase reliability and stimulate reflexivity about the interpretative process.

In this project, the following steps were taken when analyzing the data: First, based on the tentative conceptual framework, the interview guide as well as scanning through the transcribed interviews, a tentative coding template was developed. The template was kept relatively short focusing on top-level themes – what was assumed would be relevant in the analysis. This was followed by detailed line-by-line analysis of three interview transcripts were carried out using the initial template. This led to the adding of several new codes emerging from the data, and revision and restructuring of previous codes. After five rounds of template revisions, the coding template was implemented in the QSR N6 software[10] for qualitative data analysis. All of the interview transcripts, interview reports and field notes were coded again in N6 using the template. This led to further revisions of the template, and the adding of a few "in vivo" codes – categories emerging from data.

[10] Often referred to by the name Nu*dist

Since all versions of the coding template were dated and saved, it was possible to track the changes in the coding process over time. Comparing the template before and after implementation in N6 reveals that several changes were introduced, primarily by finer coding in sub-categories. This is very easily done in N6 since you can code further from the initial open code, and jump back and forth between the interview transcript and coded text (Richards 2005). In addition two completely new nodes were developed, each with several sub-categories. Both of them became very central in the developing theory. And lastly, a few codes were collapsed. From an initial template of 6 top-level codes and a total of 36 codes, the final report on all nodes from N6 includes 8 top-level codes and a total of 95 codes[11]. The main structure is however fairly similar, but much more refined. Thus, the interplay had not challenged the fundamental structure but had refined and added a lot of detail to the initial conceptualizations.

Several matrices for displaying data were also developed. In these matrices the codes and sub-codes developed in the analysis were used and compared all units of observations as well as several constructed groups. The purpose was not to make claims about the variance across observations, but that counting and comparison of the condensed data would enable me to more clearly identify the key properties and dimensions of the concepts, and also identify outliers and negative instances (Miles & Huberman 1994). Search for outliers and negative instances to challenge and refine the emerging conceptual framework, was deliberately implemented in the analysis process.

Several retroductive loops occurred during the analysis process, as described above. The coding text – revising coding template process unfolded through several rounds of interfacing. The initial assumptions were used as a basis for coding but he empirical data substantially refined the coding process. This was easy to do in N6, since it enables the analyst to create new codes and code further from coded text segments. After many rounds of data reduction, display and comparisons, the analysis reached a point of saturation where no new revisions were made. Then a coherent and refined image, both grounded in the data and consistent with the analytic frame, had developed. In this "re-conceptualization" process of building coherent images of the data, the analytic frame developed in the study guided the interpretation and integration process. However, empirical data refined and extended the initial analytic frame. The main result in my study – a matrix showing tie formation processes by combinations of preconditions (a typology of four types of tie formation processes and interaction experiences associated with different types of formation processes) – can only be

[11] See appendix D for copies of the preliminary and final template of codes

described as the result of a continuous dialogue between data and theory, through which the representation of tie formation behavior in the university-industry context, has developed.

4.5 Quality criteria in qualitative research

To what extent are the findings from a small qualitative study reliable and valid? And to what extent can they and should they be used to understand other situations and groups than the ones investigated? These two questions are central issues in social research, and will be addressed in turn. After this, quality measures implemented during the course of the investigation will be presented and discussed.

4.5.1 Validity, reliability and reflexivity

In qualitative research, validity is a fundamental research design issue (Maxwell 1996), as cases and respondents are purposefully selected, the researcher is the main instrument of data collection, and data collection and analysis processes are non-standardized. With these characteristics in mind, critics and advocates of qualitative methods alike are concerned with questions like: "How will we know that the conclusions are valid?" "How will we know that the findings are based on critical examination of all data and do not depend on a few well-chosen examples?" Finding ways of addressing these concerns is the domain of validity (Silverman 2000). In quantitative research, standardized concepts and tests for validity have developed over decades, but validity is seen dominantly in relation to methodology and measurements (Kvale 1996). In qualitative research, there is no common approach, and ideas of validity depend on research strategy and philosophical assumptions. Validity is seen as relative rather than "a context-independent property of methods or conclusions" (Maxwell 1996, p. 86).

Kvale (1996) discusses the philosophical underpinnings of validity discussions in qualitative research and claims that rejection of the correspondence criterion of truth (that knowledge is a mirror of reality) in postmodern science, has led other notions of validity to the forefront of methodological discussions. He identifies three ideas of validity: i) Validity as defensible knowledge claims, ii) validity as communication and iii) validity as application. The first idea is related to validity as "craftsmanship" (Kvale 1996) and is common in book on qualitative methodology (Miles & Huberman 1994, Maxwell 1996, Silverman 2000) and will be discussed further below. Validity as communication rests on an idea that "valid

knowledge is constituted when conflicting knowledge claims are argued in a dialogue" (Kvale 1996, p. 244). This is based on a social constructivist perspective on knowledge and a consensual theory or truth. Validity as application is a pragmatic perspective on validity, where truth is related to what works in practice. The perspective sees the test of knowledge in its application and not in any inherent quality of knowledge itself.

The most fully developed idea of validity, and practices of validation in qualitative research, is related to validity as defensible knowledge claims. Inspired by Popper's idea of falsification as a way of obtaining objective knowledge, validity is seen resting on the principle of "refutability", or critical inquiry for examining biases, alternative explanations and rival hypotheses (Silverman 2000). "Validity is ascertained by examining the sources of invalidity […] Validation comes to depend on the quality of the craftsmanship during investigation, continually checking, questioning, and theoretically interpreting the findings" (Kvale 1996, p. 241). Many textbooks on qualitative methodology provide overview of different strategies to validate interpretations (for example Miles & Huberman 1994, Silverman 2000, Glaser & Strauss 1967, Kirk & Miller 1986, Seale 1999). In this perspective, validity is not restricted to data analysis, although validation is a central process in analysis, but runs trough all elements of a research design and steps in the research process (Maxwell 1996). Threats to validity cannot be dealt with once, but must be continuously addressed in all stages of the research process; in posing research problems, in choosing methodology, sampling, data collection, coding and analysis, making interpretations and communicating findings (Dalen 2004). Overall, validity in qualitative research is seen as related to reflecting upon the role of the researcher in the research process.

Maxwell (1996) also makes the point that validity must be seen in relation to different types of understanding, and that different types of understanding – description, interpretation, theory (and generalization) have distinct threats to validity.

- The main threat to descriptive validity in is inaccuracy or incompleteness of data. This is related to data quality and reliability, as discussed below.
- The main threat to validity in interpretation is researcher bias, as in imposing one's own framework on the phenomenon or only selecting data that fit the researcher's existing theory. Reflexivity about the researcher role and frame of reference (Alvesson & Sköldberg 2000), theoretical sampling, and comprehensive data treatment are ways to address this threat (Maxwell 1996, Silverman 2000).

- The main threat to validity in theory development is not collecting or paying attention to discrepant data and alternative explanations and understandings. Constant comparison of data, searching for discrepant evidence, examination of outliers and negative cases, and replications are approaches proposed to limit threats to theoretical validity (Miles & Huberman 1994, Silverman 2000).

A question which is nested within the validity discussion is how reliable the data that we collect, interpret and use to develop theories are. Reliability is often in the literature taken to mean consistency in the way data is collected and coded, where the ambition is to ensure comparability of data over time and investigators (Boyatzis 1998, Kirk & Miller 1986). The true test of reliability is often said to be the extent to which others could replicate the study. To ensure reliability describing a study's methods and procedures in detail to create an "audit trial" is central, even in studies that do not rely on standardized data collection procedures (Miles & Huberman 1994). This entails explicating a research design, and making the small and larger steps in the research process open to reflection and scrutiny. Sampling decisions, creation of case or observational protocols and interview guides, data collection and coding procedures should be made explicit and open to scrutiny. In terms of data collection, most writers recommend the use of tape recorders, video recorders and other instruments for recording observations (Kvale 1996, Maxwell 1996, Silverman 2000) as a way of ensuring reliability of data. An alternative way is to take field or interview notes and write an interview/field report on it as soon as possible after the interview. This will be of a lesser accuracy than transcribed interviews from tapes, since the level of detail is much less than in natural speech. Also reports depend on the investigators memory and will be subjected to bias, as one tends to remember issues of interest and paying less attention to other issues and discrepant evidence (Kvale 1996).

Reliability of data coding and analysis is also an important issue but less discussed in the literature on qualitative research. Coding is essentially an interpretation process, whereby segments of data are assigned a label. Qualitative research deals predominantly with words, which are ambiguous. It is usually not the words in themselves that are in focus in qualitative analysis, but their meaning. According to Miles & Huberman (1994, p. 56), words do not contain meaning like a "bucket contains water"; rather meaning is "a choice made about its significance in a given context". In this sense, coding is a subjective interpretation process. This perspective entails that texts (like interview transcripts) are always open to a variety of interpretations. Reliability, as a measure of stability and consistency in the way data is collected and coded, is for many qualitative researchers an oxymoron. Traditional ways of securing reliability of coding, like inter-coder

agreement calculations, is criticized for being built on a misapprehension of qualitative data. Boyatzis (1998) however argues that regardless of ontology and epistemology, some kind of consistency of observation is central for all perspectives (also social constructivists he adds) since it is central for the ability to communicate and interact. As a "middle ground", increasing the consistency of judgment need not be based on calculations of inter-rater reliability, but using some form of independent scrutiny of the analysis. Letting a colleague or an 'outside' expert code a sample of data and afterwards discussing similarities and differences as a way of improving the analysis, is recommended (King 2005). Independent scrutiny, according to King, can never confirm that your analytical decisions are correct, but can suggest alternatives that you had not considered, and help (or force) you to critically reflect on the process and the decisions made (ibid). In this way, it can increase the reflexivity of the researcher.

In general, since the research process in many qualitative research projects is flexible and where the design emerges in the process, reflexivity on the process and the researcher role is important. Reflecting on and checking for interpreter bias is a central part of this. "Reflection means interpreting one's own interpretations, looking at one's own perspectives from other perspectives, and turning a self-critical eye onto one's own authority as interpreter and author (Alvesson & Sköldberg 2000, vii). Reflecting on the role of the researcher in the research process, and the way this shapes its outcomes, an interpretation of the interpretation, is a central analytical process in qualitative research.

A final issue emphasized here concerns ethical rules of conduct in social research. Since social research involves human beings, sensitivity to how individuals are affected by and experience being involved in research projects is required. And over time, a set of ethical guidelines has developed in the social research community[12]. The most central focus is respect for the individual human being, and this should be addressed in terms of respect for individuals' right to choose, and the researcher's obligation not to expose research subjects to harm – socially, economically or psychologically – as a result of participating in the research. Consequently, two central guidelines have been formalized – demand for informed consent and confidentiality (Kvale 1996). Informed consent means that the individuals recruited as respondents should be given ample information about the purpose of the research and potential risks and benefits, and that their consent to participate should be made explicit. Confidentiality means protection of privacy or that

[12] In Norway, the National research ethical committee for social science and humanities has formalized a set of ethical guidelines for researchers. Available at http://www.etikkom.no/retningslinjer

private information about individuals must be treated with care and that information identifying the subjects must not be reported unless explicitly agreed upon. In addition, as a general rule, the consequences for the individuals with respect to risks and harm should be critically addressed in each case.

4.5.2 Theoretical generalization

The final criterion for evaluating research designs and findings discussed here concerns generalization, or to what extent findings from a qualitative study can and should be used to understand other situations, settings and people than the ones investigated. Many qualitative researchers claim that generalizability is not a crucial or even meaningful criterion for qualitative research, since the aim is to understand a social phenomenon and it's meaning to the people involved. And from quantitative researchers, a main criticism towards qualitative research has been that the sample or cases investigated are neither large nor representative, and due to this one cannot generalize to a larger universe or population (Yin 1994). This is associated with the assumption that the case is a 'case of something': "A case is often thought of as a constituent member of a target population. And since single members poorly represent whole populations, one case study is seen to be a poor basis for generalization" (Stake 2000, p. 23). Thus, a main point of criticism is "small N and big conclusions" (Lieberson 2000).

Other authors on qualitative research methodology do however claim that this criticism is built on a misapprehension of type of generalization sought in qualitative studies (Yin 1994, Ragin 1992, Andersen 1997, Schofield 2002). Qualitative studies do not use small samples of larger populations, and the aim is not to statistically generalize empirical findings from the case to the population. Rather, the ambition in qualitative research is theoretical generalization (Yin 1994, Strauss & Corbin 1998, Glaser & Strauss 1967). In other words, that 'small N studies' are used to develop or refine theories and concepts, which is seen as a form of generalization in the sense that concepts and theories have relevance outside the local context in which they were developed. The argument is that concepts and theories developed represents a step in a process towards increasing generalization, since all concepts and theories should be critically assessed by new evidence and further research.

This research project, focusing on understanding tie formation behavior in two different academic contexts, builds on this understanding of theoretical generalization. As seen, the contexts were deliberately selected to shed light on key theoretical dimensions. And by focusing on similarities in different contexts, the aim was not to provide a rich understanding of each individual

case, but what is similar across heterogeneous cases. Consequently, the study aims at developing a story of how ties are formed in different academic contexts. According to Schofield (2002, p. 184): "Generally speaking, a finding emerging from the study of several very heterogeneous sites would be more robust and thus more likely to be useful in understanding various other sites than one emerging from the study of very similar sites". However, the findings are here regarded as the basis for formulating research questions hypotheses to be subjected to further testing across several different contexts, and not as a basis for generalization to a population.

4.5.3 Quality measures implemented

In relation to the criteria for quality and relevance discussed above, different measures were implemented in the research process. As seen above, validity in qualitative research is not seen as a context independent property of methods or conclusions. Rather, validity considerations should be addressed in consideration with all elements of research design and in all steps of the research process. As emphasized, this research project is built on a dialogue perspective of social research in which representations of social life is developed through several analytical loops of interfacing between theory and data. Consequently, both the craftsmanship and the reflexivity of the researcher are central aspects of credibility, whilst the accuracy of the representation (in the sense of mirror like quality) is not seen as a relevant understanding of validity. With this in mind, the quality measures implemented in the course of the research will be described.

Table 7: Implemented quality measures

Quality criteria		**Measures implemented**
Reliability	General auditability	Create an "audit trial" and attempting to explicate as many steps of the research process as possible: Methodology chapter and methodological appendix
	In data collection	Use of interview and field guides and tape recorder
	In data analysis	Use of templates, use of N6, external scrutiny of coding
Reflexivity	Interpretation of inter-pretation	Explicit use of templates, use of different perspectives and data collection methods, discussions with colleagues and external scrutiny
Ethical guides	Informed consent	NSD project approval
	Confidentiality	NSD project approval
Validity	Descriptive	See reliability
	Interpretative	Use of templates and external scrutiny, theoretical sampling, comprehensive data treatment in N6 and constant comparison
	Theoretical	Most different case design, theoretical sampling, constant comparison, searching for negative evidence and outliers, comparison with similar and different literature
General-ization	Analytical Generalization	Refining conceptual models, must be subjected to further research Comparison across different contexts to increase robustness

As the table indicates, several measures to increase the quality were implemented both in respect to developing the research design, sampling, data collection and data analysis. Overall, it has been an ambition in this project to make explicit as many steps and elements of the research process as possible. This is partly found in this chapter but a methodological appendix is added to the thesis to add further detail. These two parts of the thesis constitute the "audit trail" as recommended by Miles & Huberman (1994).

In addition to the more common descriptions of sampling and data collection processes in the audit trial, this thesis has made an attempt at explicating the process of coding and analysis of data, which is less common in qualitative research reports. To do this, it has been attempted to develop an analysis approach that allows the researcher to reflect and use the pre-understanding

as well as letting this frame be critically assessed in light of new empirical data. The template analysis approach and the use of qualitative data analysis software for coding and analysis of data have increased the transparency of the analysis process, which is beneficial for reliability (in the sense of auditability) and reflexivity about the interpretations made. Utilizing independent coders and discussing coding decisions with them also increased the transparency and hence reflexivity about the interpretations made.

Several measures were used to ensure the quality of the data collected, and to assure that the project did not violate central ethical considerations, a project description was sent to Norwegian Social Science Data Service (NSD) for approval. The suggested ways of ensuring informed consent and confidentiality were approved, and put to use in the data collection and analysis stages, and in the writing of the thesis.

The project utilized a theoretical sampling strategy, and utilized a comprehensive data treatment strategy where all data collected was coded and where outliers and negative evidence where explicitly investigated, and used to refine the analysis. Here the analysis software was very helpful, because it easily enables recoding of data as well as many forms of exploration, comparison and display. The overall design and methodology chosen contributed to increase the theoretical validity, first and foremost by selecting a most different case approach. The strength of the approach is that findings made in two different contexts can be seen as more robust. Also, by comparing the findings to similar and different research literature (pattern matching) and to other sources of data, the confidence in the findings increased (Eisenhardt 1989, Strauss & Corbin 1998, Yin 1994).

A pragmatist perspective that assumes that methodological choices are relative to the purpose of the research guided the development of a methodological framework for this study. The research problem definition and the purposes are exploratory, which entailed that a flexible research strategy was needed. Pragmatist epistemology also emphasizes that observation is dependent on presuppositions and frames, and that due to the complexity of social phenomena, mixed methodologies might be needed to understand problems. Based on these assumptions, the methodological perspective of retroduction was emphasized as a point of departure for discussing questions related to research design, data collection and analysis. In this perspective, constructing representations require both the development of analytic frames as well as images based on empirical data. Above in chapter three, the analytic frame of this study was presented. And in the next chapters, different types of empirical data that shed light on the research problem will be presented and analyzed.

Chapter 5: University – industry interaction in Norway – policies, strategies and key data

5.1 Introduction

This chapter aims at describing the policy context in which university – industry interaction occurs, as a backdrop for the following analysis of collaboration between universities and firms. The focus here is the Norwegian policy framework for university – industry interaction, looking into: a) recent Norwegian innovation and science policies; b) policy instruments, strategies and programs intended to foster interaction between public research institutions and firms; and c) existing sources of data on knowledge interaction between universities and firms in Norway.

5.2 Recent innovation and research policies in Norway

Since 1999, several new policies have been passed and implemented that are directly relevant for university – industry interaction in Norway, including several official Norwegian reports, white papers and law amendments. It has been an active period for policymaking concerning education, research and innovation, signaling an increased focus on knowledge and innovation as public policy areas (Remø 2004). This policy thrust is in line with the overall ambition of becoming an internationally leading knowledge nation in the global knowledge-based economy (NHD 2003). The policies have addressed issues like: increasing the national investments in R&D and particularly industry's part of national R&D investments, increasing the quality of research and higher education, commercialization of research results, stimulating collaboration and network interactions, and supporting regional innovation (Remø 2004). According to Remø, the latest policy efforts focus on improving the coordination and governance of innovation policies. The recent policies are based in an interactive perspective on innovation, focusing on interactions between different elements in national and regional systems of innovation. Developing coherent policy frameworks, and integration and coordination across policy domains, are seen as central. Where as previous innovation policies focused exclusively on research and

technology, recent innovation polices focus on a broad range of measures that are considered to be central inputs and frame factors for innovation, such as education and competence policies, infrastructure policies, environmental policies, labor market policies, and regional policies. Innovation policies that focus on coordination and integration across these domains are referred to as "3rd generation" innovation policies (Remø 2004). The Norwegian government's innovation plan *Fra idé til verdi* [*From idea to value*] (NHD 2003) embraces several policy domains, and can be seen as an expression of a holistic perspective on innovation and innovation policy. Before returning to this policy, some of the central policies that were made prior to, and which the plan built on, will be described. Several policies made in the years 1999 to 2002 underscored the government's increasing attention to innovation policy (Remø 2004).

The 1999 white paper on research policy (St. Meld. No. 39, 1998-1999) *Forskning ved et tidsskille* [*Research at the beginning of a new era*] established that increasing investments in R&D to reach the OECD average measured as a proportion of GDP, was a central policy goal. This yardstick for R&D investments had been seen as a suitable goal for national research policies since the mid 1980s (NOU 2000:7). In the 1999 white paper, and in subsequent policies, the low level of R&D investment in Norway as compared to other OECD and European countries was recognized as a problem. Particularly the Norwegian private sector's comparatively low share of R&D investments was seen as an impediment. Increasing private investments in R&D was seen as a central policy challenge. In 2000, a governmental committee (*Hervik committee*) issued an official Norwegian report (NOU 2000:7) *Ny giv for nyskaping* [*A new start at innovation*] to address this question.

Based on the recommendations in this report, a tax credit scheme was implemented, giving firms right to tax deductions for investments in R&D, and doubled deductions for investments made in R&D collaboration with universities, colleges and research institutes[13]. The latter was seen as an instrument for increasing cooperation between firms and research environments. Several other instruments were also proposed by this committee to increase cooperation, such as increased funding for user-initiated research and strategic research by the Norwegian Research Council (NFR), programs for stimulating network interactions and knowledge transfer to small and medium sized enterprises (SMEs), programs for stimulating mobility of employees as a form of knowledge transfer, as well as increasing commercialization of university research results. The

[13] The FUNN scheme, in 2002 reorganized under the name SkatteFUNN

committee also discussed the need for an overall quality improvement strategy for research and higher education.

In 2000, another governmental committee *(the Mjøs committee*) submitted its report on higher education and research, *Frihet med ansvar* [*Freedom with responsibility*] (NOU 2000:14), leading to the implementation of the Quality reform of higher education (St. Meld No. 27, 2001-2002). Restructuring the degree and grade systems, implementation of a national quality assurance body, and a new system of funding higher education institutions were central policy instruments intended to increase the quality and effectiveness of higher education. The focus on quality was also emphasized in the 1999 white paper on research. Establishment of centers of excellence and stipends for outstanding young investigators were implemented as quality improvement measures.

In 2001 a third governmental committee (*the Bernt committee*) submitted an official Norwegian report of relevance to research and innovation policies on commercialization of research results from universities and colleges. The 1999 white paper on research stated that better commercialization of research results, in terms of patented inventions and commercial products, was a central goal, and the committee was asked to evaluate policy instruments to increase activities in this field (NOU 2001:11) *Fra innsikt til industri*) [*From insight to industry*]. The major outcome of this report was an amendment to the law on universities and colleges, giving these institutions, for the first time, explicit responsibility for commercialization of research results and for the use of scientific methods and results in the public sector, business and industry. According to the amendment to the act on universities and colleges (Ot. Prp. Nr. 40, 2001-2002), these institutions now have the responsibility to provide higher education, carry out research and academic work including artistic work, as well as "communicate knowledge about their work and extend the understanding about and use of scientific and artistic methods and results to public administration, civil society, and business and industry" (author's translation). This responsibility for distribution and use of science-based knowledge outside the institutions is the new element in the statutory duties of the colleges and universities in Norway.

The report also led to an amendment in the law on rights to inventions made by employees (Ot. Prp. Nr. 67 2001-2002), giving the institutions right to exploit inventions made by their teachers and researchers - a right that previously had belonged to the individual faculty member. One result of these policy changes was that all of the universities established Technology Transfer Offices (TTOs), for the taking care of the universities' efforts towards commercialization.

In the last five years, several changes in the innovation policies and innovation policy instruments were also made. The Norwegian research council was reorganized in 2002, and the business oriented policy instruments were reorganized and the agencies responsible merged to one agency, *Innovation Norway*, in 2004. According to Remø (2004) these changes signaled the introduction of a holistic innovation policy. And as seen in 2003, after a few years with several policy initiatives on innovation, research and higher education, the government presented its first "holistic" innovation policy in 2003 (NHD 2003).

The overall vision by the government in the *Fra Ide til Verdi* [*From idea to value*] innovation plan was that "Norway shall be one of the world's most innovative countries" and "In important areas, Norway shall be internationally leading concerning knowledge, technology and value creation" (NHD 2003, p. 5, author's translation). To embrace this ambitious goal, a broad innovation policy integrating several policy domains was put forward. The policy had an interactive and systemic perspective on innovation, and due to this, integration and coordination across policy domains were needed to address the systems character of innovation. The vision led to the formation of six goals and five areas which made up the government's innovation policy: general frame factors for the private sector; knowledge and competence; research, development and commercialization; entrepreneurship; and electronic and physical infrastructures. The two areas, 'knowledge and competence' and 'research, development and commercialization', directly addressed university-industry relationships.

The goal for the policy area 'knowledge and competence' was that an "excellent system for learning and education will give the private sector access to people with relevant knowledge of high quality" (ibid, p. 22). To achieve this goal, the government aimed at increasing the quality and relevance of education at all levels, strengthening the competence in natural science and the recruitment to natural science subjects, strengthening life-long learning, and fostering knowledge flow between the private sector and "knowledge and competence environments" regionally, nationally and internationally. The latter goal directly addressed increasing interaction and cooperation between universities/colleges and firms. In addition to stimulating collaboration across sectors, the policy highlighted that mobility was seen as a central knowledge transfer tool:

> Mobility is important for transferring knowledge across different sectors and industries. At the same time mobility is important for the interaction between academy and industry. The relatively strong connection between prior industrial employment and later research

> collaboration confirms this. At the same time, the mobility between the academy and industry is relatively low in Norway, as compared to the other Nordic countries. Therefore, it is important to increase the access to researchers in industry. At the same time, industry must strengthen its ability to use researchers and their competencies. (NHD 2003, p. 25, author's translation)

The overall policy aim for the area 'research, development and commercialization' was simply "a more research-based private sector". To achieve this, the government proposed several goals: increasing the level of R&D investments to the average OECD level, increasing the quality and internationalization of research, stimulating research and development in industry, fostering commercialization of research results, and stimulating interaction between knowledge institutions and private sector. According to the policy, R&D was seen as one of the most important sources of innovation and economic growth, and that R&D was central in both radical and more incremental innovation processes. Since universities, colleges and research institutes both produce knowledge themselves and are "import harbors" for knowledge and technology produced internationally, firms need a closer interaction with these institutions to gain access to new knowledge and technology.

Thus, it was a general policy aim to increase the interaction between public research institutions and private sector firms. According to the policy document: "to foster innovation in the private sector, the firms' interactions with research environments, in the form of collaboration, mobility and networks, is of vital importance" (NHD 2003, p. 30, author's translation). Further, that there was much potential for further interaction, and the government posed that collaborative projects and partnerships should be used to a larger extent than today.

All of the policies made since 1999 highlight interaction and cooperation between business and industry and public research institutions. But the 2003 holistic innovation policy emphasized university-industry interaction as one of the key instruments for innovation, and particularly for increasing the private sector's part of national R&D investments. The latter is now regarded as the most central aim for national R&D policy. In 2005, the holistic innovation plan was followed by a governmental report on the status of innovation policy implementation (NHD 2005). According to the then minister of trade and industry, Bjørge Brende, this report was an invitation to start the "innovation lift". According to the report, most of the initiatives that were posed in the innovation plan, had been implemented or were in the process of being implemented by 2005. The government planned presenting a comprehensive action plan for innovation in 2006. But in the general

election in September 2005, the conservative government that had been in responsible for all of these policies left office for a left-side coalition government. What will happen to the "innovation lift" is presently uncertain, but there is a broad agreement on science and innovation policies in the Norwegian parliament, making a continuation of current priorities likely. The new coalition government's policy platform, the so-called Soria-Moria declaration[14], highlights the same overall research policy goals as the previous government, as laid down in the 2005 white paper on research.

In spring 2005 the latest white paper on research (St. Meld. No. 20, 2004-2005) *Vilje til Forskning* [*Commitment to research*] was passed, laying down the Norwegian research policy until 2010. The white paper stated that the government's vision was that Norway should become an internationally leading research nation, and that this would require further increases in national R&D investments. The prior goal of reaching the OECD average at 2,5 percent of GDP by 2005 was not met[15], and the new goal laid down was to reach 3 percent of GDP by 2010, in accordance with the EU Lisbon strategy. Again strengthening the private sector's share of R&D investments was seen as the most central, and should by 2010 account for two-thirds of R&D investments. But increasing public investments was also seen as necessary, and channeled to prioritized areas. In terms of structural areas, the white paper emphasized three research political priorities: 1) increasing internationalization; 2) increasing quality in fundamental research and more focus on technology, natural and mathematical sciences; and 3) research-based innovation and value creation. In addition to these general priorities, the white paper proposed to strengthen research within four thematic areas (energy and environment, oceans, food and health) and three technology areas (ICT, new materials and nanotechnology, and biotechnology).

Research-based innovation and value creation was one of three main priorities in the research policy. As in the 2003 innovation plan discussed above, stimulating for research-based innovation in business and industry focused on strengthening the firms' internal capacity for R&D as well as collaboration with public research institutions (ibid, p. 98). The policy maintained that basic and strategic research carried out by public research institutions contributes to innovation in several different ways:

> It happens directly when research results and ideas are commercialized, and indirectly through recruitment of candidates and researchers by the firms, through contracted research,

[14] http://odin.dep.no/filarkiv/260512/regjeringsplatform.pdf
[15] In 2005, total R&D investments accounted for 1,75 percent of GDP. The private sectors share was approximately 60 percent. More on this in section 5.4.

> knowledge transfer and competence development in collaboration with business and industry (St. Meld. No. 20, 2004-2005, author's translation).

According to the white paper, the quality and quantity of interactions between public research institutions and business and industry "is of great significance for Norway's innovative capabilities" (ibid, p. 87, author's translation). The policy was based on an interactive perspective on innovation, and highlights the role the public research institutions play in the system of innovation. "Innovations happen in interactions between people, organizations and firms. Firms can hardly have the full picture over, have or handle all relevant knowledge, and are therefore dependent on interacting with other firms and knowledge environments" (ibid, p.102, author's translation). Simply put, the policy maintained that interaction between industry and universities is fundamental for innovation, and consequently more innovation in Norway would require more interactions between business and industry and universities and colleges:

> Even though the interaction between research institutions and business and industry has significantly increased and improved, the government thinks that there is still too little flow of people and knowledge between universities, colleges, research institutes and business and industry (ibid, p. 102, author's translation).

Consequently, the white paper addressed policy instruments already implemented to stimulate collaboration as well as proposed to extend most of them, as well as development of new initiatives, such as regional innovation centers, centers for research-based innovations and an industrial PhD program. The existing policy instruments, as well as new initiatives for UI interaction, are reviewed in the next section.

5.3 Policy measures for stimulating for increasing interaction between industry and universities in Norway

Current policy measures consist of a variety of direct and indirect measures intended to stimulate innovation in firms through firm capacity building and cooperation with public research institutions.

The two largest schemes for public funding of industrial R&D are the *Programs for user-initiated R&D*, and the above-mentioned *SkatteFUNN* scheme. Where as the first provide direct support to industrial R&D and collaboration, the latter provides indirect support through tax deduction for

R&D investments. In SkatteFUNN, to stimulate for collaboration with public research institutions, firms have to cooperate with approved public research institutions to get maximum tax benefits. The Norwegian Research Council runs the programs for user-initiated research, and these are the most direct policy measure for stimulating R&D in business and industry (St. Meld. No. 20, 2004-2005). The intention behind these programs is that the firm initiate, control and co-fund research projects to ensure that the research is relevant for industry and that the results are put to use. A secondary motive is to increase collaboration between public research institutions and industry, but co-operation is not mandatory to get support. 25 percent of all PhD students funded by the NFR were funded by the user-initiated programs (ibid, p. 94). The latest white paper on research emphasized that both SkatteFUNN and user-initiated R&D will be continued and strengthened as measures for stimulating private sector R&D investments and collaboration with public research environments.

Several policy measures have been developed with the goal of increasing the interaction between public research institutions and business and industry (St. Meld. No. 20, 2004-2005). Several of these measures focus on interaction between SMEs with little prior experience in R&D, and regional research institutions such as colleges. The *Mobilization for R&D related innovation* program in NFR organizes several such initiatives[16]. This program has three sub-programs, all intended to support competence development in SMEs:

- Industry oriented focus on colleges
- Research based brokering
- ARENA (pilots in regional innovation systems and clusters)

These measures focus on building up capacity and competence, stimulating network development, and competence brokering as ways of getting more firms involved in R&D and strengthening the role of research institutions as suppliers of R&D to industry. A related program is *Value Creation 2010* that aims at stimulating firms to work with researchers on innovation, organizational change and value creation, emphasizing broad participation within single firms and development networks of firms and public research institutions.

The *FORNY program* also run by the NFR is a program intended to stimulate commercialization of R&D results from public research

16 http://www.forskningsradet.no/servlet/Satellite?pagename=mobi/Page/HovedSide&c=Page&cid=1088796668976

institutions. The program supports development of infrastructure and competence as well as funding for commercialization processes in universities and colleges. This program does not support university- industry collaboration directly, but has as a sub-goal to stimulate interaction between public research institutions, industry and public authorities, as well as investors and entrepreneurs.

The 2005 white paper on research also outlined several new policy instruments. Amongst the most central new initiatives is *Centers for research-based innovation*, which focuses on supporting long-term basic research carried out in cooperation between public research environments and research-intensive companies. Selected UI collaborations will receive funding for 5 to 8 years to carry out basic research with high industrial relevance. The firms co-fund the centers, and are involved in controlling the centers as well as carrying out research. In addition to producing and transferring knowledge, training of new researchers is a goal of the program. The scheme was implemented in autumn 2005, and had by December 2005 received 58 applications.

Another measure that the latest white paper proposed to stimulate UI collaboration is *Centers of expertise*. These centers are to be regional centers of innovation focusing on stimulating networks and competence development through cooperation between regional research institutions, business and industry, and public authorities (St. Meld. No. 20, 2004-2005, p. 102). The centers are funded to coordinate and stimulate connections and collaborations between participants in regionally based networks and clusters.

A third measure to stimulate interaction proposed by the white paper is the development of an *Industrial PhD* program. The goal in this measure is to strengthen recruitment of researchers in industry. The idea is that a PhD student is hired by a company to work on a firm R&D project in collaboration with a university. These two latter schemes are still under development.

Several programs have been set up to stimulate collaboration between public research institutions and business and industry. Some focus on supporting R&D investments in firms, like SkatteFUNN, and several programs directly support interaction between research environments and the private sector. Some focus on regional innovation systems, some target non-knowledge intensive SMEs, and some focus on large knowledge intensive firms. As seen in the section on recent science and innovation policies, and in this brief

overview on policy measures[17], there is currently a very strong belief in the power of interaction between universities, and other institutions in the public research system, and industry. The Norwegian policies very much emphasize the "networks are good belief" as discussed in chapter 1. The policy emphasis in the last few years has been on closer coordination and institutionalization of network interactions, as seen in the development of Centers research-based innovation and Centers of expertise. In the Norwegian policies interaction is in itself seen as beneficial for innovation, and it is also seen as a key strategy for stimulating the private sector investments in R&D – a general goal of research and innovation policies in Norway. Although there is currently a strong policy belief in interaction, there is a lack of accurate and updated information about the extent and character of interaction between industry and public research environments in Norway. There has never been carried out a survey specifically targeting knowledge interaction between universities/colleges and industry, but several data sources give insight into UI collaboration in Norway.

5.4 Key data on interaction between industry and universities in Norway

At presently, there is no exact picture of the extent and character of interaction between public research institutions and business and industry in Norway. Since knowledge interaction is a multifaceted phenomenon encompassing several types of activities between multiple agents in different sectors, as discussed above, it can be difficult to get a complete and clear picture about the extent of university-industry collaboration. But there are some existing national datasets that give insight into the extent and variation of knowledge interaction, as well as central preconditions for UI interaction: "*The Norwegian research and innovation system*" statistics and "*The university survey*". Here the data of relevance to university-industry interaction from these surveys will be described, but without any detailed analyses of the material. The "Norwegian research and innovation system" statistics are collected biannually for the Norwegian Research Council[18]. The latest data are from 2003, published in 2005 and 2006. The statistics cover a large number of indicators on R&D and innovation in universities and

[17] A full overview of all policy instruments for innovation in Norway is found in European Commission (2005): "Annual Innovation Policy Trends and Appraisal Report. Norway 2004-2005" It can be downloaded at (24.04.06) http://trendchart.cordis.lu/reports/documents/Country_Report_Norway_2005.pdf

[18] Available at (24.04.06): http://www.forskningsradet.no/servlet/Satellite?pagename=indikatorrapporten/Page/HovedSide&c=Page&cid=1113847748761

colleges, research institutes and business and industry, both in terms of input and output data. In this dataset, two issues are particularly relevant - data on funding of R&D, particularly in universities and colleges, and firm data on collaboration on R&D projects in relation to industrial sectors and size of firms. "*The university survey*" is a survey of all tenured academic staff in Norwegian universities carried out every ten years by the research institute NIFU STEP. The latest data are from 2001 and includes items on interaction behavior by university faculty.

5.4.1 Data on funding of R&D

In the R&D and innovation statistics reports, the central measure for interaction is data on funding of R&D. In 2003 the total level of investments for R&D reached 1,73 percent of GDP. 49 percent of R&D was carried out in the private sector, 27 percent in the university/college sector and 23 percent in the institute sector. In terms of sources of funding for R&D, the following table specifies sources of funding by sector of use, in terms of expenditures:

Table 8: R&D expenditures by sectors and sources of funding. Billion crowns and percent

Sector	Industry	Public sources		Other sources	Abroad	Total
		Total	NFR			
Business/industry	11,1	0,8	0,2	0,5	1,1	13,5
%	82	6	1	4	8	100
Research institutes	1,4	4,0	1,6	0,2	0,7	6,4
%	22	63	25	3	12	100
University and colleges	0,4	6,5	1,4	0,4	0,2	7,5
%	5	87	18	5	3	100
Total	**12,8**	**11,4**	**3,1**	**1,1**	**2,0**	**27,3**
%	**47**	**42**	**11**	**4**	**7**	**100**

Source: NFR (2006)

As seen in this table, business and industry spent 82 percent of their funding on R&D in their own sector. 22 percent of the R&D expenditures are funded by business and industry in the institute sector, and only five percent of the R&D expenditures in universities and colleges are funded by business and industry. 87 percent of the R&D expenditures in universities and colleges are covered by public funds. All source of funding for R&D taken into account,

the private sector's funding of R&D in universities is modest. This level, around five percent, has been stable over several years (NFR 2005a).

As seen above, several public initiatives have been implemented to stimulate interaction between firms and research environments that ties public support to firm R&D to the need for cooperation. But as seen in the table above, public funding covers 6 percent of firms' R&D expenditures, and just one percent of the expenditures to firm R&D is covered by the NFR. What is referred to as "other sources" is funding through the SkatteFUNN scheme, accounting for 4 percent of firm expenditures. For public funding for private sector R&D in total, 41 percent was from governmental sources, 12 percent was from the NFR, 7 percent from Innovation Norway, and 40 percent from SkatteFUNN (NFR 2005b).

All in all, the total numbers for direct funding of R&D by business and industry in universities and colleges, and the public funding firms receive to R&D through the NFR (which often is linked to collaboration with public research institutions) indicate that interaction between firms and universities is a fairly small-scale phenomenon, as measured by funding streams. The same pattern is also found in international comparisons of R&D funding; around 5 to 6 percent of R&D expenditures in universities and colleges are funded by industry in EU and OECD countries (Gulbrandsen 2003). According to Gulbrandsen (2003) this level seems to be "surprisingly low" considering the massive policy thrust and build-up of strategic initiatives the last ten to fifteen years. He further discussed three reasons for why the level is low and not rising, in spite of the increasing policy focus:

1. The optimum level of interaction is reached. Due to traditions, task divisions, culture, capacity further interaction between the sectors should not be expected.
2. The macro level data hides the large differences that exist between different institutions and between different scientific fields.
3. Macro level data underestimate the degree of interaction since a lot of interaction is either not funded, or not classified as R&D.

The first explanation is hard to verify due to lack of data. Qualitative data do however suggest that knowledge interaction is difficult and that it involves a considerable degree of skepticism on both parts. This could suggest that there are structural issues that limit the growth of UI interaction. In terms of the second point, research and other statistical material show that a few science fields have substantial levels of industrial funding, where as others have little or no external funding. The latter can be seen in the following figure.

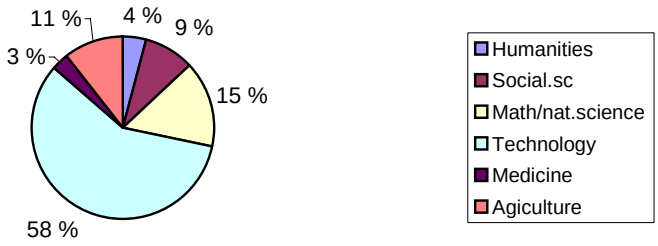

Figure 9: R&D expenditures funded by business/industry by subject fields (excluding industry internal R&D) (Source: NIFU STEP R&D statistics)

Close to sixty percent of R&D funded by industry in public research institutions is within technology, followed by natural sciences, agriculture, aquaculture and veterinary sciences, and social sciences. The institutional distribution of private sector funding of R&D in universities and colleges portrays a similar distribution. The Norwegian University of Science and Technology (NTNU) is the main recipient of industrial R&D funding, followed by the University of Bergen, University of Oslo, the University of Environmental and Biosciences, and "others", which includes several public and private colleges including the Norwegian School of Management, BI. According to Gulbrandsen & Larsen (2000) 11 percent of the R&D expenditures at NTNU were funded by business/industry, 3,5 percent and 3,4 percent at the University of Bergen and Oslo respectively, and 1,8 percent at the University of Tromsø. Of the colleges, the university college in Stavanger (now the University of Stavanger) had 13,3 percent R&D expenditures covered by industry. This is due to its connection to the oil industry located in the Stavanger region. The Norwegian School of Management BI is in a particular position among the scientific colleges, where more than one-fifth of all R&D is funded by industry.

Thus, as seen in both the institutional and science field distributions, private sector funding of R&D in public research institutions is largely channeled to technological subject fields and institutions. This entails that in some subject fields like technology, agriculture or management, and the institutions that specialize in such areas, business and industry is far from a marginal source of R&D funding. Consequently, average level of industrial R&D funding is not a good indicator for interaction between universities and firms because it hides the fact that interaction in the form of R&D contracts and collaboration largely takes place in applied technological fields or fields close to the

market (Schartinger et al 2002). This does not mean that interaction does not occur in other fields or institutions but that R&D funding statistic is not sensitive to different forms of interaction.

The third explanation for why the level of industrial funding is fairly low is that there is much more interaction between universities and firms that what is revealed in funding stream statistics (NFR 2003). Firms and universities interact in many different ways, and funding does not always follow interactions. Thus, interaction might not be captured by institutional or macro level R&D statistics on funding. Several studies, for instance Schartinger et al (2002) and Gulbrandsen (2003), indicate that informal cooperation and personal relationships, networks, mobility, education and competence development programs, and student related activities are common forms of interaction between universities and firms. The latter form of interactions is not covered by the R&D funding statistics. Formal R&D projects with contracts and funding is 'the icing on the cake' on UI relationships. The primary data collected for this study, as will be presented in the following chapters, on establishment of formal R&D projects indicate that formal R&D agreements most often grow out of long-term informal relationships and small-scale projects.

5.4.2 Data on university – industry interaction

In Norway, the "university survey" carried out every ten years by NIFU STEP gives access to individual level data about interaction behavior by academic employees. Gulbrandsen (2003) claims that micro level data probably gives the best overview on the extent and character of relationships that cuts across sectors. In the latest survey from 2001, tenured university faculty were asked to report on their interaction with business and industry. They were asked to report on whether they had a) had R&D collaborations with business and industry in the last three years, and b) had received funding from business and industry in the last five years. The following table describes collaboration with and funding from industry across subject fields over time:

Table 9: Collaboration with and funding from industry amongst tenured academic staff in universities, by subject fields and period. Percent.

Science fields	Funding from industry			Collaboration with industry		
	Share of academic staff					
	1982	**1992**	**2001**	**1982**	**1992**	**2001**
Humanities	3%	3%	3%	2%	3%	4%
Social science	7%	8%	15%	6%	8%	12%
Natural science	9%	25%	26%	8%	22%	27%
Medical science	8%	19%	25%	7%	19%	21%
Technology	-	68%	61%	-	64%	68%
Total (N)	**7% (108)**	**20% (367)**	**21% (448)**	**6% (92)**	**19% (348)**	**21% (446)**

Source: Gulbrandsen (2003)

These individual ldata indicate that one-third of university employees either have collaborated with, or have received funding from, industry the last five years (Gulbrandsen 2003). The data also indicates that collaboration grew in the 1980s and stabilized in the 1990s, as a response to policies and new initiatives. Besides from the humanities, the share of university respondents who collaborated with industry, or received funding from industry, more than doubled in this period. The table also indicates that interactions are very common in technological fields, but also substantial in natural science and medical science. Social science respondents indicate that interaction is less common, but sharply rising and have doubled from 1982 to 2001. These levels correspond to the industrial R&D funding by subject fields as presented in figure above.

Gulbrandsen & Larsen (2000) also analyze interaction behavior of academic staff seen in terms of previous experiences. They find that there is a strong connection between previous employment in industry and collaboration with industry. This pattern is strong in all subject fields, but particularly important in social and natural sciences.

A last data source that sheds light on interaction between industry and universities and colleges are data on firm's collaboration behavior in R&D as reported by firms (NFR 2005b). According to this survey, about half of the firms (45 percent) that have carried out R&D activities have formally collaborated with others in one or more R&D projects[19]. In terms of who

[19] Here formal collaboration is defined as projects where several agents participate in a common project or through several independent projects linked together, but

firms report to have collaborated with, the following figure portrays the distribution across partners.

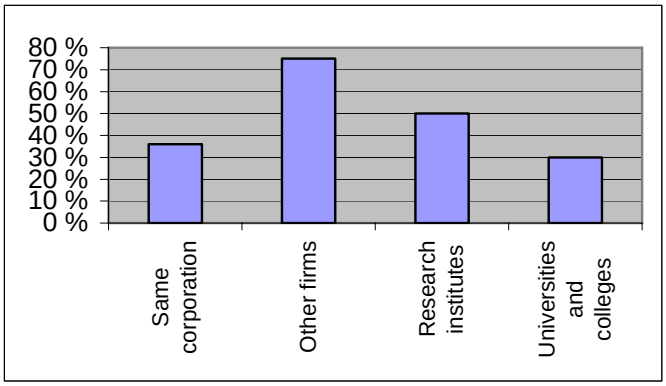

Figure 10: Firm's R&D collaboration by partner. Percent. (Source: Statistics Norway)

Collaborating with other firms, as well as businesses within the same corporation, is most common, followed by research institutes at 50 percent and universities and colleges at 30 percent. Collaborating with public research institutions is most common for firms within the industries: production of chemicals and chemical products, production of non-metal mineral products, and production of metals. The share of firms within these three industries that have collaborated with public research institutions is 83 percent and higher, and 64 percent of them have collaborated with universities and colleges (NFR 2005b, p. 28). Collaboration with public research institutions is also related to the size of the companies. Larger companies more often than smaller companies interact with public research institutions.

excludes buying and selling of R&D without two-way transfer of information as well as "researcher visits" (NFR 2005b, p. 26).

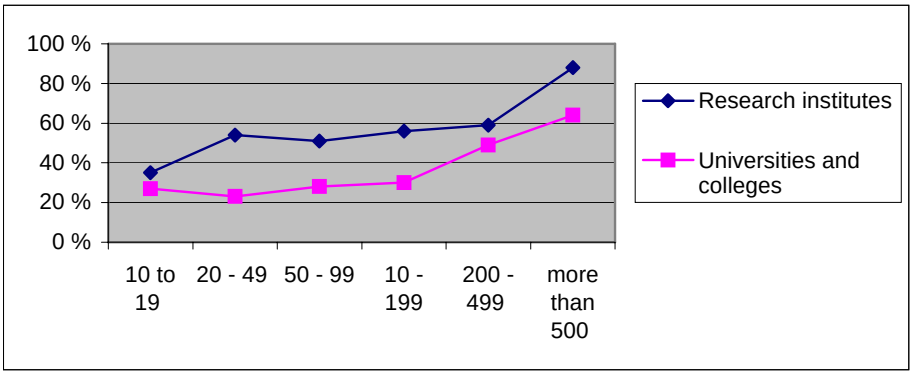

Figure 11: Collaboration with public research institutions by size of firms (Source: Statistics Norway)

This illustrates that larger companies are more R&D intensive and have a larger capacity, which also makes them cooperate more with public research institutions.

5.5 Policy and practice of UI interaction in Norway – a summary

This chapter focused on describing the policy developments the last seven years in Norway as well as key data on interaction. At the turn of the century several policies were passed concerning research, higher education and innovation in Norway. The Hervik, Mjøs and Bernt committees submitted official Norwegian reports (green papers), which had several implications and led to reforms of the higher education and research systems. Two white papers on research and two law amendments were passed giving the universities and colleges statutory duty to interact with external users, and a right to utilize results from research commercially. In all of the recent policies, higher education, research and knowledge are seen as strategic instruments for innovation in the private sector. The last ten years, the OECD average of 2,5 percent of GDP has been a central yardstick in Norwegian research policies, and Norwegian industry's low level of R&D investments were recognized as a problem for economic growth and welfare. Many initiatives have been built up to strengthen the level of R&D investments in business and industry, and most of the policy instruments have focused interaction with universities as a key measure for innovation and increased R&D capacity in firms. The policy analysis reveals that the 'power of interaction' focus is strong in Norwegian polices.

The last section of the chapter looked into existing national data on interaction between industry and public research institutions, focusing on R&D funding data and university and firm survey data on interaction behavior. The data indicate that in spite of policy initiatives knowledge interaction as measured as a level of private funding of R&D in universities and colleges is low – about five percent. But as seen, this not a Norwegian phenomenon, as similar numbers is found in most OECD and EU countries.

The analysis made by Gulbrandsen (2003) indicates that industrial funding for R&D is not evenly distributed but is channeled to subject fields and institutions in technological areas. In some institutions that specialize on technological subjects, industrial R&D funding is substantial. However, the macro data on R&D funding also does not take into account that most of the interaction between industry and universities are not covered by these formal R&D statistics (Faulkner & Senker 1995, Gulbrandsen 2003, Schartinger et al 2002). This could indicate that interaction either focuses on other activities that those that are classified as R&D, or that funding is not received or reported to the institutions. Individual level survey data indicate that 21 percent of tenured academic staff have interacted with industry and received funding from industry. The distribution of academic staff that have interacted with industry shows that, similar to the funding stream data, researchers in technology areas interact the most. Here the majority of researchers are involved in UI relationships. Data also indicate that previous employment in industry is important for later interaction behavior. This is particularly central for social scientists, and less important for technologists. This could indicate that previous interaction, networks and mobility are very central for formation of formal R&D collaborations.

With this in mind, qualitative data on tie formation and interaction experience in two academic fields will be presented and analyzed in the next chapters. The analysis of the qualitative data focuses on developing images of how and why collaborative R&D projects are formed and how the interaction is experienced. This analysis offers insights into micro-level processes of interaction between firms and universities. Utilizing the conceptual framework as a sensitizing tool, the next three chapters present data from interviews with researchers and managers involved in collaborative R&D projects, along with analysis of some field observations and documentary evidence collected. Chapter 6 emphasizes the respondents' reflections about motives and incentives for forming ties, chapter 7 focuses on how ties are formed, and chapter 8 focuses on researchers' interaction experiences. Finally in chapter 9, further data reduction through a comparative perspective and a synthesis of the analyses, through which a theoretically sensitized and empirically grounded image of tie formation and exchange processes in the university-industry context, is developed.

Chapter 6: Tie formation motives

6.1 Interpretative framework

In this chapter, emphasis is put on why collaborative R&D projects are formed; focusing on the interviewees assessments of motives and inducements for tie formation. As discussed in chapter 2, motivation is a dominant focus in literature on UI relationships and this is usually seen as a reflection of characteristics of interacting organizations, emphasizing an interdependence explanation of tie formation. In chapter 3, this perspective was discussed more generally looking into environmental contingencies (Oliver 1990, Eisenhardt & Schoonhoven 1996) that might induce organizations to form ties to others, particularly resource dependence.

The analysis of the researchers' accounts of tie formation motives focused on developing conceptual categories as presented in the table below[20]. The categories serve to highlight central analytical dimensions and properties (Strauss & Corbin 1998). The interview data on motives was analyzed firstly through developing conceptual categories that are grounded in the data - divided into perceived firm motives and perceived university motives. The second step involved utilizing a theoretical perspective to further analyze the conceptual categories in light of an interdependence perspective on motivations for tie formation. The reason for this was that the first-order analysis revealed some interesting dimensions and patterns that could be further understood by interpreting the descriptions of motives in light of different interdependence dimensions.

[20] This way of using conceptual tables for displaying analytical focus areas was developed by Marstein (2003).

Table 10: Conceptual analysis: Tie formation motives

Conceptual focus area	Conceptual categories	Conceptual property focus
Tie formation motives	Perceived firm motivation	Informants' perceptions of the partner firms' motivations in forming a tie to them
	Perceived university motivation	Informants' perceptions of the university and researchers' motivations for forming ties to firms
	Perceived Interdependence	The informants' perceptions of interdependence between them and their partner firms

The conceptual categories are here treated as sensitizing concepts that facilitate focusing on central analytical dimensions of tie formation between firms and universities. The break down in sub-categories, properties and dimensions are furthered in the following sections.

6.2 Perceived firm motivations for tie formation

The respondents discuss different motives that firms have when they choose to enter into relationships with universities. However, this is an interpretation made by the respondents, which is not necessarily representative for how the firms think. Both the respondents in economic/administrative sciences and chemistry/material sciences share common ideas about the main motives of the firms. The two main motivations respondents discuss are problem solving and supporting competence environments in universities. Less frequently discussed firm motivations for tie formation are risk sharing and access to resources.

6.2.1 Problem solving

An important tie formation motive is that collaborations with universities are formed with the purpose of solving a particular problem. In chemistry/material sciences, problem solving focuses on improving technologies. The following quote from an R&D manager illustrates this focus:

> *When firms approach universities it is because they have a complex problem that they do not have the competence to solve themselves. The collaboration is characterized by problem solving, not creation*

> *of new ideas. Firms do not call universities and ask if they have any good ideas in store. Firms are not interested in creating new ideas, but in solving the problems they have with their existing technology.*

For researchers in economic/administrative science problem solving concerns improving 'soft technologies' (Bozeman 2000) like leadership programs, organizational structures, improving the understanding of the firm's markets etc. Problem solving can here entail monitoring processes or projects going on in the firm and suggesting ways to improve them. This quote from a researcher involved in a collaborative R&D project with a large Norwegian firm illustrates this: *They had recently implemented a tool for selection and assessment of leaders. What they wanted was to monitor the development and implementation of this process.*

But in the data material 'problem solving' means different things. Some collaborative projects set up to solve a particular problem are narrow in scope. By that it is meant that they focus on improving limited aspects of existing technologies. Other projects have a broader problem solving focus, in that they attempt to create new knowledge or innovations that are new to the company. Examples of the latter from the interviews are companies that intend to use the collaborative project as a way to commercialize basic research, developing a new catalyst technology, and a company that intended to use the research collaboration as a way of creating new business models and markets. These are however exemptions. For the most part problem solving is narrower in scope, focusing on improving established technologies or monitoring ongoing processes. Within chemistry and material science, the problems the collaborative projects address include:

- Testing materials for creating ceramic membranes for hydrogen separation from gas
- Reconstruction of chemical catalysts in fertilizers
- Specification of chemical catalysts in oil/gas production
- Testing and improving the performance of solar cell materials
- Improving technologies for oil and water separation in oil production processes
- Creating and improving membranes for chlorine separation in magnesium production

Problem solving is not an equally important motive according to the economic/administrative researchers interviewed, but a few of the collaborative projects have problem solving focuses, including:

- Understanding markets and regulation in the telecom sector

- Monitoring the development and implementation of a leadership development tool
- Monitoring the development of new business models

6.2.2 Supporting competence environments

For most of the interviewed economic/administrative science researchers, problem solving is not a central focus. Rather, firms' motivation concern supporting "competence environments"[21] and general development of knowledge in areas of relevance to the firm. This is a different logic behind forming ties than solving existing problems, but the two are not mutually excluding. According to the respondents, the motivation often can be to support general knowledge development and the building up of university-based competence, as well as getting help to solve a particular problem that a company has. According to respondents, firms collaborate with universities as a way of ensuring that research is carried out in their areas of interest, or in areas they see as strategic, but where little public research funding is available. The motivation is also to ensure that education is informed by updated knowledge, since the firms recruit graduates from these departments. A professor in economic/administrative science describes the motivation for the collaboration in the following manner, which illustrates this way of reasoning:

> *The contract is written exactly for this purpose: to develop a competence environment, which can contribute to increasing the understanding of central problems in this sector. And for [the company] to draw upon this competence, they need access to the knowledge in this environment, but not in the form of a report.*

All of the professors and several of the researchers in economic/ administrative science interviewed express that competence development, rather than problem solving, is the main motive behind the collaborations they are involved in. Several of them are critical to projects with a narrow problem solving focus. One professor's statement illustrates this: *For me they are meaningless, besides from being a suitable introduction course for academic staff in need of some grounding in what is really going on.*

The respondents in chemistry/material science also emphasize the broader goal of competence development. But the respondents that focus on this do not see it as something that in itself contrasts with problem solving. Two of the respondents, which work on research problems that are closely related to industry interest, talk about how their research groups have a role as a

[21] Kompetansemiljøer in Norwegian

competence environment that the firms utilize in different ways. And also that education and recruitment are central motives behind collaborations. A professor of chemistry describes what he thinks is the main motives of his collaborating firms:

> *To do research in fields that the industry is interested in, so that new knowledge is created. Off course they are interested in knowledge, but also in the education of candidates that they later on want to hire, since they are in possession of tailor-made knowledge.*

A researcher in chemistry describes how his research group works as a competence environment for industry. This respondent works in a partly industry funded research center. This is the only example of an institutionalized competence environment in the data, so it's the exemption rather than the norm. But it illustrates how competence environments can work.

> *Each firm is a member of our board, where they can play a part in deciding over the future development of the lab (…) And they have other advantages, like at any time they can send people here to use our instruments to test things in the lab. They can also have students here, working on their master thesis and things like that.*

In these reflections on firm motivations for supporting development of university based competence environments, recruitment of graduates is seen as a key motive by several respondents. This can either be a more general focus on assuring that educational programs are of such a quality and relevance that firms can recruit the candidates, as illustrated by the following quote by a professor of chemistry:

> *The focus has been to ensure that one has environments that have competence in fields of knowledge, which are seen as important to the sector. And to assure that it exist educational programs from which firms can recruit competent employees.*

In other cases recruitments is an explicit motivation for forming collaborations. This is not seen as central to the respondents. Very few of them say that recruitment was an explicit motivation of the firms, particularly the professors. However several of junior researchers (PhDs and postdocs) interviewed said that discussions about recruitment had been "very present" in the interactions they had had with the firm. In some research groups, that have very close interactions with particular firms, recruitment can be the dominant motivation. A professor of chemistry/material science

tells the following story of how a recently formed collaborative project with a company started:

> *This process started with their plans for building up a totally new activity (…). So they were out to buy candidates. They invited two of our candidates to Copenhagen for interviews, and are now hiring one of them. The contract is that he is to be partially located here and partly in Haldor Topsø, and in connection with that, an expansion to include students that will work with this candidate, who is to be partly employed in this research group but paid by the company.*

There are a few other examples of dual affiliation mentioned by the respondents interviewed here, typically in areas where there is a high degree of interaction and interdependence. This is explored further in section 6.4.

6.2.3 Access to resources and risk sharing

The final category of firm motivations discussed by the respondents concerns access to specialized resources and sharing of risks. Although access to resources is a theme that several of the chemistry/material science interviews, it is not by the respondents seen as a main motive by the firms they interact with. But as seen above in the discussion of competence environments, access to specialized instruments is a part of the interaction. Some of the instruments these researchers work with are sophisticated, rare and very expensive, so sharing instruments are sometimes necessary.

According to the respondents risk sharing is a tie formation motive for firms when the innovation represents something totally new to the firm and outcomes are uncertain. In these processes involving research environments in universities provide the firms with access to new knowledge and also access to public research funding, which shares the economic burden and alleviates risk. One of the respondents, a researcher in material science, illustrates this when talking about a collaborative project his research group was involved in with a Norwegian firm:

> *We joined in since we had a particular competence that Hydro did not have at the time. And possible also because Hydro was uncertain about whether the project would succeed or not. So maybe it was better to involve the university rather than developing all the competence that would be needed in-house. That is what you do when you are certain that the project is successful. Then you evaluate whether you should take it inside the company, due to business opportunities and secrets. But at that time, it was uncertain.*

Several of the collaborative projects have a significant part of public funding through the Norwegian Research Council. A recent evaluation of user-initiated R&D projects have looked into access to public funding as a motivation for firms, and they find that public research funding is very important for firms to form collaborative projects with universities and other public research institutions (Hervik, Bræin & Bergem 2004). This will be further discussed below in the discussion of resource dependence as a framework for understanding tie formation behavior in section 6.4.3. But first the motives that researchers in universities have for forming ties with firms will be described.

6.3 Researchers tie formation motives

When the respondents discuss their own and their institutions' motives for entering into collaborative projects with firms, the range of responses is much narrower than for what they think firms' motivations are. Answers to this question also tend to be shorter and they obviously have very clear opinions on this question. The answers are either access to research funding and other needed resources, or "real life orientation" (what a few of the economic/administrative science researchers refer to as "grounding"). But it is not an either or question, as frequently both motivations are seen as important.

6.3.1 Access to resources

Access to funding for research is seen as a central motivation by the researchers. A majority of the economic/administrative science researchers think this is the most important motivation, and a few of them say that availability of funding was the only reason for why formed a collaborative project. A researcher in economic/administrative science explains his motivation in the following manner: *I had no previous contact with the company. My only motivation was to get money for a PhD project. The department's motivation was to secure funding for a PhD student.*

Most of the respondents highlight that access to external funding enables them to fund students, PhDs and postdocs, equipment and labs. Access to research funding is, according to the respondents, less scarce in parts of chemistry and particularly material science to which public research money currently flows. Several of the professors in chemistry claim that access to able students is a more important "resource deficiency" for their research

groups. For some of these having collaborative projects with industry are seen as a way of attracting students. In this way, access to job opportunities for their students is a motivation for collaborating with firms, although this will interact with other motivations, as a kind of a positive byproduct of collaboration.

Access to public research funding is a motivation for interacting with firms that economic/administrative science researchers and chemistry/material science researchers share. Several of them say that it is easier to get funding from the NFR's programs that supports UI collaboration projects than from the basic research programs.

> *There are two application procedures in the research council. One of them is user-initiated projects. And it is easier to get support if you have contact with firms. It is much more resources available, and it has a lot to say what the firm contributes with.*

The quote above is from a professor in economic/administrative science who talked about a collaborative project he had been involved in establishing a few years back. At that point in time there was to fixed application deadline, but if you had a project idea and a company partner that had agreed to support you, the NFR would more or less automatically match the funding from the firm. The process is more systematic now, according to him, with program application deadlines and systematic project assessments. Researchers in chemistry/material science also pinpoint this motivation for collaborating with firms.

> *It is a very tough competition to get a project funded by the research council. If industry supports you and they say that they are interested, this counts in the allocation. This is also important for allocation of EU research funding. In large EU projects, it is absolutely necessary to have industry partners. Possibly the most important criterion to get funding is that you have active industrial partners.*

Since governmental and EU research funding are intended to foster closer collaboration between firms and research institutions, researchers need to interact with firms to get access to funding.

6.3.2 Ensuring relevance and use of knowledge

In addition to access to resources, the respondents express other reasons for why they interact with firms, related to the different kinds of input the

researcher think they will get from interacting with firms. Getting access to relevant research problems, testing ones ideas in practice, or making sure that the research is relevant for someone, are reasons frequently mentioned by economic/administrative science researchers, particularly by the junior academic staff interviewed. One of the respondents interviewed refers to this as "grounding". By this concept he does not mean that the research should solve particular firm problems or even be based on data collected in firms. Grounding according to him is about *"the dialogue about the research problem and the relevance of the findings"*. He further describes how this dialogue with practice is central in research:

> *But it probably informed a lot of … not probably; it did inform many of the research problems I later have worked on, precisely since it made me see the conflicts between the models that were used, both by the company and the consultants they used, and reality.*

For the chemistry/material science researchers this is not equally central, but competence about application of technology is a similar type of motivation that some of them think are important, as illustrated by the following quote:

> *What is positive is that you work on something that is concrete, a concrete goal. You want to have a product in the end. So it is easy to say, that's where we want to go. Let's find a way there. I think it is positive and challenging.*

Also, some see interaction with industry as a service to society, as part of the mission of universities and colleges to develop and spread scientific knowledge to different users. For one respondent in economic/administrative science, interaction with firms is a natural extension of what he sees as the mission of research institutions like universities and colleges – to create and distribute knowledge. He explains his motivation and views on collaboration with firms in the following manner:

> *We have to understand that we are a node in a network where we have the responsibility to investigate a few things, and we have the responsibility to administer this knowledge on behalf of everybody. At the same time we are a node in the network and are also responsible for bringing the whole picture to our users - our students, public authorities and firms.*

This respondent does not see an inherent contrast between research carried out to generate knowledge and to inform educational programs – the two traditional missions of universities – and transferring knowledge to external users. Many of the respondents share his view, in that collaboration with

firms is not seen by them as something in addition to what they normally do. Interaction with firms is an extension of their daily work.

6.4 Perceived interdependence

Firms, researchers and universities have different motivations for interacting according to the respondents interviewed. But the reasons and explanations for why some firms and universities are motivated to form ties were not explored above. But as seen in particularly the sections on firm motivations, and the contrast between problems solving versus supporting competence environments, there are differences of opinions both across academic fields but also within chemistry/material sciences, relating to how important or central the interaction is to the firm. As seen in chapter three, frameworks looking to identify why organizations choose to form ties with others often see it as a strategy for coping with dependence. In this perspective, organizations are not self-sufficient, but rely on others in their environment for the achievement of an action or to obtain a desired outcome. They are dependent on others for resources, which create uncertainty and instability. Forming ties to others are seen as a strategy for coping with dependence. Below the data on motivations presented above will be further explored in light of an interdependence perspective, looking into three dimensions of dependence that is of relevance to ties between firms and universities. The three aspects are all reflections of resource dependence but with somewhat different emphases since the dependencies of each party in question is not the same.

Table 11: Conceptual analysis: Perceived interdependence

Conceptual category	Sub-categories	Sub-category property focus
Interdependence	Knowledge intensity	Firms that are dependent upon scientific knowledge are more motivated to form ties
	Core technology	Firms are more motivated to form ties if the problem relates to a core technology
	Mutual trigger dependence	Firms and universities are motivated to form ties through their mutual dependence on triggers for resources

6.4.1 Knowledge intensity

Utilizing the dependence framework for exploring tie formation between universities and firms, one would expect that firms and industries that were dependent on scientific knowledge in production or as production would be more motivated to form ties to research environments. As discussed in chapter three, high demand for knowledge in firms is also related to internal knowledge capability, as absorption of knowledge requires internal R&D capability (according to the theory of absorptive capacity). Industries or individual firms that are "knowledge intensive", in that they require scientific knowledge as input in production and possess internal capabilities, have higher incentives to form ties to universities. Knowledge intensive firms and industries are as discussed in chapter two are characterized by radical innovations, they have internal R&D departments with employed research staff, and use a substantial part of their revenues on funding R&D activities internally and externally.

In a recent industry report knowledge intensive firms are referred to as "R&D and innovation heavy companies", operationally defined as firms that spend more than 20 million Norwegian crowns on R&D (TBL 2004). These twenty firms in this report use approximately 6.5% in average of their turn over on R&D, and represent 2/3s of all investments in R&D by TBLs[22] members. They are the "R&D locomotives" according to TBL. As opposed to all the firms included in the survey, the R&D heavy companies are different than other companies on various dimensions. They report that universities, colleges and research institutes are the most central partners in R&D and innovation activities, as opposed to less R&D heavy companies who rate their customers and suppliers as the most important collaborators. They are international in their orientation and they market their products directly to an international market. In terms of financing R&D internal assets are the most important followed by the NFR, who is the most important external source of funding for these companies. Less R&D heavy companies rely more on other funding regimes, particularly SkatteFUNN and Innovation Norway. The R&D heavy firms have a large production of new products and services and frequently patent.

In terms of the respondents interviewed, what firms do they collaborate with and what characterizes them? The respondents in economic/administrative science interviewed are involved in collaborations between the Norwegian School of Management BI, and Hydro, Telenor, Statoil, Alcatel, Orkla and Nordea. Respondents in chemistry/material science interviewed are involved with collaborations between the University of Oslo or the NTNU and Hydro,

[22] Federation of Norwegian Industry

Borealis, Statoil, Haldor Topsø, Tandberg Data, Shell, REC, ABB, Siemens and ENI.

The respondents in administrative/economic sciences tend to collaborate with only one or two companies, where as some of the chemistry/material science researchers also collaborate with several firms, most often in several independent agreements and sometimes in networks and consortia.

But what characterizes the firms involved in the university collaborations in this investigation with respect to knowledge intensity? Most of the companies that the respondents interact with are large multinational companies within oil/gas/energy production, process industry, ICT and telecom. Hydro, Statoil, Telenor and Borealis are the four companies most frequently referred to as collaborative partners by the respondents. All of these companies are knowledge intensive. They are innovative and oriented towards international markets; they have internal R&D facilities, employ R&D staff and use a substantial share of their revenue on research and development activities. Since the production processes requires constant input of scientific knowledge, they have developed internal capabilities and interact extensively with research institutions nationally and internationally.

This is also a topic that some of the respondents interviewed are preoccupied with. How do they assess dependence due to knowledge intensity of the firm as a background for why firms are motivated to interact? A professor of chemistry discusses the relevance of their research to industry in the following manner:

> *We work on catalysis and that is highly relevant to industry. 90% of all chemical processes are based on catalysts. And what has happened in the last twenty years is that the understanding of how catalysts work has moved from an empirical to a more fundamental understanding. This occurs in university-based research groups rather than in industry. Primarily, industry is interested in collaborating with university groups to understand what is going on, to improve the catalysts and the economy of the process. For industry, in the end, it's only the economy that matters. We focus particularly on the petrochemical industry, where there is a lot of money involved. So much that if you have to stop the process and change the catalyst, which you have to do a few times a year, you loose approximately 12 to 15 million crowns. So it is important for them that this occurs quickly.*

The interdependence focus is very clear in the above quote. Many of the respondents focus on the knowledge intensity of the firm they cooperate with when they explain why the firm was interested in establishing a relationship with them. In the following quote, an industry R&D manager reflects on the differences of knowledge intensity in industries and firms for explaining tie formation to universities:

> *There are large differences between industrial sectors and between firms. They have different experiences and needs. Large R&D heavy companies have a close cooperation with universities and research environments. In less R&D intensive companies, the cooperation is not so close and the needs are less. (…) But the typical firms that collaborate with universities are the large R&D heavy companies. For them, collaboration emerges because they have a relatively large number of R&D staff that need input.*

This, he explains further with reference to the internal capacity of large R&D heavy firms:

> *The companies must be able to understand the competence they receive. This requires a lot of the companies and their researchers. And this is why most often only the large companies with a lot of internal resources are involved in knowledge transfers between universities and firms.*

With respect to the internal capacity for R&D, some of the respondents comment that many of the large R&D intensive companies in Norway, which is the dominant partners for universities, have a past as a public company and/or that the state owns a majority of the shares. One of the economics/administrative science respondents discusses the role that national telecom operations played in innovations in this sector:

> *All of the telecom companies had large R&D labs, which were serious research labs; they were not product development departments. They were serious research labs. This is due to the fact that they were public for a long time, public with a mandate to transfer knowledge. So they were not new to research and the significance of research. And this has been furthered in their use of external research environments.*

Several of the respondents highlight the particular situation and status of the oil/gas industry in Norway. As seen above, several of the companies that the interviewed respondents interact with are oil/gas or petrochemical

companies. One of the respondents from NTNU highlights the particularity of the oil/gas sector in Norway.

> *Offshore, that is oil and gas, have always been a very critical industry with very close ties to NTNU. If you go over to the department for petroleum technology and applied geophysics, you'll see that people are very accustomed to working with industry. If something happens, they just call. They have large formalized projects; they know all the oil companies that exist on the Norwegian shelf, right? They are very used to working like that and industry fund a lot of what is going on.*

A few researchers interviewed that works close with oil companies also highlight that in this particular sector there is a division of labor between research environments in universities and firms with respect to R&D tasks. They claim that several oil companies have "closed or downsized" their internal R&D departments and now rely on buying and commissioning research in the universities.

The division of labor between firms and university-based research also influences what the researchers think about the interaction partners. Several of the respondents express that interaction with companies that have internal capacity, in terms of R&D departments and personnel, is much more rewarding, and that the process of collaborating is easier. According to a professor of chemistry, discussing the different firms he has cooperated with, illustrates this:

> *Traditionally it has always been more interesting to cooperate with Hydro, since they have an established research center and have a focus on basic research. Statoil is a much younger company with a focus on problem solving with a shorter time frame. And that suits the university less. We have to think long term; if we are to be good at something we have to work on it for years. That is the nature of our relationship with Haldor Topsø. That is a very research-intensive company that uses a large part of its budget of research. Much more than Hydro or Statoil does. They have a lot of knowledge.*

Knowledge intensity seems to act both as a motivation for firms to interact with research environments and might also have an impact on how the interaction process is carried out and experienced by the researchers. Firms that are knowledge intensive both have greater need for knowledge as well as capability for knowledge generation and absorption. The latter element seems to influence the interaction process positively, since firms that have

R&D capabilities both contribute with knowledge themselves, and through this probably understand the requirements and process of scientific research, which the university based researchers interpret as positive and necessary in collaborative research. This will be explored further in chapter 8. However, even though knowledge intensity seems to be a central contingency, several of the interviewees address a related element, which according to them is related to both the motivation for tie formation and interaction process – the extent to which the collaborative project is related to a core technology in a company.

6.4.2 Dependence between core and complementary competences

Several of the respondents highlight that whether or not the collaboration is related to a core technology of the firm has a strong impact on how they experience the interaction process. What is meant by core technology here is that it constitutes a central tool or process in the firms' production or a central competence for the firm. According to some of the respondents, in projects that are related to core technologies or competencies, the firms have a much stronger incentive and are much more involved, in terms of people and resources, then in projects that address peripheral or 'new and promising' technologies. Thus, when the collaboration is related to research on a core technology, the firms have more at stake and are likely to be much more committed. In short, the interdependence is stronger in core technologies. Three examples serve to illustrate differences between collaborative projects that address a core versus peripheral technologies in the same company.

The first example is a project that addressed a core technology and was funded over corporate budgets. According to the professor of chemistry involved in this collaborative project:

> *In this cooperation Hydro contributed with their experts and their competence. In this case we had a very close dialogue. But this project was directly related to the core business of the firm. And then the expertise is always there.*

But cooperation with universities tend not to address core technologies, since the firms prefer to do research like that in-house. They involve universities in projects related to technologies they think are promising, but still too uncertain for bringing them 'inside'. Another example from a project between chemistry/material science researchers and Hydro partner addressed a promising and uncertain technology:

> *We joined in since we had a particular competence that Hydro did not have at the time. And possibly because Hydro was uncertain about whether the project would succeed or not. So maybe it was better to involve the university rather than developing all the competences that would be needed in-house.*

Then the respondent goes on to discuss why, in his opinion, the project did not become a success, and eventually was terminated when the funding from the NFR ended.

> *Because then they had to use their own money, and to defend using money on it. They have many other research projects which are more relevant to Hydro's interests. So to defend doing research in the area that our project addressed, it had to be a very promising project in a way, and maybe Hydro did not think it was promising enough.*

The third example is from a collaborative R&D project with Hydro involving researchers from administrative/economic sciences, funded partly by the NFR. In this project, the respondents experienced a lack of interest from the firm, which they attributed to the project not being "critical enough" for the firm. This is illustrated in the following quote: *But it was a problem, and this is related to the issue of research being a critical input, it was a challenge to get attention on the contributions we made.*

Many of the researchers in administrative/economic sciences have similar experiences, and they tend to explain negative experiences by reference to that the project was not important or critical for the company. Comparing the chemistry/material science projects with the administrative/economic science projects in terms of collaborative partners, one can see that the firms that both of the groups of researchers collaborate with to a large extent are the same companies. This could indicate that firms that have long experiences in collaborating with university-based research groups in their core technologies, also "transfer" this practice of collaborating to other parts of their business and to other tasks. In this way, the knowledge intensity of the firm might also explain why they collaborate in other areas than traditional R&D tasks. But since the interdependence in practice is less, since these projects tend not to address core processes or technologies, firms are less committed and the process of collaboration is experienced as different. This will be further explored in chapter 8.

6.4.3 Mutual trigger dependence

University dependence on firms, as a framework for explaining why they choose to form ties, focuses on how universities use collaborative ties as a way of procuring resources. Through getting access to external resources, particularly money, universities reduce their dependence of public financing and through that reduce uncertainty (Slaughter & Leslie 1997). In this framework, universities do not directly depend on firms for resources, but they are dependent on resources for research in general. Collaborating with firms ensures them access to resources, which lessens the dependence on public resources or makes access to public resources easier. This dimension of interdependence is clearly visible in the interviews with the researchers. Both researchers in chemistry/material science and administrative/economic sciences highlight that cooperating with firms gives them access to research funding, and that this is a very important reason for why they cooperate. Administrative/economic science researchers highlight this more than chemistry/material science researchers, but very seldom is it expressed as the sole motivation. A related motivation, which both groups of researchers are preoccupied with, is that cooperating with firms makes it easier to get funding from the NFR.

Firms also use collaborations to provide access to resources, both directly from the universities, and cooperate with universities as a way of getting access to public R&D funding. As seen in section 6.2.3 above, when technology is new and outcomes are uncertain, access to public funding alleviates risks by sharing the economic burden. Other recent research reports into firm R&D behavior, also indicates that most joint R&D projects would not have been implemented if they not had been partly funded by public means (Hervik, Bræin & Bergem 2004; TBL 2004).

In terms of interdependence, both university-based researchers and firms depend on the NFR for resources. The NFR is a powerful triggering agent that motivates firms and universities to collaborate, since current research and innovation polices emphasize collaboration as a condition for funding, as seen in chapter 5. The NFR see collaboration as an important way to transfer knowledge from universities to industry. In the data collected, particularly projects that address promising but uncertain technologies or non-core competences, the role of NFR as triggering agent seems to be vital. Amongst the researchers interviewed, half of them where involved in NFR funded collaborative projects, and half were funded through a bilateral agreement with a firm. But even though the research council has been successful in fostering interaction, by proving a motivation for both firms and research groups, does this motivation determine who collaborates? The

next part will look into how the interviewees experienced the tie formation process, focusing on between whom and how ties were formed.

6.5 Summary

In this chapter, the question of why firms and universities form ties in the form of collaborative research projects has been explored. The respondents interviewed indicate that there are many reasons for collaboration, and that they have different motivations for forming ties with firms. The respondents were also asked to reflect on what they, in their experience, thought were the firms tie formation motives. In terms of firms' tie formation motives, the respondents see two general motivations, to solve particular problems and to support university based competence environments, which they later can use as a resource and recruit graduates from. Although the two motivations are not contrasts, they do represent somewhat different logics firms can have in mind when they choose to cooperate with universities. A tie formation motive that researchers and firms share is access to resources. Researchers state that access to funding for research is an important motivation for them, either directly from the firm or from the Norwegian Research Council. Grounding their ideas in practice and communicating with the world outside the academy are other motives researchers put emphasis on.

In the latter half of the chapter, a theoretical frame for exploring further the motivations for tie formation was utilized. Here, three sources of interdependence that were of relevance to ties between firms and universities were presented and discussed. Knowledge intensity of firms, seen in terms of the demand for scientific knowledge input but also the internal capability, was explored as one source of interdependence. The data collected here, but also other sources, indicate that large, R&D heavy companies see universities as central innovation partners. Smaller, less R&D heavy companies do not interact to the same extent with universities. One reason for this, that respondents also discuss, is that large companies have R&D departments with scientists on staff, and these employees have an interest in interacting with researchers in universities.

A second dimension of interdependence is whether the collaboration is related to a core technology or a core competence in the company. Interdependence is stronger when the knowledge is of relevance to a core technology, and the respondents express that it is different to cooperate on projects that is related to core rather than on peripheral technologies or competences. Three examples from different collaboration projects in the same company were used to illustrate this.

The third source of interdependence discussed was mutual trigger dependence, here more narrowly defined as resources to fund and carry out research projects. Researchers see access to external research funding as a dominant motivation, but firms also see access to public funding as a central motivation for cooperating but then in non-core technologies. The NFR triggers research environments and firms to collaborate, since both environments are dependent on public funding of research.

The table below summarizes the findings and compares the two groups of respondents, economic/administrative science researchers and chemistry/ material science researchers, with respect to the conceptual focus areas found on "tie formation motives".

With respect to the perceived motives or reasons for why ties are formed, the interviewed researchers in business/economics highlight that the firms they interact with are interested in having access to competence environments. Access to competence environments is seen as a more central firm motivation than problem solving, but several researchers also highlight that the projects they are involved in address problems with existing tools and "soft" technologies. Problem solving is highlighted as a central motivation for the chemistry/material science respondents, both for addressing issues with existing technologies, but in some cases also to create new technologies. Recruitment of graduates and risk reduction through access to public research funding are also mentioned. Both groups of respondents emphasize that access to additional resources for research (money, equipment, students) is a central incentive for them to collaborate with firms.

Table 12 Conceptually order matrix on "Motives for tie formation"

Respondent groups	Perceived firm motivation	Perceived university motivation	Perceived interdependence		
			Knowl. intensity	*Core tech*	*Resource dep.*
Economic/ administrative science researchers	1) Supporting research environments in universities and colleges, to be used as a competence resource for firms 2) Problem solving related to soft technologies. Narrow/incremental in scope, focusing on improving existing programs, practices, tools	1) Access to research funding seen as most central. This concerns funding from firms but also public research money through user-initiated programs 2) "Grounding" or receiving input from the world outside, ensuring relevance and use of knowledge.	Collaborates with large, firms, often multinationals. The firms are "R&D heavy", have internal R&D facilities, employ scientists and use a substantial share of their turn-over on R&D	Projects do not address core technologies or competences in the firms	Mutual dependence on public research funding: Cooperation with firms to get funding from NFR
Chemistry/ material science researchers	1) Problem solving related to existing technologies. A few cases of more radical problem solving and developing new technologies. 2) Recruitment of graduates 3) Risk reduction and access to public research money. Particularly for radical innovations	Access to resources to fund labs, PhD students, and access to students and jobs for graduates. Seen as much easier to get access to research funding from the NFR if one collaborates with firms.	Collaborates with large firms, often multinationals The firm's are "R&D heavy", have internal R&D facilities, employ scientists and use a substantial share of their income on R&D Particularly in oil/gas and petrochemical industry	Projects tend to involve new, promising and uncertain technologies. A few cases of projects that address the core technology of the firm.	Mutual dependence on public research funding: Cooperation with firms to get funding from NFR. Particularly for new/uncertain and non-core technologies.

In terms of the knowledge intensity dimensions of interdependence, both groups of respondents collaborate with large, R&D heavy firms with an international orientation, many of them in oil/gas production and petrochemical industry, like Statoil and Hydro. But also firms in the IT and telecom industry, such as Telenor, Tandberg and Alcatel, and international chemical companies such as Borealis and Haldor Topsø are mentioned as partner firms by the respondents. Some of the economics/administrative science respondents also interact with firms within service industry, such as banking and consultancy firms. In general, many of the respondents regardless of academic fields interact with the same firms, particularly Hydro and Statoil. This could indicate that these large and previously publicly owned firms are central knowledge partners for researchers in several academic fields. However, although the majority of the respondents interact with the same firms, they collaborate with different divisions and groups in the firms.

This is related to the second dimension of interdependence, if collaborative R&D projects address core technologies or competences or not. In general, projects do not address core technologies in the firms in the case of economic/administrative science respondents. This entail that the knowledge created and transferred in the collaboration projects most often is not seen as a critical input for the firms, as perceived by the interviewed researchers. For the chemistry/material science respondents on the other hand there are two main clusters of collaborations. Several of the projects are related to development of new technologies, which might be promising but also risky. But there are also several cases where the projects concern problem solving in connection to an existing core technology of the firm. Notwithstanding cases in which the firms have a strong strategic need for knowledge, resource dependence seems to be a central interdependence. For both the economic/administrative science respondents and the chemistry/material science respondents, mutual dependence on public funding for R&D is a central precondition. Cooperation with firms is seen as a way of getting funding for research projects, since it is perceived as easier to get support on projects that involve users. For firms public funding (and other forms of external R&D funding) is seen as central when projects do not address a core technology or competence, or when the projects address new and risky technologies. In these cases, funding opportunities seem to trigger tie formation. Thus, the question of how ties are formed is addressed next.

Chapter 7: Tie formation processes

7.1 Interpretative framework

In this chapter the focus is moved from the respondents' assessments of why the collaborative R&D projects were formed to emphasizing how the projects were formed. Chapter 3 discussed how cognitive and social ties play an important part of in determining between whom and how collaborative relationships are formed. The social structure in which an agent is embedded and the resources that are available through this, structural, relational and cognitive resources, facilitates the formation of new relationships (Nahapiet & Ghosal 1998). Structural resources point to opportunities, resources and positions that are accessible due to links to others in the network. The structure of the network and a focal agent's position in the network influences the agent's opportunities to gain access to information about potential partners and opportunities for linkage. The theory of strength of weak ties emphasize that weak ties are beneficial for gaining access to novel information and new opportunities, but that stronger ties are beneficial for transferring and utilizing knowledge (Granovetter 1973, Hansen 1999, Nooteboom 1999). Stronger ties, characterized by ongoing and close interaction, are also seen as a source of relational resources like expectations, trust, obligations and identification, which are seen as positive for forming new ties and for positive interaction experiences. Cognitive resources are particularly central for relationships that are intended to generate and exchange knowledge. Several related concepts, such as homophily, absorptive capacity, cognitive proximity all address that in relationships intended to transfer knowledge, both "senders" and "receivers" must have somewhat similar capacities so that the parties understand each other and are able to share knowledge. These cognitive resources develop through direct interaction and/or partaking in a shared social environment (Nooteboom 1999).

In the following sections, the qualitative data will be analyzed to illuminate between whom and how the collaborative R&D relationships were formed. First emphasis is put on how previously established relationships between the actors, both personal and impersonal relationships were used to develop collaborative projects. The focus is on how new ties are formed, also emphasizing the role of brokers in tie formation between universities and firms. The last section of the chapter analyzes the cognitive dimension of the ties between firms and universities, and how that is related to tie formation.

The analysis is based on field notes and interviews with researchers in material science/chemistry and economic/administrative sciences, as well as several respondents brokering such relations. The respondents were asked to talk about, in as much detail as they could recall, how the collaboration they currently are or recently were involved in came into being. The great majority of the respondents talked freely, in detail and lengthy about how their relationship started and how the projects were formed.

Table 13: Conceptual analysis: Tie formation processes

Conceptual focus area	Conceptual categories	Conceptual property focus
Tie formation processes	Prior ties	Respondents' accounts of using prior established relationships when establishing new ties
	New ties	Respondents' accounts of developing collaborative ties to new actors to whom they have had no relationship before
	Cognitive proximity and distance	Respondents' accounts of the cognitive similarities and difference between them and their partners, and the sources of this

The categories shed light on two interrelated analytical dimensions related to resources used in tie formation processes: the strength of prior relationships and content of prior ties. As will be discussed below, the categories have several sub-categories related to the sources of prior established relationships and tie formation processes.

7.2 Using established ties to form collaborative projects

Prior established ties in this context means that the actors, in advance of the establishment of a particular collaborative project, have interacted with each other before, either through previous formal collaborative projects or on a more informal basis, like friendship. According to theory discussed in chapter 3, such established ties are positive for formation of new ties, and that interaction processes based on prior ties are experienced as positive. This is because previously established relationships can be a source of trust, positive expectations, familiarity and other relational resources. There is

however some differences in the character of the previous relations on which new relationships were formed.

7.2.1 Personal relationships

Some established relations can be characterized as more informal social relationships, like friendships. Using previously established relationships to form ties is the most common way of initiating projects in the interview data collected. With the exemption of few cases that the respondents discuss, new collaborative projects are founded on already established direct contacts between firms and universities. This pattern of tie formation is similar in both material science/chemistry and economic/administrative sciences. When asked how the project came into being, a typical answer from the respondents can be as the following quote from a professor in economics/administrative sciences:

> *The background for the project is, well I guess it's partly a coincidence. But it has something to do with that I personally knew someone in the leadership group. […] The short version of it is that it was a personal contact that turned into a project.*

A professor in chemistry/material science expresses the following with respect to how collaborative project emerge:

> *The most common way is that there is a dialogue that has surfaced because you already know the scientists in the firm. In Hydro and Statoil, you have known them for a long time – since university. These are people that you know. So in Norway, collaborative projects emerge because you know each other anyhow and you know what everybody else is doing, since the conditions are small.*

Personal relationships seem to be a very important source of opportunities for forming new collaborative projects. In the cases referred to above, the contacts were initially established when the key actors from the firm and the university were at university together. Informal networks established at university seem to provide recurrent opportunities for formation of new collaborative projects according to the respondents. This is illustrated by the following quote from a department leader in chemistry/material science:

> *It completely depends on the persons and their contacts. It is important to have contacts, particularly former students and colleagues. Projects flow through previously established contacts.*

> *On the other hand, this pattern is a limitation. Since projects are established at the personal level, they never become large.*

A researcher that had been involved in a collaborative project with a large Norwegian firm underscores this and explains how the personal contacts were central in establishing the collaborative research project:

> *It was particular people that were important, particular individuals that we already knew. It was a relationship with a department right, with the department manager, and several people who work in that department. We know several people there, but we only work with two or three of them. Other people in Hydro also took part in the project, who I did not know in advance. But in principle it was based on a previously established personal relationship.*

7.2.2 Education-based networks

It is, as seen, quite common for the people involved in collaborative projects to have a personal history together, often stemming from a common educational background. Such education-based networks are a topic that many of the respondents are concerned with. When asked if the respondents think that established social networks, formed for instance in universities, are central for establishing ties to industry, some of the respondents immediately associate this question with one university, the Norwegian university of science and technology (NTNU) in Trondheim[23]. A leader in an industry organization, discuss education-based social networks in the following way:

> *Social relations matter a lot. Many in industry have a background from Norwegian Technical University. This probably lead them to approach their own kind, since then they know what they will get. My experience, from many years in industry, is that those who are from the Norwegian College of Technology have extensive networks and they use them actively.*

None of the respondents interviewed that were from NTNU were particularly concerned with social networks stemming from education, but several of the respondents based at the University of Oslo and the Norwegian school of management considered social networks as a particular strength of NTNU. A professor at the University of Oslo expresses the

[23] Many of the respondents still refer to the former Norsk Teknisk Høyskole (NTH) [Norwegian Institute of Technology], which merged with the University of Trondheim in 1996.

following when asked if social networks have been important to establish collaborations with firms for his research group:

> *For the most part no. The private sector is mainly filled by people from the NTH. So we do not have particular advantages in a social network. Amersham, on the other hand, is one of a very few UIO firms. We only compete on quality and relevance. But at the same time, the social networks are changing due to more international recruitment in the firms.*

Another professor underlines the relationship between educational ties, recruitment of candidates and the opportunity for creating collaborative R&D projects:

> *It is obvious that candidates from the University in Trondheim are more oriented towards the needs of industry. And Norwegian industry has to a large extent employed civil engineers and doctors of engineering, which have a background that is more similar to their bosses' backgrounds. But it is changing somewhat, so now we have a large part of our candidates in industry, particularly within R&D in industry.*

Networks established in universities, and reinforced through recruitment of graduates, give access to social capital resources that seems to be central for forming new ties. Being "NTH people" give access to opportunities, but also identity and establishes trust and familiarity, resources that are used to form further ties. As seen above, some of the respondents discuss firms as 'belonging' to different universities, like that "Amersham is an UIO firm", or that "Telenor is run by NTH'ers".

But respondents do emphasize that since that many of the firms today are oriented towards international markets, operate in many parts of the world, and as a consequence recruit internationally, the established social networks matter less today. Many of the respondents in chemistry/material science increasingly cooperate with non-national firms, for example Shell, ABB, Siemens, ENI and Haldor Topsø. Also the Norwegian firms they cooperate with are very internationally oriented, such as Statoil and Hydro. Since these large and R&D heavy firms increasingly are globally oriented, they interact more with international research environments as well. Several of the respondents see competition from international research environments as much heavier than from other Norwegian environments. And according to respondents from chemistry/material science, there are very different mechanisms that generate R&D collaborations with these companies, as illustrated by the following quote.

> *But the foreign firms have approached us because they have seen what we have published. They have seen that we are pretty advanced in this field and that is why they want to collaborate with us. So it's a different mechanism when you move outside the local environment.*

Access to highly specialized expertise according to this respondent is a motivation in international cooperation projects, which requires searching for collaborators outside the immediate local or national networks. This will be explored further in section 7.3.

7.2.3 Previous collaboration

A third form of prior established relationship is that the interactors have previously been involved in collaborative projects with each other. Through this they have gained direct experience from collaborating with each other. As seen in chapter three, direct experiences of collaborating can lead to development of trust between the parties and a reputation for being trustable and reliable, which are seen as vital resources for formation of further collaborative relationships. Several of the respondents emphasize that the collaborative R&D project they currently are, or have been involved in, grew out of previous collaborations, in some cases through many years of interactions of various kinds, leading up to the formation of a large formal R&D collaboration project.

In several instances, the collaborations have grown out of small collaborative projects, in many cases student projects. This is more common within chemistry/material science than economic/administrative science. Several of these respondents say that it is quite common for firms to contact them with a problem they would like a student to work on for a Master dissertation. When asked how collaborations emerge, a professor of chemistry replies:

> *Often the researchers are contacted by industry with a problem they want a student to investigate for a master dissertation, and sometimes a PhD student.*

Such projects require little investment for the firms, and could be seen by the firms as a way of getting to know the research group and their expertise before making a larger commitment. The following statement made by a researcher in chemistry/material science illustrates this:

> *It was somebody from Hydro that contacted the university. But I was not the first one that was involved in this. At first it was a master*

> *dissertation project. But then they discovered something interesting, and then they wanted to extend it for a larger PhD project.*

Other small-scale projects can also work as foundations on which larger, and more formal, collaborations are built. A professor in administrative/economic sciences expresses how "small commissions" enable you to establish "a name" in a company. Having a name, in the sense of being known and having a positive reputation, is central for establishing formal collaborative projects, as illustrated by the following quote:

> *The other ting was that both my and [another researcher's] name was known in Hydro. She had done a small commission, which was small in size but it was done well. This contributed to making her name well known. So then she became actively involved as well.*

Reputation, trust and access to opportunities stemming from previous interaction seem to be resources that the researchers interviewed actively use when they form new collaborative projects with firms.

7.2.4 Recurrent relationships

In several of the respondents' stories of how the collaborations were formed, the interactors have a long history of repeated interactions behind them. These ties can be characterized as recurrent relationships that seem to 'ebb and flow'. At certain times, particular firm-university relationships are close and at other times the relationship is more distant. These repeated interactions give the interactors experiential knowledge about each other, establishes positive expectations and trust. In the data collected, the cases of large, long-term R&D collaboration or lengthy sponsorship arrangements, which require substantial investments by the firms involved, are with research environments to whom they have a history of repeated interactions. This can be seen in both economic/administrative science and chemistry/material science. This is illustrated in the following statement made by a researcher in chemistry/material science:

> *We had established contacts. We already knew the people in Hydro. We have had several collaboration projects with them and Hydro has given us support for PhD students as well as other projects. So it was already established good personal relationships. They knew that we existed, and knew what competence we had and what we could do.*

A researcher in administrative/economic science provide insight into exactly how previously established contacts can be used to form a collaborative project, as illustrated in this statement

> *The first time we asked them was at a client dinner with the managers of the firm. They responded positively to the idea at once, and this was followed up by a formal agreement. This sprung out of a long-term cooperation with the company. We had established personal and professional relationships to particular people in particular departments.*

Another researcher in chemistry/material science emphasizes how long-term personal and professional relationships are central for developing collaborative projects:

> *[Name] had previously established many collaborative projects, where several companies were involved to fund basic research projects to understand problems that the industry had. So he has established many contacts along the way. He has a name in industry and contacts that he has had over many years. So it has only grown over time.*

The relationships change over time in these ongoing relations. In several of the ongoing relationships that the administrative/economic science researchers are involved in, the relationship was originally intended for purposes such as teaching, consultancy etc, but develops into research collaboration over time. The following respondent discusses how he first became involved with the firm he presently collaborates with, and how that relationship has developed over time.

> *So it was more than 9 years of collaborations related to education programs and actually several research projects that had been financed over a long time before the relationship was finally formalized at the institutional level.*

Moving from informal relationships to establishing formal project-based relationships seems to be the most common way of forming ties. In some cases, the collaboration develops further from individual contacts and projects, towards institutional agreements. This is, for the researchers interviewed here, not as common as ongoing relationships that move from project to project. Reflecting upon when the relationship was formalized by an institutional agreement, the following respondent says:

> *It came at a time when the company went into more formal agreements with several institutions. So we where on the list (…). We were on the list, probably due to [another professor's name] and several of us had ongoing relationships with them, and it was clear what we stood for.*

Most of the collaborations investigated here are not long-term institutionalized agreements, and many of the projects are small and short-term "stunts" (according to a respondent). Nevertheless the process of forming ties utilizing established contacts are similar according to a large majority of the respondents.

7.3 Establishment of new relationships

The concept "new ties" in this context means that the agents prior to forming a tie have not had previous personal interaction, formal or informal, but that the contact was mediated through a third party referral or broker of some kind. According to theory presented in chapter 3, "weak" and indirect relations have important information benefits since new ties can give access to novel knowledge (Granovetter 1973, Nooteboom 1999, Hansen 1999). Thus one can assume that if the motivation is to gain access to knowledge which is new for the firm, in creating a new technology or radical innovation processes, establishing completely new links to university based groups could be a way to gain access to that knowledge.

It is not very common to establish completely new ties for the researchers and R&D managers interviewed. But all of the respondents interviewed that are not actively involved in research collaborations, are preoccupied with how new links can be made, as this is partly their job to broker new relationships between firms and universities. However, three respondents claim that they or other members in their research group had no previous ties with the partner in the collaborative project prior to its formation. The respondents tell about three ways that collaborative ties can be formed without prior contact between the parties: by a referral from a previously established contact with another agent, through impersonal channels particularly publications, and through some agent that broker and facilitates the formation of a tie.

7.3.1 Referrals and publications

In three of the cases, the collaborative projects were formed without previous contact between the parties, by using what is here referred to as indirect links. By this it is meant that the parties have not been in direct contact previously, but that there are some indirect links between the parties that mediated the formation of the relationship. For instance, in one of the cases, a project in chemistry/material science, the firm involved had previously cooperated with a research group abroad, and it was this other group that had contacts to a research group in a university in Norway. Their collaboration partner then referred this new partner to them. In the other case, a firm had previously been involved in several collaborative R&D projects with another Norwegian university, but according to the respondent they were not satisfied with this project and contacted the research group that the respondent worked in. But the firm had no previous interaction with this institution, according to the respondent. Both of these examples, even though they amongst the respondents interviewed are rare, are cases of indirect links being used to form new ties. Referred ties seem to be of less importance for forming ties between firms and research institutions. For most of the cases, establishing collaborative R&D projects seem to depend on having developed a network and having previous direct relationships. In a seminar between firm representatives and university scientists, the participants discussed this as a main challenge for UI collaborations. One of the participants expressed this in the following manner: *The problem is that concrete collaborative project – stunts - depend upon that one already has established networks.*

A particular form of an indirect link that is used to form new collaborations is scientific publications. Through scientific publications, research groups and individual academics demonstrate their expertise in some field of knowledge. Such information can be used to establish contact between a university and a firm. According to one of the respondents in material science/chemistry, this is of particular relevance in international collaboration projects. As already discussed, respondents say that there are different mechanisms outside the local environments, and that established contacts and networks do not matter to the same extent. Here it's the particular competence that is central. This implies that the international firms, even to a larger extent than local firms, have internal R&D capacity and scientists on staff. Although the focus here has not been particularly on how the process of establishing international research collaborations occur, the examples involve firms that are highly knowledge intensive, and the firm representatives involved are themselves scientists. This seems to suggest that large geographical distance requires small cognitive distance when the aim is to transfer knowledge.

7.3.2 Brokering and formation of new ties

Since the opportunity for forming collaborative projects to a large extent seems to be related to having established contacts and networks, there are organizations and individuals that have as their main task to create networks and to broker and facilitate formation of new ties, in cases where such relations are weak or missing. As to gain some further insight into how this process of brokering occur, interviews were also made with respondents that were involved in brokering new ties. Also, a workshop between representatives from firms and researchers in material science, aimed at fostering networks and creation of new ties was observed, and afterwards two of the persons responsible for this event were interviewed.

The data suggests that there are many organizations that play brokering roles, including state agencies, the Norwegian research council, Innovation Norway, industry and trade associations, research institutes, research parks and at the universities, the Technology Transfer Offices (TTO) recently established fulfill such a role. Other agencies might also be included, but the respondents explicitly mentioned the above agencies. Data was not collected from all of these different organizations, as this was not a particular goal of this investigation. Rather, the data collected focused on why and how tie formation occurs through brokering, rather than describing the extent of and who is involved in brokering ties between industry and universities.

According to respondents, the purpose of brokering is to create and stimulate the development of networks and ties between firms and university research environments, through creating and coordinating meeting places and arenas for interaction. In the interviews, three main motivations are mentioned for why brokering occurs:

- To foster connections between university environments and small and mediums sized enterprises (SME) that traditionally have not cooperated with universities and have less internal capacity for R&D. As seen in chapter 5 this role has also been stressed in recent policy documents.
- To foster connections between firms and research environments which have not traditionally collaborated, but which have cooperated with other environments.
- When the problem industry has requires multidisciplinary research, a broker can work as a contact point for industry and coordinating the collaboration with several research envirnments.

The first of these are seen as a most central motivation for brokering, by several of the respondents. According to a TTO representative:

> *Where we have a particular role to play is for small and medium sized firms that are uncertain. They do not know who to call and have to previous relationships with the university. Like oh my, they have more than 4000 employees. No, that's too big for me.*

He further explains the role that Technology transfer offices can play when brokering a contact between the university and an SME:

> *We have several examples on firms that contact us, because they do not dare to pick up the phone and call the switchboard at the university. How on earth will I get in tough with the right person? But if they contact us, we have the necessary knowledge about the areas of expertise here at the university. … So it would be easier for this person to contact me, and then I can, if I not already know which person he should talk to, do a search through the network I have established here.*

Several of the respondents also highlight that smaller firms have less resources, and as a consequence are usually less knowledge intensive. This not only poses challenges for how to establish relationships with universities, but also for how interaction processes will be carried out and how the knowledge can be absorbed and utilized by the firms. A senior manager at the NTNU expresses this as following:

> *SMEs do not have a natural point of entrance to the university. The larger firms usually have employees who have studied here, who already know the university and things like that. But the smaller firms in many cases think that it is difficult to gain entrance, and they are often afraid that they will not understand what the researchers say, that the culture is too different, and everything.*

The question of communication that is involved in this, about the necessary degree of homophily between participants, is seen as such a problem that brokers in some cases define their role as "to translate" between the SMEs and the universities. An R&D manager in an industry association highlighted that communication problems can be large. He has received many complaints from firms, who are not used to interact with universities, that they do not understand what scientists say when they present their results. And that is why his organization defines as one of their task to:

> *Translate between firms and universities. We help firms to make clear what they want from the universities and assist the scientists to communicate better and easier with firms, for instance by cutting*

> *down the number of overhead foils from 100 to 10. Our meeting place strategy represents such a translator role.*

At a general level, the motivation is to facilitate the creation of new connections. But how do brokering processes occur? According to the respondents interviewed, two related issues are involved– building up networks and connections, and coordinating meetings. In terms of the first, the brokers must develop their own networks. One of the respondents describes how he has to work "inwards and outwards", both to establish connections with scientists at the university as well as in industry. In the university the TTO has to be proactive and to market their services to the scientists. They also have to gain a high degree of knowledge about what is going on in the university. They also have to create and maintain an industrial network, and the respondent claims that the personal networks each broker had prior to working in the TTO is of vital importance. Having an established industrial network is, according to him, the most important resource they contribute with to the scientists in the universities:

> *If you are sitting and discussing research with a scientist and you say: 'I think I will give this person in Statoil a call, because I know that he is also working with this'. Then you create added value for that professor or researcher instantly. And maybe you have created a new relation, or at least he will have some further answers.*

Using established networks is a central role for brokers. But they also crate places of meetings for universities and firms, where the ambition is to form and foster new relationships. The respondents discuss different types of meeting places involving different actors. Organizing national thematic conferences where university researchers and representatives from industry meet is one approach, but the respondents indicate that smaller, more intimate events are better for establishing new relationships. The respondents describe a range of different events, such as workshops, round table conferences etc, that they have been involved in arranging. This can be between a particular firm or several industry representatives and researchers at the universities working on a particular issue.

> *We coordinated a meeting with Aker Kværner. Twelve to fifteen of their people were there. It lasted a whole day. We had about three parallel workshops on clearly defined areas, in which Aker Kværner saw particular challenges. And then NTNU and Sintef could present the research they had done on those issues. The idea was to see whether there were any particular matches here and now, or if we saw any future opportunities to define new research projects, apply to the research council and things like that.*

As part of the data collection, I participated in several arrangements like this, with the purpose of observing how such meeting places and brokering events can work for initiating collaborations. A description of the workshop *Technological arena* [Teknologisk Møteplass] serves as an illustration.

Technological Arena is the joint effort of two industry associations – Federation of Norwegian Manufacturing Industries and Norwegian Electricity Industry Association. The purpose of this effort is to create an arena for interaction between research environments and industry with the aim of increasing the industry's participation in R&D, innovation and value creation. Strategies to reach this goal are to facilitate the creation of networks within strategic service/product areas and to spread knowledge to associated organizations.

Technological arena organizes meetings between their members and academic environments. The conference observed was a meeting at the University of Oslo, where invited firms met with researchers from Center for Material Sciences at the University of Oslo and Institute for Energy Technology. 25 people were present including representatives from The Norwegian Research Council and Innovation Norway. The purpose of the meeting, according to the coordinators, was to exchange ideas and for the firm to get introduced to the research environments that work on material science and energy technology in the Oslo region. According to one of the coordinators, the firms did not know this environment very well, as they have traditionally interacted with other research and technology environments, and "know what they get when they contact the NTNU". Getting to know each other, and the competence they have, is seen as a necessary step for establishing further ties and collaborative projects. A respondent from the university expressed the purpose as:

> *The goal is to get acquainted and get to know the competence the others have. This is a necessary starting point if we are to establish further partnerships and collaborative projects. The aim is to create a network for future collaboration, to create a contacting surface. In this we can use Technological Arena as a catalyst.*

The purpose then was to get acquainted with the people and competence that exists on these issues in Oslo and to create new contacts. Several researchers presented their work on ceramic membranes, solar cell materials, hydrogen technology and new energy technologies. Most of the presentations were followed by lengthy discussions and many questions from the firms to the researchers. It was apparent that the representatives from the firms had extensive knowledge in the knowledge arenas involved. The participants also discussed many issues related to industrial policy and R&D policy, and

agreed upon that creating arenas for interaction and strengthening the ties between universities and firms were needed, but that this required establishment of networks and better mobility between the sectors.

A few days after the seminar two or the coordinators of the meeting were interviewed, one at the university and one in the industrial association, focusing on what their expectations had been and what they now thought could come out of it. Both of them had expected that the meeting could lead to the formation of new ties. Both the industry respondent and the university respondent had been contacted by some of the firm representatives present that were now interested in further collaboration. So immediately after the meeting it seemed that this arena had the contact creating effect that they hoped for.

To sum up, very few of the researchers interviewed say that they had no direct ties to their partner prior to forming a collaboration project. Three of them do and in their cases the collaboration was mediated through third-party referrals from previous collaborators, publications, and brokers. To gain some further insight into the process of forming completely new ties between firms and universities, interviews with persons that had brokering of such ties as a task were carried out. Brokering of new ties are carried out by several organizations and the purpose is to stimulate networks and collaborations between previously unconnected partners. Brokers describe partly their role as translating and bridging competences between industry and universities. As will be addressed further below, the cognitive distance between previously unconnected collaborators and the cognitive proximity of previously tied partners, represent a central dimension in tie formation.

7.4 Cognitive proximity and distance in tie formation processes

In terms of the resources needed to form ties between universities and firms with the aim of transferring knowledge, cognitive resources are seen as particularly important (Nooteboom 1999, 2002, Nahapiet & Ghosal 1998, Hansen 1999). The relationship between conceptualizations of knowledge and communication is central for understanding knowledge transfer. In recent innovation theory, knowledge is seen as tacit, complex and situated, and transfer requires complex forms of communication and sustained interaction between participants. If transfer of knowledge requires active interaction between the parties, then the agents' ability to share and absorb knowledge is central. This ability is based on previous experience according to Nooteboom (1999). This is a basic insight from cognitive science: to learn

something new you must utilize what you already know to provide interpretation and context for new sensory data. The same principle is used on the organizational level of analysis in the absorptive capacity argument (Cohen & Levinthal 1990). If this insight is true, then the similarity in knowledge repertoire between participants will influence the knowledge transfer process positively.

The principle of homophily in its several expressions (Rogers & Bhowmik 1970, Granovetter 1973, Cohen & Levinthal 1990, Nooteboom 1999, 2002) underscores the point that transfer of knowledge requires some degree of similarity between "senders and receivers" in a knowledge exchange process. But the same time, since innovation processes concerns novel knowledge, it requires a balance between similarity and difference, or it requires a cognitive distance small enough to allow for understanding and absorption, yet large enough to yield non-redundant knowledge (Nooteboom 1999, Hansen 1999). In terms of formation of ties, this analysis suggest that when relationships are entered into with the purpose of transferring knowledge, some degree of similarity but not overlap in cognitive capacity is a precondition for tie formation.

It is apparent that pre-existing ties between firms and research groups in universities have a cognitive dimension. As presented above, both direct relationships and weaker, indirect relationships between firms and universities are centered on knowledge activities. The knowledge relations might lead to the development of social resources that can be used to form formal R&D collaborations. However, previous ties can also be a source of cognitive resources. Cognitive resources provide "shared representations, interpretations and systems of meaning among parties" (Nahapiet & Ghosal 1998, p. 244). According to Nooteboom (1999) cognitive resources develop through participation in a shared environment and in mutual interaction. In this context, education is an important source of common cognitive repertoire of highly educated employees in industry, as well as in universities.

In the interviews with academics interacting with industry, there is a lot of information about links that are used to form new collaborative projects. Personal relationships and networks between firms and university-based researchers, both of which are seen as central for tie formation by the respondents, are often formed in or spring out of universities. These informal relationships are a source of relational resources but also of cognitive resources. The data collected here indicates that in university-industry relations, the two resources are often two sides of the same coin. A common educational background is one source that give the interactors a common knowledge foundation or "shared representations, interpretations and

systems of meaning". If the parties have previously been involved in collaborative projects together, this can further reinforce the joint cognitive repertoire.

What knowledge ties do the informants discuss in relation to tie formation? As seen above, a range of direct and indirect ties are used to form collaborative projects. The respondents mention the following six links. The ones at the top are "stronger", entailing direct and personal links, than the ones at the bottom. Without providing a detailed analysis, as a lot of this was discussed in the above sections, focus is here on the cognitive resources that develop in such links.

- Personal relations
- Previous R&D collaboration
- Education based networks
- Third-party referral
- Brokers
- Research literature

Most of the respondents that claim that prior established personal relationships were central for the establishment of the formal collaborative R&D project, say that they had known this person since university or that it was a former student or colleague of them (or their supervisor). Several of the respondents emphasize strongly that social networks established in university are central mechanism for forming collaborative R&D projects. One of the respondents explains this logic quite to the point: "Many in industry have a background from NTH. This probably leads them to approach their own kind, since "then they know what they will get". Shared understanding stemming from a common educational background is by the respondents seen as central for interaction, and the interview data indicates that networks and personal relationships established in universities are very central for establishing collaborative projects as well. However, when asked directly the question of where the people in the firms that they collaborate with are educated, several of the respondents say that many are from NTH but that it also varies, and that it is not a clear-cut picture.

As also discussed, the majority of the collaborative R&D projects grew out of prior collaboration experiences. These prior experiences were often small projects involving little investment, like student projects, and could also be in other areas, such as teaching programs, consultancy, etc. The latter is more common for the administrative/economic science respondents. These prior experiences contribute to establishing a common understanding between the partners. A few of the respondents use expressions like "they knew what competence we had" and "they knew what we stood for" as a

result of having previously interacted, and that this experiential knowledge was important for crating a larger joint R&D project. This experience-based knowledge seems to be particularly central when large formal collaborations, that require substantial investments, are formed.

In general, prior direct interactions between partners were reported as central for the formation of a collaborative project by all but three of the respondents. This indicates that the large majority of the cases utilized established relationships when ties were formed. Also, the researchers do not emphasize only one of the above links, but often several are used at once - personal relationships, networks and prior smaller-scale projects. Over time this reinforces the cognitive proximity between the partners, like for instance in the relationships described above as ongoing or recurrent. In these longer-term relationships, the actors have developed a thorough understanding of each other, and a joint understanding of the problem field. One of the respondents discuss how after a decade of interaction, the firm entered into a formal institutional agreement with the research institution, and the reasons for this.

> *I think that one of the reasons why they were so positive to creating a formal agreement was that we already had a relationship that worked substantially. […] What was left for us was to make visible that we were a competent partner. And here I believe that the lengthy experience they already had in collaborating with us, visualize this.*

On the other hand, some collaborative projects are formed without prior relations, and where the partners have less shared knowledge. As seen above, this is not as common in the data collected for this project, but when such ties are formed, the motivation tends to be to solve a particular problem that the firm does not have the capacity to solve internally. The reason for why they enter into partnerships with organizations or groups that they do not know in advance is because the new partner possesses a particular knowledge. A primary benefit of weaker ties, according to theory, is the capacity to carry new knowledge. New ties, as indicated by the respondents, are formed by using referrals, publications, brokers, and mobility.

In the cases where new ties are formed, the motivation seems to be to get access to a particular new competence, which also entails that the cognitive distance is larger. Broadly defined there are two situations in which this occurs in the data. In one setting, the firms are knowledge intensive and have previously collaborated with other institutions but not with the one in question. In the other case, firms have never collaborated with universities and have no natural point of entry to universities. In the two settings, the

formation process is different. In the first, referrals through joint contacts or publications facilitate formation. In the second, brokers facilitate creation of ties. In the first setting, the cognitive proximity is smaller that in the second, since the firms involved tend to have large internal knowledge capacity. Firms that have never cooperated with universities before have a very large cognitive distance to them. Several of the respondents indicate that this is main challenge when attempting to broker relationships between SMEs and university environments.

The question of cognitive distance runs through all of the interviews connected to brokering. One role that brokers claim to have is “translation”. This can be interpreted as a strategy to help minimize the cognitive distance between parties. Making the competence visible was also the dominant rationale for the “Technological arena” as described above, and was by the participants claimed to be a necessary condition for further formation of partnerships and collaborative projects.

Based on the above analysis, it seems fair to conclude that having some degree of shared cognitive repertoire is, as seen by the respondents interviewed, a central precondition for forming R&D collaborations. Further, that a common educational background and networks that grow out of universities, as well as previous collaboration experience, provide joint cognitive resources needed for further formation of collaboration projects. So the implication of this cognitive capability perspective is that knowledge interaction requires some degree of shared understanding. If cognitive proximity is positive for transfer and sharing of knowledge, and that previous direct interaction and common educational background are the central sources of cognitive resources, then how are interactions that are formed based on previous ties experienced? And are collaborative projects that are formed without prior contact experienced differently? These questions are addressed in the next chapter.

7.5 Summary

This chapter aimed at shedding light on how ties are formed between firms and university-based research groups. Three conceptual categories were developed, which highlighted the social and cognitive resources used in tie formation processes. The analysis indicates that for the large majority of the respondents, prior established contacts are central for formation of new collaborations. Personal relationships, education-based networks and previous small-scale collaboration projects are different types of prior

established relationships utilized in tie formation processes. In many cases several of them are used simultaneously, and in some cases the relationships can be described as recurrent. But a few of the respondents' accounts of how their collaborative projects with firms came into being do not fit this modal pattern of tie formation. In a few cases the partners had no direct relations prior to forming a tie. Third-party referrals, publications or brokers are examples of indirect ties that mediate formation of completely new relationships.

The second dimension in tie formation concerned the cognitive dimension of the ties. It is apparent from the data analysis that the cognitive dimension is highly central in tie formation processes between firms and universities. The respondents use words like "they knew what competence we had" when describing how formation occurs and with whom they form ties. In forming new ties between partners that never has interacted, the cognitive distance between them is often seen as a problem, and "translation" is seen as necessary. As seen in the analysis, cognitive proximity, or similarity in cognitive repertoire such as shared representations and interpretations, is related to prior direct ties, particularly education based networks and prior R&D collaboration. New ties often have more cognitive distance. But not always, as R&D heavy firms with high absorptive capacity can be cognitively proximate but socially distanced and relying on weaker ties. The following table summarizes the data and compares the respondent groups. Here, theoretical sampling of people fulfilling brokering roles was needed for conceptual clarification, and hence, administrative support staff is included as a respondent group in this table.

To sum up, for the researchers interviewed in this study R&D collaborative projects were formed mainly by utilizing prior established relationships. The researchers say that they "interact with particular people in particular departments", which they have know for a long time, often "since university". They also highlight that joint educational backgrounds and/or previous interaction is central by making clear the competences each party have and what contributions the researchers can make to the firm. Issues related to cognitive proximity are highlighted by most of the respondents as central for tie formation. However, the chemistry/material science respondent particularly emphasizes this aspect when discussing the particular status of networks growing out of the Norwegian University of Science and Technology.

Table 14: Conceptually order matrix on tie formation processes

Respondent groups	Social resources		Cognitive resources	
	Prior ties Personal friendships, networks and previous collaboration	*New ties* Network referrals, brokers and publications	*Proximate* Common understanding, high comprehensibility benefits	*Distant* Novel knowledge, high information benefit
Economic/ administrative science Researchers	**Very important:** All but one of the respondents claim that previously established relationships is central for establishment of collaborative R&D projects Ex: "it was a personal contact that turned into a project"	**Not very important:** Only one respondent highlight that a project was established without previous contact. In that case it was mediated through referral Ex: "they proceeded to contact us by calling the switchboard at the institution who referred them to us"	**Very important:** For the formation of ties, particularly large formal agreements with considerable resource involvement Ex: "they knew what competence we had", "they knew what we stood for"	**Not important** for tie formation Only one respondent experienced this However due to loose anchoring and loss of contact persons, cognitive distance often increase mid-stream (cf. Chapter 10)
Chemistry/ material science researchers	**Very important:** All but two of the respondents claim that previously established relationships was central for the establishment of collaborative R&D projects. Particular status of the "NTH network" Ex: "collaborative projects emerge because you know each other anyhow"	**Not very important for domestic but important for foreign firm collaboration** Publications and referrals are then used. The firms are knowledge intensive. Ex: ""but the foreign firms have approached us because they have seen what we publish".	**Very important:** The researchers establish collaborative projects with firm representatives with similar educational and professional qualifications Ex: "Many in industry have a background from NTH. This probably lead them to approach their own kind, since then they know what they will get"	**Not very important for domestic but important for foreign firm collaboration:** Important particularly for projects related to radical innovations. The firms have high internal capability Ex: "They have seen that we are pretty advanced in this field and therefore they want to collaborate with us"
Administrative and supp.	**Important:** Recognizes that previous contact and networks are important, and sees it as a important job to create places of meetings between industry and university groups Ex: "our most important task is to establish and coordinate networks"	**Important, but problematic** Brokering seen as important for the establishment of ties between previously unconnected partners. Highlights particularly SMEs Ex: "Where we have a particular role is for SMEs that are uncertain,"	Recognized as important, but not a focus for them	**Important, but problematic:** Brokers see as one of their main roles is to translate between SMEs and universities Ex: "and they are often afraid that they will not understand what the researchers say"

A small number of respondents say that they have formed ties to firms they had no previous contact with in advance. A few of the chemistry/material science respondents also highlight that initiating collaborations with foreign firms is different, in the sense that other mechanisms are used to establish contact. Here academic publications are important and such ties are often formed as a response to a need for knowledge. This is also the case in the other three instances where ties are formed without previous contact. Cognitive distance or new knowledge seems to be more central when weak ties are used.

The support staff and leaders interviewed highlight the role of creating contact and brokering ties between previously unconnected firms and universities, particularly SMEs. But they do see a lot of challenges with this mission; both in terms of the capacity such firms have for knowledge interaction, and the differences in culture and focus between SMEs and universities. So with respect to the conceptual focus areas, the researchers interviewed from both academic fields emphasize that prior ties and cognitive proximity are important when ties are formed, rather than forming new ties with more cognitive distance. This is in contrast to recent policies, as discussed in chapter 5, which highlight the importance in creating new contacts and brokering new ties between previously unconnected agents. Why the researchers involved in collaborative projects stress the role of previous relationships becomes apparent in the next chapter, focusing on interaction processes between firms and universities as experienced by researchers.

Chapter 8: Interaction experiences

8.1 Interpretative framework

Some degree of similarity between participants is seen as central in theories of knowledge exchange. This perspective maintains that successful knowledge interaction requires that the participants share cognitive repertoires that enable them to establish a common sense of understanding, for instance by having a common set of codes and know-how. An implication of this interpretation - that cognitive proximity is positive for transfer and sharing of knowledge (Hansen 1999, Nooteboom 1999) and that previous direct interaction and common educational background are central sources of cognitive resources (Nooteboom 1999) – could be that interactions that are formed based on previous ties are experienced differently than collaborative projects formed without such resources. Are there any relations between how the project is formed and how interaction is experienced? And does motivation shape experience? These questions are explored in this chapter.

To explore the potential relations between how a collaborative tie was formed and how the interaction was experienced, the interviews with the researchers will be analyzed. The respondents were asked several open questions about how the interaction was carried out, how they assessed the success of the partnership, if particular problems or challenges had risen and what they thought of the future of the collaboration. The data analysis has focused on developing conceptual categories that highlight central characteristics and dimensions in researchers' experiences of interaction with industry. Careful consideration has gone into developing categories through several revisions of the coding template, as described in chapter 4.

8.2 The knowledge interaction process

All respondents were asked questions about how they perceived the interaction process after the collaborative project had been formed. The conceptual categories were developed from their accounts of and reflections on the interaction process, and are here used as sensitizing concepts that enables focus on central analytical dimensions of the knowledge interaction process.

Table 15: Conceptual analysis: Knowledge interaction process

Conceptual focus arena	Conceptual categories	Conceptual property focus
Knowledge interaction	Arenas	Informants' accounts and perceptions of the activities and arenas that were used for knowledge interaction purposes
	Exchange	Informants' perceptions of the process of knowledge exchange between them and their partners
	Actors	The informants' accounts of the actors involved in knowledge interaction activities and the roles they play
	Anchoring	Informants' perceptions of the organizational affiliation and management of the collaboration process

The respondents' descriptive accounts of the interaction process are quite similar, regardless of academic field. Also, how the interaction is organized and the arenas and linking activities that are used follow a common format with few differences regardless of size, length or type of projects. The practical organization of the interaction seems to follow a common form. But with respect to actors and anchoring, the experiences are quite different, and the two categories seem to be related to each other. This will be explored further below.

8.2.1 Arenas for knowledge interaction

In terms of the interaction arenas, that the respondents mention when asked how they interact with the firms, three activities stand out in terms of being mentioned by the majority of respondents: workshops and seminars, informal collaboration and co-location According to a professor of chemistry, university – industry collaborative projects are typically organized and carried out as following:

> *First, a contract is written, followed by the establishment of a board of directors. It usually is regular contact meetings, where the researchers and students present and discuss their findings. In some instances the students or researchers carry out parts of their work in the company's lab, or they divide their time in the university lab and the firm. This depends upon the problem and the equipment needed.*

All of the respondents say that the most important arena for knowledge exchange is participating in seminars and workshops. Formal contact points are usually carried out in "status meetings" held every six months, but can be carried out more often. These meetings are coordinated by the firm, which also often invites other partners as well. A professor of chemistry explains how the interaction typically occurs:

> *We do not meet very often, usually every six months, when the firm invites to seminars, often with several of their collaborators at once. Here the students present the parts of their work that they can discuss openly in a plenary session, and in private with the two-three people that work on this in the firm.*

A researcher in administrative/economic sciences reflects on the mode of interacting in the following way:

> *The most important arena for knowledge exchange is workshops and conferences. This usually takes place at the firm's headquarters, where we present findings and things like that to particular departments. Another type of arrangement is conferences for the firm's stakeholders. Then they invite their customers, public authorities, etc to seminars on different topics.*

Between such "status meetings" and workshops, the contact between the university and the firm tends to be more informal. Also some of the respondents at times work in the companies. This seems to be equally common for both knowledge fields. However, in administrative/economic science, several of the research fellows work for the firms, in their so-called "duty time". Some of the respondents highlight that informal discussions with key people in the firm is the most central arena for exchange, and that they are seen as resources for the firms. Within chemistry/material science, there are a few examples of joint affiliation of staff. In these cases, the firm recruits and employs members of the research group, but they continue to work in the university lab.

There are very few examples of the firm and the university group actually working together in the projects. The tasks are specified, and most often all the practical research work is carried out by the university based research group. Thus, the work is distributed. A professor of chemistry/material science explains how collaboration is carried out as following:

> *Task division is important. We first define the research problems, and after that we work separately. We have joint meetings where status and results are presented and discussed. When the firms work*

on partial projects, they also present their work. But usually the industry people do not disclose what they do in their labs. But on the other hand, they indirectly use their competence when they discuss our work. The discussions are never one-way, always two-way.

Although most of the firms require written reports to be handed in at fixed intervals, written reporting is not seen as a central way of transferring knowledge. In economic/administrative science, less than half do any form of written reporting at all. Several respondents claim that this is intentional, and that the companies see no use for reports, but rely solely on oral presentations and discussions face to face. For the chemistry/material science respondents, written reporting is more central and done at frequent intervals. In general, the respondents indicate that the collaboration projects are more 'hands-on' and managed in chemistry/material science than in administrative/economic science.

8.2.2 Exchange of knowledge

As indicated above, face-to-face interaction is seen as the most important way of exchanging knowledge according to the respondents. The workshop has a particular status in knowledge exchange in the respondents' perspectives, as the firm and university actors interact face to face and create a dialogue. Why do the respondents highlight the seminar as a knowledge transfer tool? One of the respondents, a professor in administrative/economic science puts forward his opinion about what knowledge transfer is about:

I think it is a dialogue. I think we have to understand that knowledge is a social phenomenon, and therefore knowledge transfer needs to be a social phenomenon as well.

A related interpretation is made by another of the administrative/economic science respondents, who reflects on what they can contribute with to the firm partner.

What 'academia' can contribute with is to initiate the firm's own thinking process. If you are able to do this, you have won. This is why the seminar is so important. The company does not want papers, but the intellectual discussion related to concrete problems. This is what we can contribute with. Selling 'the best solution' should be left to consultancy firms, who are much better at those kinds of things.

The chemistry/material science respondents are less preoccupied with explaining how they see knowledge transfer, and when they do, it is at a more concrete level. They do not problematize knowledge transfer, which most of the economics/administrative science respondents do. All of these respondents highlight that dialogue between equally knowledgeable persons characterizes the contact. A researcher in material science reflects on the process of knowledge transfer in the following manner

> *In the beginning, they have to transfer knowledge to us, for us to have a solid background for the problem statement, what it is that this is really about. But later on, the dialogue is more focused on what we have done and to adjust this knowledge to what they already know in industry. So the process is two-ways.*

It is interesting that even though the researchers from both knowledge fields interact with firms in similar ways, the majority of the administrative/economic science respondents express that they see knowledge transfer as difficult, where as the chemistry/material science researchers do not. One reason for this, as indicated by the respondents is that the researchers interact with different types of firm representatives. It seems that who they interact with shapes how they experience knowledge transfer. The issue of actors is addressed next.

8.2.3 Actors

Who participates in the arenas and linking activities is a relevant dimension for understanding knowledge exchange. From the universities, the active researchers always participate (usually the PhD candidates or postdocs) along with the senior professor who is formally in charge of the project. If the projects are large, other faculty members might also participate. This seems to be similar in both of the investigated academic fields. In terms of the roles that the different participants fulfill, task division is central, as seen above. According to the respondents, the firms seldom carry out research, which is mainly carried out in the university labs by the students, PhDs and postdocs. This is also similar for both sets of respondents. But with respect to the firm participants, there are clear differences in the respondents' accounts of whom they interact with.

The chemistry/material science respondents interact with a small number of firm managers and staff, and usually only with R&D or technical staff. A professor of chemistry/material science claims that who they interact with depends on what type of project it is.

> *It varies by project type. In KMB projects[24] the industry actors are mainly project managers. These tend to be scientists or have previously been scientists, but are not necessarily experts in the particular area. I assume that they pass on their experiences in the company. On the other hand, we have projects where the collaboration is directly between scientists. An example of this is a PhD project funded fully by Hydro. In this project, Hydro participated with their experts and used their competence. Here the dialogue was very close. But this project went directly into the core business of the firm. Then the expertise is always there.*

Another respondent from chemistry/material science further specifies what he sees as characteristics of firm participants:

> *Not everybody have a strong science background. Typically they are the people who coordinate; they have a job that involves solving problems with the process, with separation and things like that. And they know that they can understand this better by participating in R&D projects. So some of them do not have a pure science background, but they have a lot of knowledge about the problems involved. They usually know what they want and what the aim is. (…) Most often, at least for Norwegian firms, they have a background from the NTNU; usually civil engineers and often they have PhDs too. And in the foreign firms it is pretty much the same. But most of them have not worked with research for many years.*

The chemistry/material science respondents interact with people who are quite similar to them with respect to competence, and the respondents see them as professionals in their own field. This form of interaction is by a respondent referred to as "only meetings where professionals talk to each other[25]". Another professor of chemistry/material science also underscores that the interaction between researchers is what these projects are about. And even though the firm participants do not always work in R&D departments they often have similar educational backgrounds as the university researchers. This obviously facilitates communication. According to one of the chemistry/material science respondents, it is interesting to talk to people that have other backgrounds and perspectives, since they can learn a lot from

[24] KMB: Kompetanseprosjekter Med Brukermedvirkning. NFR supported collaborative R&D projects between public research environments and large R&D heavy firms.

[25] In Norwegian the sentence is "Bare faglige møter hvor fagfolk snakker med hverandre". The concepts "faglig" and "fagfolk" here entails people with a particular professional expertise. I have not found an English concept that covers the term exactly.

people in industry, but that "it is much easier to talk to people with PhDs". These statements from the respondents give support to the knowledge proximity perspective on knowledge transfer; that exchange is dependent upon similarity of cognitive repertoire. It is experienced as easier and more rewarding to communicate with people that are similar. The respondents who interact with people who are similar with respect to educational background do not seem to experience knowledge transfer as problematic.

The administrative/economic science respondents' accounts of actors involved, on the other hand, indicate that there is much larger variety of people from the firms that participates in the projects. One respondent reflects on who he has interacted with in the firm he currently has a collaborative research project with: "*From the CEO to somebody that works on a concrete product of some kind. So they are from all levels and divisions of the organizations"*. In general, it seems that the administrative/economic science respondents interact with more people and from more diverse settings than do the chemistry/material science respondents interviewed. The projects they are involved in do not seem to be as tightly linked to particular departments or groups in the firms. The administrative/economic science respondents do however not interact with the R&D departments, and the people they interact with do not necessarily have a similar educational or professional background. This seems to be a major difference between how chemistry/material science and administrative/economic science respondents carry out the interaction with the firms, since they to a large extent interact with the same companies. Also the top management level is usually involved in the projects in administrative/economic science, which in general is not the case for the chemistry/material science researchers. To use a term that several of the administrative/economic science respondents use, the collaborative projects are not "anchored"[26] to the organizations in the same way.

8.2.4 Anchoring

The topic of organizational anchoring is a major issue of concern in the interviews with the administrative/economic science researchers. For them, anchoring plays a central role for how they experience the interaction and what happens in the interaction process. This is related to the institutionalization of R&D collaboration and how they are organized in the firms. But it also concerns wider issues, which are related to the preconditions and motivations for tie formation. As seen in chapter 7, prior established relationships between individuals in firms and universities are common when collaborative projects are formed. These personal

[26] "Forankret" in Norwegian

relationships are a foundation in the collaborations, as illustrated by the following quote from a senior manager at a university:

> *It is a lot of personal relationships involved. They are the foundation in all of these things. They are also the foundation when larger collaborations are established, when a center is established and things like that. The background for why it all happens is these personal relationships.*

The way that the relationships are formed seems to have a lot to say for how they get "anchored" in the organization. The concept anchoring, which is used by several of the respondents, concerns who is seen as responsible or who 'owns' the project in the firm. Anchoring concerns to whom and at what level the project is connected to the firm. This might be overlapping with who is formally responsible, according to the contact. Formally, ownership and responsibility might be assigned to a department, an advisory board or reference group is created, and a project manager is commissioned. However, these instruments are not always overlapping with whom the researchers perceive as their contact in the firm.

As the majority of the collaborative R&D projects are initiated and formed based on personal contacts, these persons are perceived as the link to the firm. Most of the collaborative projects are based on personal level anchoring. As seen in the previous section, the chemistry/material science respondents interacts with a small number of R&D or technical staff and the projects are anchored in research or product development departments. But the interviewed respondents do not seem to think that this is an issue of concern. Several of the administrative/economic science researchers interviewed focus on this issue as a potential problem, as will be discussed below. Three of them make the following statements with respect to person level anchoring:

- *The anchoring depends on particular persons*
- *That the relationship is dependent on particular persons and is not institutionalized influences a lot.*
- *The collaboration depends on particular persons*

On part of the universities, the link tends to be between research groups and firms. The department level is formally responsible, but the anchoring is always to particular academic staff. In many of the institutions, institutional agreements exist, but these are broad formal agreements with few collaborative R&D components. Some of the respondents interviewed that are not academic staff, express that they would like to have a better

institution-wide coordination of UI collaboration, as to "create more synergies" and "ensure that the university gets a stake in it". But at the same time, this is an area that "manages itself" and that it works fine so they see no need "to fix what is not broken". In general, the impression is that in the three institutions investigated there is little institutional coordination of R&D collaboration with industry. Leaders in the universities have a feeling for what is going on, but no real knowledge of the extent or character of UI collaboration in their institutions. This indicates that both in the firms as well as in the universities, the institutionalization of UI collaboration is weak, and that concrete R&D collaboration is anchored at departmental, and most often personal levels. This feature seems to have implications for how the researchers experience the collaboration process, which will be discussed in the next section.

8.3 Researcher's interaction experiences

Where as the last section emphasized the descriptive accounts of how the interaction was carried out and organized, this section focuses on how the researchers have experienced and how they perceive and assess the collaborative relationships. The conceptual categories that organizes this section emerged during the data analysis process and where not predefined. All of the respondents talked a lot about their experiences and it required little structuring from the interviewer's side.

Table 16: Conceptual analysis: Interaction experience

Conceptual focus area	Conceptual categories	Conceptual property focus
Interaction experience	Performance perception	Informants' assessment of the success or lack of success of the interaction
	Challenge perception	Informants' perception of the challenges the interaction met
	Future perception	Informants' perception of the future of the collaborative tie
	Explanatory foci	The informants' interpretations and explanations of why or why not they think the collaboration was successful

As a general observation, the researchers regardless of the academic fields experience university – industry knowledge interaction as challenging. It is by none of the respondents seen as an easy process; all have experiences of things that they see as significant challenges. Even the respondents that have experienced the process as overwhelmingly positive experience challenges, and that it take a lot of negotiation, coordination and experience to address problems. Overall, researchers from both administrative/economic and chemistry/material science experience the interaction in similar ways and have experienced similar challenges. But the respondents interviewed perceive the effects of the challenges differently. This will be explored below.

8.3.1 Performance perception

The interviewees discuss several different criteria of performance, like publications, conference participation and concrete applications and innovations that have sprung from the projects, but most of them talk about the success or lack of success in terms of how they perceive the performance of the collaboration. Most of the researchers interviewed also emphasize that they cannot speak on behalf of the companies they have interacted with. The ones that talk about what they think the firms' assessment would be do so by pointing to that they did not get any open criticism; they perceived the firms to be happy etc. So it's the researchers' subjective perceptions of interaction success - 'performance talk' - that is emphasized.

When asked how the respondents assess the collaboration, most of the respondents assess the collaboration as moderately positive. A researcher in chemistry/material science assesses the collaborative project in the following manner, which is typical for the respondents:

> *I hope that it was a good result. I thought it was very exiting. I think that we are further now. There are a lot of questions that it would have been nice to have an answer to, but there was limited time. But in terms of what industry think, I hope that they experienced it positively. (…) But to what extent it was a success for industry? I guess you have to ask them. But I think that we have achieved many interesting results, so I think we have come a long way. But we have not solved the whole problem.*

Several respondents make similar statements. They are for the most part quite cautious in expressing whether they think that the collaboration projects were successful or not, like this professor in administrative/economic science:

From my point of view, I think that it has been very successful. I have also had some signals from them that indicate that they also experience it as positive, but I cannot say what they on the other side of the relationship really think.

As seen, several of the respondents indicate that they are uncertain about the success of the collaboration and they perceive that the firms might have other success criteria than themselves. Also the researchers might strive to appear non-biased in their judgment, according to norms of behavior amongst researchers, which might also explain their reserved attitude as to claiming success. However, the large majority considers the collaborative projects as positive, even though they take reservations in what they can have opinions and knowledge about.

However, two of the respondents have experienced the collaboration as negative. One of them, an industrial researcher, evaluates the project he has been involved in with a university group in material science, in the following manner: *"To be frank, it was total failure. It was not a success. It failed completely. I just have to realize that"*. The other respondent who also claim that the project failed, is a researcher in administrative/economic science. This respondent also talks about how the collaboration project "died" even before the contract period was up. Both of these respondents also experienced a large number of challenges related to the interaction process.

8.3.2 Researchers' perceptions of challenges

The respondents highlight a number of difficulties, tensions or challenges related to the interaction process. Technical and resource problems, ownership and contracting issues, and knowledge transfer challenges are some of the issues that the respondents point to. However, there are two dominant foci in the interviewees' reflections about the challenges in the interaction process: the "cultural cleft[27]" and "contact loss".

The cultural cleft

The cultural cleft is a concept that is used by several of the respondents. More than half of them talk about how they have experienced a large cultural divide between industry and academe, or that they are "two separate worlds" with very different norms, attitudes, ways of working etc. The respondents have experienced this in both knowledge fields, but where some of the respondents have experienced it as a huge obstacle; others downplay its importance in the interaction process. In these instances, some of the

[27] Several of the respondents use the concept "cultural cleft" or "cultural cleavage". Translated from the Norwegian concept of "kulturkløft"

respondents talk about how they have developed ways of dealing with the cultural differences through spelling out expectations and negotiating the terms for the collaboration, in advance and during the interaction process. Also, the respondents in chemistry/material science in general are much more detailed in how they experienced the cultural cleft. They tend to work with industry more closely, and in problem solving projects. It is likely that the conflicts and tensions surface more here than in the collaborations that the administrative/economic science respondents have, since they experience a closer form of collaborating.

When the respondents talk about the cultural cleft, it is usually in relation to two interrelated issues – problem solving focus and time perspective. According to the respondents interviewed, the focus of industry and university in how they address research problems is substantially different. In relation to that the time frame or the understanding of time they have diverges, in the eyes if the respondents. According to one of them, a firm representative interacting with a research environment in material science, such differences can be very challenging:

> *When you run a company, you get very focused on particular issues, and you have to focus because you really do not have the opportunity to follow all the interesting research problems that you identify along the way. You just have to focus to get where you are really going, to create what you are supposed to create. But at the university, well not necessarily the university in general, but at least the people we were involved with at the university, they were very academic in the sense that they were concerned with free research. For them, it was completely subordinate if this could be used in the product or not. They were so concerned with following the problem statements to very detailed levels. So after a while we got a strong conflict about the direction of the project.*

Where as this respondent find that working with university scientists is a problem, many of the university scientists interviewed feel the same way about their firm partners - that they just do not have the same focus. A chemistry/material science respondent, involved in collaborations with several oil/gas companies, explains how the problem solving focuses in industry and academy are different:

> *We are university so we want to understand. If we see a problem, we want to understand why it happens. Industry wants to solve it. Solve it and then hope that it does not come back. But to make sure that it does not come back, most often you have to understand it and why it happens.*

Related to the problem solving versus understanding difference in focus, the question of different time perspectives in industry and the academy is emphasized by the respondents. When asked what respondents think are main challenges, the following respondent from chemistry/material science expresses how he sees focus and time as related:

> *I think that it is the time perspective on when things should be implemented (…). I do understand that if you are to make money you have to try to find the optimal solution faster. This is also related to how good the technology has to be before you try to implement it.*

Industry's perspective of time is expressed in the following quote from an industrial R&D manager.

> *The problem is the long time perspective. For industry, if you try to see much longer than two years a head the picture gets blurry. […] That is why it is difficult to put money into, to invest in something that has more than a two-year perspective. And most basic research projects have a 5 to 10 year perspective to commercial applications – at least. If it is a 5-year perspective then you are really, really lucky, 10 years and you are still lucky and 20 years I guess is more common.*

University based researchers on the other hand experience the short time perspective of industry as the most difficult tension in R&D collaborations. They often feel that the firms only want quick solutions and that their priorities shift rapidly. University researchers say that they want to understand the problems and that this requires an in-depth problem solving strategy. Firms on the other hand, want shorter time from research to commercialization. Depth of focus and length of time perspective seem to be closely related.

What is that the respondents that do not think that the cultural cleft is so large do? In the data it seems to have a lot to do with whom they form ties to. Firms that are used to interacting with university based researchers are more familiar with the style of working in universities. And likewise, research environments that are familiar with industry experience the cultural cleft as less negative. Social capital resources like familiarity and understanding stemming from previous interaction seems to be central in the interaction process. Who they interact with is related to how they experience the interaction and its challenges, as in the words of a professor in chemistry/material science:

> *Traditionally it has been more interesting with Hydro, because they have established a research center, and they have done more basic research. Statoil is a younger company that focuses more on short-term problem solving. And this suits the university less. We have to think long-term. If we are to become good we have to work on issues for many years.*

A researcher in chemistry/material science expresses how experience mediates the cultural cleft as following:

> *I think that it is important to be clear about the differences: That industry understands that the universities think differently and vice versa. Because at least then it won't be become a shock. (…) It is important that they have some lenience with each other. A bit more like – we knew that they were not so interested in this, and that we had a different focus. But that went ok really. This probably has something to do with Hydro being a large company and that they have collaborated with many others before us. That makes it much easier immediately.*

This also goes the other way. Firms that interact with universities emphasize that the university based researchers need to understand how firms work. The respondents interviewed that have an industrial background emphasize that research environments are very different with respect to their familiarity with industry. One of them reflected on how he had been involved with several different institutions and why it was easier to collaborate with some research environments:

> *Because they are proactive, they are industry specific, and first and foremost they are sensitive to what problems industry finds relevant and they have an understanding of industry. They have so much interaction with industry that they understand what industry is interested in and some of them have spent time in industry themselves.*

Due to previous interaction and mobility of personnel between industry and universities, they seem to have a better understanding of each other, and this familiarity is a vital resource in the interaction process.

Shifting priorities, reorganization and contact loss

The second main challenge that the respondents are concerned with is how the short time frame and shifting priorities by the firms often lead to significant changes in the resources they utilize in the projects and the

interest they have in the R&D collaboration after it has been established. The majority of the respondents from administrative/economic science and several of the respondents from chemistry/material science say that changes occurred "mid-stream", and that this had a significant impact on the knowledge interaction process. Most of the respondents, both chemistry/material science and administrative/economic science respondents who say that such changes occurred, were involved in collaborative projects with the same company. All projects where Hydro was the industrial partner experienced similar changes. However several other administrative/ economic science respondents involved with other firms also experienced "mid-stream" changes and their effects on the interaction.

According to the respondents, the reasons for the shifting priorities lie outside the R&D collaboration. Due to technology shifts, market changes, mergers and acquisitions or other factors external to the projects, the firm's focus can shift and internal reorganization is carried out. What often happens then, according to the respondents, is that the people involved in the collaboration from the firm leave the project to work in other parts of the firm, or in some instances get fired or quit. This loss is experienced as quite dramatic by several of the researchers. The respondents, particularly the administrative/economic science respondents, see loss of key persons due to firm reorganization as a challenge, and sometimes a large problem. One of them reflects on the effects of loss of key persons on the interaction process:

> *After a while, after about two years, these contact points, the arenas of interaction, became fewer. We had less contact. In my opinion, this was primarily because Hydro changed the people that were in charge. The ones that had initiated the collaboration were very interested in the research part. They had visions about the program and visions about research collaboration. And we had very good personal relations between us. But then they left. First one of them got new tasks and then the other one. In all, I think that four or five people have been in charge of the project. And the interest in this project has varied a lot from person to person.*

As seen in chapter 7 and section 8.2, collaborations are formed from previous personal contacts and rely on person-level anchoring to the firm. Due to this, the loss of contact persons seems to have negative effects, as experienced by the respondents:

> *External factors have changed the collaboration, particularly because our contact persons or champions have been moved. Since the relationship is very dependent on key persons, and is to a little*

extent institutionalized, this has had a large effect on the interaction process.

The respondents from chemistry/material science that has experienced such changes in general think that it has less negative effects. They feel that it sets them back, but that after a while the process gets back on track. Two of the chemistry/material science respondents that interacted with Hydro on separate projects in two different divisions of the company experienced more or less the same thing when the firm reorganized:

> *Around 2000 something happened, because they reorganized and then there was almost no people left in the project from Hydro. (...) We did get new contact persons, but that was not so problematic. We had to get them up to speed, because they did not know much about the project when they got into it, to say the least.*

The other respondent has a fairly similar reflection on the effects of loss of key contact persons:

> *For me, it meant a setback, because we had already gone through different solutions that we believed in. We had frequent meetings where we discussed everything. And then the new people came in after that and they did not know what we had previously discussed. So then we had to explain that we had already discussed this a year ago.*

Loss of initial contact persons seems to have less importance for the chemistry/material science respondents than for the administrative/economic science respondents. As seen above, these collaboration projects are most often anchored in particular R&D or technical departments, and they interact with a smaller number of firm participants, which also often have similar educational and/or professional backgrounds. In these environments, R&D collaborations seem to be more institutionalized and less dependent upon particular people in the interaction process, even though personal contacts are seen as decisive for formation of these ties as well. The administrative/economic science respondents' projects are anchored in parts of the organization, and to people who do not have R&D as their main task. They interact with more people in the firms and their key contact persons are most often not scientists. In the interview data, it seems that in these instances, the weaker institutionalization entails that loss of contact persons is experienced as more negative. Several of the respondents experienced that when this happened, the interaction process started to break down.

The interest has varied from person to person, and also the anchoring in the project has been weak. In the beginning it was new and exiting and they were unsure of how the program would work out. And our research group provided a lot of input which they used to improve the program. But after a while it became more of a routine, and then they lost interest. So after a while this became a problem, and then we had to push them to have meetings and channels for knowledge exchange.

8.3.3 Explanatory foci and future assessments

As seen in the above section, the explanations that most of the respondents have for negative experiences tend to be project external. By this it is meant that the respondents, for the most part, point to factors outside the project, which they perceive as explanations for why they think the collaboration did not become completely successful. This is illustrated by the following quote by a researcher in chemistry/material science:

It was unfortunate for the project that Hydro downsized. It was many of the ones that I would say had a lot of experience and knowledge that went into early retirement. I though this was a loss for Hydro because these people had so much knowledge. (…) And it was a shame that the ones that replaced them in our project were less open minded.

When the firm reorganizes, this alters the R&D collaboration project, since the researchers often loose contact with their key contact persons. This might not be intentional. But since these projects tend to be loosely coupled to the organization and rely on personal contacts, these initial personal relationships are central for forming ties but also for the interaction process and how the researchers perceive the success.

Interestingly enough the two respondents that experience the collaboration as very negative focuses on project internal explanations, focusing on the experienced cultural cleft in the interaction process. The following quote made by an industrial R&D manager illustrates this internal explanation focus:

The most important thing is the people. And also to make sure that one in advance has clarified and tested that the partners have common goals for the project. This was the problem in this case. We had one goal and the people from the university had a completely different goal. And in the end these could not be reconciled. The

longer into the project we came, it became more and more clear that the goals were so different that they would never go together.

Most of the respondents say that when the collaborative projects formally end, the interaction between participants often continues informally. Very few of the respondents claim that there are concrete plans for extending the collaboration project when the contract period ends. Only the respondents that are involved in highly institutionalized collaborative relations, or working on issues that is extremely industry relevant, expect that the collaboration will continue after the current project ends. But also very few of them say that there are no chances for future collaboration, and these are the ones that experienced the interaction as negative. Most of the respondents express that the contact is kept up and sustained informally and that these informal ties lead to the formation of future collaborative projects, if or when new opportunities rise.

8.4 Summary

The interaction process was described by using four conceptual categories: arenas, exchange, actors and anchoring. In terms of arenas for knowledge interaction, respondents in both fields agree that arenas which offer opportunities for direct interaction are the most central. Of particular significance is the seminar or workshop. Knowledge transfer is, by the respondents, seen as a social process; hence the respondents highlight the opportunity for dialogue and interaction. Due to this, the question of actors in the interaction process becomes central. On this issue, the chemistry/material science respondents and the administrative/economic science respondents' experiences differ. Chemistry/material science respondents interact with a smaller number of firm representatives, usually only with technical or R&D personnel with fairly similar backgrounds as them selves. Administrative/economic science respondents interact with more people and more diverse people, in terms of positions, tasks and educational/professional backgrounds. The knowledge exchange process is different, and is seen as more problematic for these respondents. Related to this is the concept anchoring. As seen in chapter 7, collaborative projects come into being by personal contacts and these remain to a large extent the contact point and anchor for the researchers, even though formal coordination procedures have been arranged. Anchoring has a lot to say in how the interaction is experienced. The following table summarizes and compares the two respondent groups.

Table 17: Conceptually ordered matrix on "knowledge interaction"

Respondent groups	*Arenas*	*Exchange*	*Actors*	*Anchoring*
Economic/ administrative science Researchers	Regular contact meetings Seminars and workshops Ex: "the most important arena is workshops and conferences"	Social interaction Dialogue Ex: "the company does not want papers but the intellectual discussion related to concrete problems"	U: Senior professor and research staff I: Senior managers often at corporate levels as well as a multitude of firm representatives Ex: "From the CEO to somebody that works on a concrete product"	Person level anchoring is very important for initiation Projects are for the largest part very loosely coupled to the firm, and susceptible to contact loss Ex: "The relationship is dependent upon particular persons"
Chemistry/ material science researchers	Regular contact meetings Seminars and workshops Ex: we do not meet very often, usually every six months, when the firm invites to seminars"	Social interaction Dialogue Ex: "So the process is two-ways"	U: Senior professor and research staff I: a small group of project managers or firm R&D or technical staff with similar educational and professional backgrounds Ex: "Some of them do not have a pure science background, but they have a lot of knowledge about the problems involved"	Person level anchoring is important for initiation of projects Anchoring to lower organizational levels (often the R&D dept) creates firmer institutionalization which insulates the project Ex: "we did get new contact persons but that was not so problematic"

In terms of main similarities and differences between the respondents from the two academic fields, the researchers from economic/administrative science and chemistry/ material science focus on similar ways of interacting with firms. Regular meetings and seminars is the dominant activity, and the main form of knowledge transfer is face-to-face interaction in these settings. With respect to who participates, the two groups are similar with respect to who participates from the university side, but differs with respect to what type of firm staff they interact with. Chemistry/material science respondents interact with mangers and staff from R&D or technical departments. Economic/administrative science respondents interact with senior managers often at corporate level, but also often with a large variety of firm

employees. Also, in both cases, personal level anchoring is seen as central by the respondents, as key contact persons are central for formation of ties. However, the two respondent groups contact persons seem to be located at different levels in the organization. The chemistry/material science projects seem to be firmer coupled to the firm, and less susceptible to loss and external changes than the economic/administrative science projects, that seem to be "higher" and "looser" anchored to the firms. These differences in how the projects are organized seem to be related to what type of challenges collaboration projects meet.

As a general observation, the researchers regardless of knowledge fields experience knowledge interaction between firms and universities as challenging but positive. To gain insight into their experiences, three concepts were developed: success assessment, challenge perception and reflections on the future. Most of the respondents think positively about the success of the collaboration, but are careful in assessing what the firms think about this issue. Only two respondents experienced the interaction as very negative, but a few have a balanced assessment highlighting both positive and negative issues. There are no clear-cut differences between the two groups in their overall assessments. The respondents that though the collaboration was unsuccessful highlight the problems and challenges related to what several of the respondents refer to as the "cultural cleft". The respondents see contact loss and the cultural cleft as the most central challenges in interaction.

Two aspects of the cultural cleft are highlighted: problem focus and time perspective. Both researchers from economic/administrative sciences and chemistry/material sciences experienced similar challenges related to cultural differences, but there are differences related to who they form ties with, according to the respondents. Familiarity, stemming from previous interaction and commonality in cognitive repertoire, seems to mediate tensions. This goes both ways. Firms and university groups alike experience the process as less challenging if they have previous experience. Contact loss is also a challenge for several respondents in both fields. External factors lead firms to restructure, which often means that the people that were involved in the collaboration with universities change. Since the collaborations are dependent on key people, loss of contact persons are experienced as very negative, but more so for the economic/administrative respondents than for the chemistry/material science respondents. In terms of the future, most of the respondents say that when formal collaborative projects end, there are no plans for new projects but that the interaction is carried further informally. If opportunities rise, new collaboration projects can be developed. Only the respondents that experienced the interaction as

negative express that further interaction will not occur. These findings are presented in the table below:

Table 18: Conceptually ordered matrix on "knowledge interaction experienced"

Respondent groups	*Success perceived*	*Challenges perceived*	*Future assessments*
Economic/ administrative science researchers	For the most part positive, in the researchers point of view. Unsure about the firms' opinions Only one project seen as "failed" Ex: "From my point of view, I think that it has been very successful"	Reorganization and loss of contact persons seen as a main challenge. Ex: "Since the relationship is very dependent on key persons, and is little institutionalized, this has large effects on the interaction process"	No concrete plans for continuation except for one project If opportunity rises, most expect that further collaboration will emerge Interaction continues informally
Chemistry/ material science researchers	For the most part positive, in the researchers' point of view. Only one project seen as a failure Ex: "I hope that it was a good result. I thought it was very exiting"	Cultural cleft seen as the main tension, particularly related to problem solving focus and time. Contact person loss less important Ex: "We discovered that it was a significant cultural difference between running a firm and working in a university	Most expect continuation, but few have concrete plans when projects end. These works in areas were industry – university interaction is institutionalized, and on problems that are very industry relevant. Interaction continues informally

To sum up, how the interaction is carried out is similar but who the respondents interact with in the firms differs. Also, the researchers share similar experiences of performance and challenges in interaction processes. The data presented in this chapter indicate that there are some relevant differences between the groups, but that experiences of interacting with firms in collaborative projects are fairly similar and that there seems to be connections between the conceptual categories developed in the previous chapters and the categories developed here. In the next chapter, a focused comparison on conceptual categories is made. After this, a synthesis of the data focusing on key concepts and their connections is presented for the purpose of developing an image based on the empirical data.

Chapter 9: Comparison and synthesis

The aim of this chapter is to pull together elements developed in the previous chapters, to integrate them in a theoretically informed and empirically grounded framework for understanding tie formation between firms and universities – the overall purpose of this dissertation. To do this, central concepts and dimensions in the data material will be highlighted by way of a comparative approach. As described in the methodology chapter, the comparative method is the key analytical process in grounded theory methodology, as comparison of main similarities and differences is seen to enable a clearer focus on key concepts and dimensions. As such it is a central data reduction process (Glaser & Strauss 1967). In this comparison, similarities in the accounts of the respondents in both academic fields will be highlighted as the two contexts were selected due to an assumed difference in significance for industry. Thus, the focus is not on describing why the two contexts are different and what accounts for such differences, but on what is similar despite assumed differences in context. The argument posed for this design was that increasing variance in context could lead to more robust understandings of relationships between central concepts. Consequently the comparative method is not an end in itself, but a means to develop conceptual categories and clarify relationships between concepts from empirical data (Glaser & Strauss 1967). Also, an implication of this approach is that the basis for the comparison is the conceptual categories. Below, comparisons of conceptual focus areas in the interviews with respondents from two academic fields will me made. Then the relationships between central concepts, will be highlighted and discussed.

9.1 Comparison of conceptual categories

As seen in the methodology chapter and in the data presentation chapters, the analysis of the researchers' accounts of R&D collaboration with firms focused on developing conceptual categories that provide insight into their perspectives and experiences, and the categories highlight analytical dimensions and properties. The emerging conceptual categories have been treated as sensitizing concepts. The analysis led to emphasis on three broad conceptual focus areas: tie formation motives, tie formation processes and knowledge interaction experiences. Below, the respondent groups' accounts

in light of these three focus areas will be described and compared. Concept labels developed are outlined in cursive.

9.1.1 Tie formation motives

With respect to the *perceived motives* or reasons for why ties are formed, the respondents in business/economics highlight that the firms they interact with are interested in having access to competence environments. Access to competence environments is seen as a more central firm motivation than problem solving, but several researchers also highlight that the projects they are involved in address problems with existing tools and "soft" technologies. Problem solving is highlighted as the most central motivation for the chemistry/material science respondents, both for addressing issues with existing technologies, but in some cases also to create new technologies. Recruitment of graduates and risk reduction through access to public research funding are also mentioned. Both groups of respondents emphasize that access to additional resources for research (money, equipment, students) is the dominant incentive for them to collaborate with firms.

In terms of the *knowledge intensity* dimensions of *interdependence*, both groups of respondents collaborate with large, R&D heavy firms with an international orientation. In general, many of the respondents in both academic fields interact with the same firms, such as Hydro and Statoil. This could indicate that in Norway these large and previously publicly owned firms are central knowledge partners for university researchers in several academic fields. However, although the majority of the respondents interact with the same firms, they collaborate with different divisions in the firms.

This is related to the second dimension of interdependence, if collaborative R&D projects address *core technologies or competences* or not. In general, projects do not address core technologies in the firms in the case of economic/administrative science respondents. This entails that the knowledge created and transferred in the collaboration projects is often not seen as a critical input for the firms. For the chemistry/material science respondents, on the other hand, there are two main clusters of collaborations. Several of the projects are related to development of new technologies, which might be promising but also risky. But there are also several cases where the projects concern problem solving in connection to core technologies of the firms. But besides from the latter cases, in which the firms have a strong strategic need for knowledge, joint *trigger dependence* seems to be a central dimension of interdependence between firms and universities. For both the economic/administrative science respondents and the chemistry/material science respondents, mutual dependence on public

funding for R&D is seen as a central driver of tie formation in this context. Cooperation with firms is seen as a way of getting funding for R&D projects from the Norwegian Research Council, since it is perceived as easier to get support on projects that involve users. For firms, public funding (and other forms of external R&D funding) is seen as central when projects do not address a core technology or when the projects address new and risky technologies. In these cases, funding opportunities seem to trigger tie formation.

9.1.2 Tie formation processes

Regardless of academic fields, for most of the researchers interviewed in this study, collaborative projects were formed by drawing upon *prior ties* by utilizing resources available through previously established relationships. The researchers say that they "interact with particular people in particular departments", which they have known for a long time, often "since university". This is common for respondents in both academic fields. They also highlight that joint educational backgrounds and previous interaction experiences are central, by making clear the competences each party have and what contributions the researchers can make to the firm. Issues related to *cognitive proximity* are highlighted by most of the respondents as central for tie formation. However, the chemistry/material science respondents particularly emphasize this aspect when discussing the particular status of networks growing out of the Norwegian University of Science and Technology.

A very small number of interviewees say that they have formed *new ties* to firms they have had no previous contact with. A few of the chemistry/material science respondents also highlight that initiating collaborations with foreign firms are different, in the sense that other mechanisms are used to establish contact. Here academic publications are important, and such ties are often formed as a response to a need for knowledge. This is also the case in the other three instances where ties are formed without previous contact or using indirect relationships or referrals. *Cognitive distance* seems to be more central when weak ties are used. At the same time, the administrative support staff interviewed highlight the role of creating new contacts and brokering ties between previously unconnected firms and universities, particularly SMEs.

9.1.3 Knowledge interaction experiences

In terms of main similarities between the accounts of the respondents in the two academic fields, the respondents describe similar ways of interacting

with firms. Regular meetings and seminars are the dominant *activities* and the main form of *knowledge transfer* is face-to-face interaction in these settings. With respect to *agents* or who participates, the two groups are similar with respect to who participates from the university side, but differs with respect to what type of firm staff they interact with. Chemistry/material science respondents interact with mangers and staff from R&D or technical departments. Economic/administrative science respondents interact with senior managers, often at corporate level, but also often with a large variety of firm employees. But in both cases, personal level *anchoring* is seen as central by the respondents, as key contact persons are central for formation of ties. However, the two respondent groups' contact persons seem to be located at different levels in the organization. The chemistry/material science projects seem to be firmer coupled to the firm, and less susceptible to loss and external changes than the economic/administrative science projects, which seem to be looser anchored to the firms. These differences in how the projects are organized seem to be related to what type of challenges the collaborative research projects meet.

As a general observation, the researchers regardless of knowledge fields experience knowledge interaction between firms and universities as challenging, but positive. There are no clear-cut differences between the two groups in their overall *assessments of success*. The respondents see contact loss and cultural differences as the most central *challenges perceived* in interaction. Both researchers from economic/administrative sciences and chemistry/material sciences experienced similar challenges related to cultural differences, but the there are differences related to who they form ties with. Familiarity stemming from previous interaction and commonality in repertoire seem to mediate tensions. Contact loss is also a challenge for several respondents in both fields. External factors lead firms to restructure, which often means that the people that were involved in the collaboration with universities change. Since the collaborations are dependent on key people, loss of contact persons are experienced as very negative, but more so for the economic/administrative respondents than for the chemistry/material science respondents. In terms of *assessment of future collaboration*, most of the respondents say that when formal collaborative projects end, there are no plans for new projects but that the interaction is carried out informally. If opportunities rise, new collaboration projects can be developed.

Table 19: Conceptually ordered overview matrix by groups of respondents

CONCEPTUAL FOCUS			RESPONDENT GROUPS **Econ/adm**	**Chem/mat**
TIE FORMATION	**Motives**	*Motives*	▪ U: Access to resources ▪ I: Access to competence environments	▪ U: Access to resources ▪ I: Problem solving and recruitment
		Inter-dependence	▪ Firms are knowledge intensive ▪ Projects do not address core technologies	▪ Firms are knowledge intensive ▪ Projects are related to core technologies or development of new and risky technologies of relevance to industry
		Triggered	▪ Mutual dependence on public funding.	▪ Mutual dependence on public funding.
	Resources	*Strong ties/ cognitive proximity*	▪ Previously established relationships dominant in tie formation ▪ Cognitive proximity central for formation of ties	▪ Previously established relationships dominant in tie formation ▪ Cognitive proximity central for formation of ties
		Weak ties/ cognitive distant	▪ Not important for tie formation	▪ Not very important for formation of ties to domestic firms but more important for foreign firms. ▪ Also more central for radical innovations
KNOWLEDGE INTERACTION	**Exchange process**	*Interaction process*	▪ Regular seminars ▪ Two-way exchange	▪ Regular seminars ▪ Two-way exchange
		Actors	▪ Many actors involved, not R&D personnel ▪ Corporate level responsible	▪ Few actors involved, mostly R&D or technical personnel ▪ R&D dept or technical dept responsible
		Anchoring	▪ Personal level anchoring in initiation ▪ Loose anchoring to the corporate level	▪ Personal level anchoring in project initiation ▪ Tighter anchoring to particular R&D/technical dept
	Exchange experienced	*Perceived success*	▪ Positive careful perception	▪ Positive careful or positive perception
		Perceived main challenge	▪ Loss of contact persons	▪ Cultural cleft
		Future assessments	▪ No immediate plans for continuation ▪ Informal interaction continues	▪ Expects continuation if new opportunities rise ▪ Informal interaction continues

By displaying the comparison of the findings from the two academic contexts on the conceptual categories in matrix form, one can clearly see the key similarities and differences across respondent groups. In general, there seems to be a high degree of similarity with respect to how ties are formed, perceptions of motives, as well as exchange experience and performance perception. The clearest difference between groups of respondents concern who they interact with in the firms, but this aspect seems to have important relationships with knowledge exchange.

9.2 Emerging relationships between conceptual categories

Comparing similarities and differences in experiences that researchers in both subject fields have, with respect to formation of ties and experiences in interacting, enables a focus on central concepts and the relationships between them. The analysis gives support for an empirically grounded interpretation highlighting that there is a relationship between how ties are formed and how interaction is experienced. The central concepts and the links between them will here be highlighted and discussed, with the aim of developing an integrated framework for understanding tie formation behavior in the university-industry relationship context.

9.2.1 Relationships between inducements and opportunities in forming ties

As seen in chapter 7, R&D collaborations are formed either through the use of previously established contacts, or through formation of completely new relationships relying on brokers or referrals. Previously established contacts were seen to carry with them both social and cognitive resources, giving the actors involved in forming a R&D collaboration benefits in terms of common understanding, familiarity and trust. Such resources are seen as beneficial for forming ties and also for coordinating and carrying out interaction processes. In knowledge interaction processes, which R&D collaboration is about, common understanding and joint cognitive repertoire are seen as particularly important resources. Collaborations formed based on prior relationships could be described as more cognitively proximate than new ties, which have the benefit of carrying more novel knowledge due to cognitive distance. In chapter 3, these two dimensions and their overlapping character in the UI context was conceptualized as “knowledge networks”.

The large majority of the university-industry collaborations investigated here were initiated and formed through the use of already established contacts.

These contacts are often personal friendships formed in university or through educational/professional networks and/or through previous small-scale collaboration projects. A small minority of the interviewed researchers say that the industry collaboration projects they are, or have been, involved in were formed without previous contact between the parties. However, administrative staff interviewed as well as recent policy documents, as reviewed in chapter 5, emphasizes brokering relationships between previously unconnected firms and universities. In these cases referral from a third party, brokering by an external agent or publications contributed in establishing contact and set up a collaboration project. In the cases found where a collaboration project had been formed without prior contact, the collaborations often had a clear goal based on a particular need for new knowledge by the firm. The firms involved in R&D collaboration in the cases investigated can all be characterized as knowledge intensive. For the most part, they are large, internationally oriented companies who invest a lot in internal R&D. Several of them have corporate R&D centers and employ people with science backgrounds. As seen, the firms involved collaborate with public research institutions on different types of projects and for different purposes. Some projects are related to core technologies or core competences in the firms, other projects concern development of new technologies, which can be uncertain and risky, and some projects are not related to core competences, but are seen as more generic competence development. In the cases where collaborative projects have been formed without prior contacts or with indirect contacts, the motivation often seems to be development of a promising but uncertain technology. The collaborative project has been initiated because the firm sees the need for a particular competence that the university possesses. In these cases, there is interdependence between the partners – as the firms have incentives to collaborate with the university to gain access to particular knowledge resources, and the universities have incentives to collaborate to gain access to resources for research.

Collaborations that are based on previously established contacts can also be based on a mutual interdependence based on particular knowledge needs. In some of the cases investigated, research carried out in university groups (such as in the examples from catalyst research within chemistry) is of high relevance for existing core technologies in the firms. In these cases, the relationships seem to be very tight and the interaction is continuous or recurrent. Also, when the project is related to a core technology in the firm, the interviewed researchers have experienced that the firms are more motivated and more actively involved in the interaction.

But in many cases it is not a concrete need for knowledge behind the establishment of a collaboration project, rather it seems to be a common

interest in relevant research problems. Since the majority of the firms involved are knowledge intensive and have scientist and other highly educated employees on staff, it seems that in many cases personal interests and contacts between firm employees and university employees are central in establishing collaborative projects, not specific knowledge needs. In these cases, the availability of public funding for collaboration seems to triggers the formation of new collaborative R&D projects. Access to public funding through NFR's user-initiated programs and related initiatives seems to be particularly important when the interdependence is low or the risks are high.

The administrative staff that have been interviewed, as well as recent policy documents, emphasizes that more ties between universities and firms should be created, particularly to previously unconnected firms like SMEs, which often do not have a natural point of contact to university environments. The respondents interviewed that fulfill brokering roles underscore that to initiate collaborative projects require that one already has established contacts and networks. But, they do not problematize that the incentives that SMEs have for interacting with universities also might be less.

To summarize the relationships found between motives and resources in tie formation, the data indicates that there is a relationship, but that it is not linear. The following table summarizes the findings:

Table 20 Relationships between motives and resources in tie formation

	Weak ties/cognitive distant	Strong ties/cognitive proximate
Weak inducement	**Created collaborations** Relationships are "engineered" or facilitated by an external broker	**Opportunity driven collaborations** Relationships emerge because there are previous relationships between the parties and availability of funding. Projects are often non-core or high risk.
Strong inducement	**Needs driven collaborations** Ties which are formed based on a strategic need without previous interaction between the parties	**Interdependence driven collaborations** Relationships emerge because the knowledge is a critical input and established ties are close and recurrent.

In the cases where ties are strong and inducements are strong, interdependence driven collaborations can be seen. In these situations, the firm is highly knowledge intensive and the R&D project is related to a core

technology for the firm – giving the firm a strong motive to collaborate. The research carried out in the university is highly industry relevant and there is a density of established ties between the firms and university, which exists prior to forming new projects. A small number of cases from chemistry/material science fit here. An illustrative example of this is the following quote made by a respondent working on chemical catalysis: "We work on catalysis and that is highly relevant to industry. […] Primarily, industry is interested in collaborating with university groups to understand what is going on, to improve the catalysts and the economy of the process". These relationships are usually recurrent or institutionalized, as described in section 7.2.4.

On the other hand, examples where motives are weaker, in the sense that that firms are not knowledge intensive and no not require scientific knowledge as an input, there are likely fewer or no ties between university environments and firms. There are no examples of R&D collaborations that can be characterized as such in this data, but this is a central focus of recent policies aiming at fostering collaboration between SMEs and universities, as well as for several of the managers interviewed, as described in section 7.3.2. This is illustrated by the following quote made by a respondent responsible for technology transfer activities at a university: "Where we have a particular role to play is for small and medium sized businesses that are uncertain, they do not know who to call and have to previous relationships with the university." Such formation processes are referred to as created or 'engineered'.

But in the data collected in this study, the majority of the tie formation processes does not fit in either of these categories. And in these processes, the relationship between the motives and resources in tie formation is less clear-cut. In almost all of the economic/administrative science respondents' accounts, the role of previously established contacts between actors was key to tie formation while the motive by the firms was not connected to access to critical knowledge. This is also the case for several of the chemistry/material science respondents. According to the economics/ administrative science respondents, the projects tend to be on the side of core technologies by the firm. For the chemistry/material science respondents, the projects address new and uncertain technologies, as seen in section 6.4.2. In these cases it seems like prior established contacts are particularly central for establishing collaborations between firms and universities, whilst the availability of public programs that funds R&D collaboration triggers the formation of ties, as described in 6.4.3. Illustrations of collaborations formed through prior established relationships with less defined motivations, can be seen in the two following statements. The first quote is made by a respondent from economics/administrative science interacting with Hydro: "So we created a

memo where we drafted a project proposal and got Hydro's support to initiate a project. But at the same time we agreed to apply for funding from the NFR". And in chemistry/material science, the following statement is made by a respondent also involved with a collaborative project with Hydro: "it was a consortium of several industry partners where the aim was to develop new methods for … and then they [the firm] were asked to join in. […] we had already had several collaboration projects with them. So they knew that we existed and they knew what kind of competence we had and what we could do. So then we were asked if we wanted to join in". These formation processes are labeled opportunity driven tie formation.

But, as seen, the opposite situation is also found in the data material. In a few cases the collaboration was established without previous contacts and in those cases there was a strong need for knowledge behind the formation, as described in section 7.3. The following statement from a material science respondent serve as an example: "Our idea was to take this technology which we had a concrete commercial application for, something that we planned to use it for". Such tie formation processes are here labeled as needs driven collaborations.

9.2.2 Relationships between tie formation and interaction experiences

The second question the analysis has focused on is how the researchers experience knowledge interaction, and if similarities in how ties are formed are associated with similarities in interaction experiences. To explore this potential relationship interview data on how the researchers interacted with the firms after the collaboration had been initiated and how they assessed and perceived the interaction process was analyzed. In terms of how the researchers interact with firms, both the economic/administrative science respondents and the chemistry/material science respondents see the knowledge interaction process as a social interaction, where the direct interaction between firm and university representatives was seen as the most central activity, as described in section 8.2.2. This is usually organized through regular status meetings and seminars with the people in charge of the project in the firm, but the firms invite other interested parties or other collaboration partners, as described in section 8.2.1. Extensive informal collaboration is also common. But where the two groups of respondents are markedly different are in respect to whom they interact with and how the collaboration projects are organized and coordinated in the firms, as seen in sections 8.2.3 and 8.2.4. The chemistry/material science respondents interact with a small number of firm representatives, and they usually work with firm R&D or technical tasks and have a fairly similar educational background as the university representatives. The projects are anchored lower in the

organization and usually in R&D or technical departments. They interact with firm representatives who they see as fairly similar to themselves in terms of competence and interests. The economic/administrative science respondents interact with a larger set of actors in the firms, with a much larger variance in tasks and professional backgrounds. At the same time, the projects are anchored at a higher organizational level – often in the corporate leaderships. Who the researchers interact with and how the interaction is anchored seem to be associated with the motivation the firms have for interacting. The projects that are related to a core technology, and where the firms have high strategic needs, seem to be anchored lower than projects that are not as central for the firm, or where there is considerable uncertainty and risk. On the other hand, this might be a reflection of the different purposes of collaborations in chemistry/material science and economic/administrative science. The competence that the economic/administrative science respondents have is interesting for the leadership and administration, where as the competence of the chemistry/material science respondents is primarily interesting for people who work with industrial production and processes in the firms. And since the respondents use personal contacts to establish new collaborative projects, and such contacts often have been formed in universities, the two groups of respondents have contacts at different levels and parts of the organization.

Who the respondents collaborate with and how the projects are anchored, seem to be connected to how the respondents assess the interaction, with respect to a general perception of success, challenges perceived and the potential for further collaboration. This again also seems to how the ties were formed.

Table 21: Relationship between tie formation and interaction experiences

	Weak ties/cognitive distance	Strong ties/cognitive proximity
Weak inducement	**Created collaborations** No cases, policy emphasis	**Opportunity driven collaborations** - Careful positive assessment of success, but often experienced as challenging - Very dependent on key contact persons: Loss of contact persons a main challenge - No concrete plans for continuation, but possibly if new opportunities rise
Strong inducement	**Needs driven collaborations** - Negative assessment of success - Cultural differences experienced as a main challenge - No plans for further collaboration	**Interdependence driven collaborations** - Positive assessment of success - Do experience cultural differences but have developed ways of tackling such issues - Expects continuation

The matrix indicates that needs driven collaborations formed with strong inducements due to a strategic need for new knowledge, but with weak ties and high cognitive distance are experienced as difficult and not very successful, as described in section 8.3.1. In these cases, cultural differences, in terms of depth of focus and time perspective, are seen as large problems. The lack of experience and the cognitive distance seem to create a gap between expectations - that are high - and how the interaction is carried out and what it delivers. The two examples explored that fit best in this category were experienced as failures by the respondents, cultural differences as huge obstacles and that the relationships died. The need for new knowledge that was a motivation for forming the tie meant that it was a large difference in cognitive capacities as well as lack of familiarity and trust. This contributed to making the interaction experience difficult, as expressed by a respondent involved in a collaboration in material science: “We discovered that there was a significant cultural difference between running a firm and working in a university. […] So after a while we got a strong conflict about the direction of the project”.

In the opposite end of the matrix, opportunity driven collaborations were formed based on prior established contacts and interaction experience, but where the inducement in terms of a strong need for particular resources was seen as less central. As seen, access to public funding is central for triggering

such tie formations. In these cases, the success of the collaboration is assessed as moderately positive. Here the researchers assessed the collaboration as positive but they express uncertainty in terms of what their partner might think, as described in section 8.3.1. Opportunity driven collaborations are also seen as challenging with respect to cultural differences, but such issues are manageable and not destructive. But a central issue in these collaboration projects is that since they are highly dependent on personal contacts for project initiation, they seem to be particularly vulnerable for external changes and reorganizations, an issue that was discussed in section 8.3.2. Loss of contact persons is a key challenge for such collaborations, particularly for the economics/ administrative science projects that seem to be anchored higher in the organization and are in general more loosely coupled to the firm. The following quote illustrates this: "After a while, after about two years, these contact points, the arenas of interaction, became fewer. We had less contact. In my opinion, this was primarily because Hydro changed the people that were in charge". When the formal project period ends, and the external funding of the collaboration stops, there are usually no concrete plans for continuation. But as seen in section 8.3.3, the respondents say that if new opportunities rise in terms of funding, new projects can be established. As compared to the needs driven collaborations, the proximity in capacity and familiarity that previous interaction has lead to, seem to make the tensions related to cultural differences less difficult to handle. A researcher in chemistry/material science typically expresses: "I think that it is important to be clear about the differences: That industry understands that the universities think differently and vice versa. Because then at least it won't be become a shock". Also since expectations often seem to be less concrete, the gap between expectations and experience is less.

In the last category, interdependence driven collaborations, previously established contacts, networks and prior collaboration are resources used when forming new collaborative projects. Due to previous interaction and, often, common educational and professional backgrounds, the actors involved share understandings of the field, but also of each other, as discussed in section 7.4. Also, the firms are seen to have a strategic need for the knowledge, as it is often directly relevant for a core technology and the firms are highly knowledge intensive. Collaborative projects with this combination of preconditions are the ones assessed as the most successful by the respondents. In these cases, the researchers perceive the firms to be more actively involved in the process - that they contribute, and that the firms' central experts are involved. It is not so that the involved parties do not experience any challenges or problems, but they do not see differences and tensions as only negative. Through previous interactions they seem to have developed ways of handling differences, and making clear expectations is a

central part or this, as described in section 8.3.2. The researchers expect interaction to continue when a concrete project ends, and often such collaborations are recurrent, as illustrated in section 7.2.4. The following quote illustrates how strong strategic needs and close ties create interdependence driven collaborations: “If you go over to the department for petroleum technology and applied geophysics, you’ll see that people is very used to working with industry. If something happens, they just call. They have large formalized projects (…) they are very used to working like that and industry fund a lot of what is going on.” Such collaborations are described as recurrent, and in some instances such collaborations become institutionalized, but there are only a few examples of institutionalized university – industry collaborations in the interview data.

9.3 Summary

The purpose of this chapter was to integrate the elements developed through the data analysis, as to build and recontextualize an empirical image of R&D collaborations between firms and universities. This was carried out by further reducing the qualitative data by using a comparative approach aimed at highlighting core conceptual categories, analytical dimensions and emerging relationships between concepts. As a result of these focused comparisons, two analytical dimensions were emphasized as central for understanding tie formation processes in this context. The two dimensions seem to be related, but which focus is most central seems to be different in specific formation processes. Due to this, a matrix categorizing four different tie formation processes was identified, which accounted for all of the observations: created, needs driven, opportunity driven and interdependence driven tie formation processes. The data analysis also indicates that there is a relationship between how ties are formed and how interaction is experienced, and by utilizing the two-dimensional framework, interaction experiences and perceptions of performance and challenges were also addressed. With this in mind, the findings will be discussed in light of the analytical framework, as well in light of other relevant data and research on UI interaction and interorganizational relationships in the next chapter.

Chapter 10: Discussion

10.1 Introduction

The aim of this chapter is to discuss the findings from the empirical study of R&D collaboration projects in light of the analytic frame, with the purpose of providing an answer on the three research questions and the overall research problem posed in the introduction. A secondary aim is to discuss the findings made in this study in light on other relevant research on UI interaction specially, and interorganizational relationships more generally. This discussion about the findings in light of the research literature is carried out as a step towards raising the theoretical level, address validity and the theoretical generalizability of the developing framework (Eisenhardt 1989). First of all, the research problem and the research questions posed in this study will be briefly revisited. After this the findings will be discussed in light of policy and statistical data on UI interaction in Norway (as described in chapter 5), and in light of related research literature (as presented in chapter 2 and 3), before ending this chapter with a reflection on the validity and relevance of the analysis and findings.

The purpose of the study was to illuminate the following principal research question: How can we understand formation of formal R&D collaboration projects between firms and universities? The reason for the chosen focus was that recent R&D and innovation policies put a very strong emphasis on interaction between universities and industry. University – industry interaction is seen as a way to strengthening innovation in the Norwegian economy, by increasing the flow of knowledge across sectors and stimulating industrial R&D investments. At the same time as a strong belief in the power of interaction is stressed in policy, research has been fairly limited with respect to understanding the preconditions for forming R&D collaboration ties, and particularly on processes of forming ties in this context. An incentive oriented explanation for tie formation is often posed in the literature, where knowledge intensive firms' strategic needs for new knowledge and universities' need for research funding creates a situation of mutual dependence, which motivates them to collaborate. However, the very few comparative studies that have been made suggest that interaction is concentrated in but not limited to interaction between knowledge intensive economic sectors and technological knowledge fields. Interaction is spread and do not follow obvious and simple patterns (Schartinger et al 2002). This observation does not disqualify the assumption that knowledge intensity is a

precondition for formation of interaction ties, but indicates that there might be other factors that are also relevant for understanding tie formation in this context. The networks individuals and organizations are embedded in, which can give rise to opportunities for forming ties, can be seen as an additional explanation to incentive oriented frameworks. The concept "knowledge networks" was developed and used as a sensitizing concept for exploring social and cognitive ties between universities and business and industry.

With these different frames in mind, the purpose of this study was to investigate formation of R&D collaboration projects between firms and research groups in two academic fields – material science/chemistry and economic/administrative science, focusing on the three following research questions: How are collaborative R&D projects formed? Why are collaborative R&D projects formed? And how do the researchers experience interaction with firms in collaborative R&D projects? Alongside the empirical investigation of tie formation of formal R&D collaboration projects, a conceptual framework was developed indicating the main conceptual foci in the study, and assumptions about their relations. As described in chapter 3, the framework assumed that both knowledge networks and incentives would be relevant for understanding tie formation behavior and probably also for actual exchange processes. The conceptualization was considered as an interpretative framework and was revised several times during the research process.

10.2 Knowledge networks and tie formation: the embedded character of collaborative R&D projects

Having the research questions and the analytic framework as a backdrop, the empirical data indicate that the collaborative R&D projects between firms and university environments are formed between people who already know each other. Projects are initiated by use of personal friendships, personal networks, and prior R&D collaboration, often small-scale collaborations like student projects. Moreover, most of the respondents indicate that these prior relationships have been formed in universities, stemming from a common educational background, and that university based networks are central for initiating and maintaining interaction between firms and universities.

This pattern is found in both academic fields investigated, and this finding is corroborated by other data sources and research publications as well. As seen in chapter 5, data from the Norwegian university surveys indicate a strong connection between prior relationships, in the form of previous industrial employment, and later collaboration with industry (Gulbrandsen &

Larsen 2000). This study also indicate that this connection is strong in all academic fields, but less dominant in technological fields, which have a high degree of firm collaboration regardless of prior industrial employment. Also, national innovation statistics for Norway indicate that industries with the highest propensity for interacting with public research institutions also are industries with a high portion of R&D personnel with PhD degrees – chemical industry, production of metals and oil/gas production (NFR 2003, 2005b). Although both of these indicators point to an interdependence perspective, this indicates that prior relationships stemming from a common educational and/or employment background play a role in initiating cross-sectoral interaction. Schartinger et al's (2002) study of UI interaction in Austria highlights that human capital relations explain propensity for interaction and indicates that prior established relationships are central in the process of forming collaborative R&D projects. Also Gulbrandsen & Larsen's (2000) interview study of university – industry interaction in Norway also emphasizes that prior social relations are vital in establishing collaborative R&D. Also as seen in chapter 3, prior relationships play a central role in forming many kinds of interorganizational relationships, such as dyads between entrepreneurial firms (Larson 1992) strategic alliances (Ring & Van de Ven 1992, Doz 1996, Gulati 1995) networks of firms in the apparel industry (Uzzi 1996), and R&D alliances (Bouty 2000).

As such, use of established personal contacts seems to be a fairly stable characteristic in tie formation processes across organizations and sectors. But where studies of tie formation emphasize the relational aspects of social capital stemming from previous interaction, particularly trust, this study has also emphasized the cognitive resources stemming from previous ties. By this it is meant that joint cognitive repertoires, a similar understanding of the problem field, and common language through which research problems are expressed and understood, are central resources in tie formation processes between firms and university environments. This is particularly central in this context because collaborative R&D projects are created for generating new knowledge and transferring knowledge between firms and research environments in universities.

The data indicate that in both academic fields, knowledge interaction and transfer is seen as a social process. The respondents see face-to-face contact and dialogue as central to the knowledge transfer process, as seen in chapter 8. As discussed in the analysis of the communicative properties of knowledge in chapter 3, some degree of similarity between participants is seen as central for transfer and absorption of knowledge (Rogers & Bhowmik 1970, Rogers 2003, Cohen & Levinthal 1990, Hansen 1999, Nooteboom 1999; 2002). However, as indicated in Nooteboom's (1999) model of the external economy of cognitive scope, transfer of knowledge

rests on a balance between similarity (cognitive proximity) and difference (cognitive distance), since a high degree of similarity would not yield new knowledge, and a high degree of difference (cognitive distance) would inhibit communication. An implication drawn from this cognitive capacity perspective is that agents are more likely to enter into relationships intended to transfer knowledge with others who have a relatively similar but not overlapping cognitive repertoire. This is also seen in the empirical analysis (section 7.3), where several of the respondents focus on the perceived match between them and their partners' competences.

However, a few of the R&D collaborations investigated were initiated without prior contact or with only indirect ties between the parties. In these cases, referral from third parties, publications, or some organization performing the role of broker seem to be central in the tie formation process and initiates contact. Such ties, according to theory (Granovetter 1973, Hansen 1999, Nooteboom 1999, 2002), have information benefits in that they give access to new knowledge. In this perspective, collaborations formed to new agents could be motivated by access to new knowledge. In the data collected for this study, very few of the respondents interviewed had entered into R&D collaborations with organizations they had no contact with prior to forming the project. This is in consistence with other studies, as indicated above. But according to the ones who have experienced this, the motivation for the firms was access to new knowledge, and for the researchers, access to funding and other resources. In addition, respondents fulfilling brokering roles (both within and outside the university) as well as recent Norwegian policy, highlight the potential for tie formation between previously unconnected firms (particularly SMEs) and university environments. Both the empirical data and the theoretical analysis indicate that there is a relationship between reasons for entering into collaborative research projects and to whom and how ties are formed.

In terms of the first research question – *how are ties formed?* – the theoretical and empirical analysis indicate that collaborative R&D projects are formed by the use of previously established contacts and to a lesser extent through the use of external brokers, referrals or other indirect means. The latter is seen by some of the respondents as increasingly important due to internationalization of research collaboration and recent innovation policies focus on strengthening universities ties to SMEs. The informal networks between industrial sectors/specific firms and university research environments seem to be very central for forming collaborative R&D projects, as it is related to how and between whom ties are formed.

10.3 Dependence or opportunities?

As seen in chapter 2, the question of why universities and firms enter into collaborative arrangements is addressed at length in the university-industry literature, but it really concerns two interrelated questions (Miotti & Sachwald 2003): What characterizes firms and, to lesser extent, university environments that collaborate on R&D? This is really a question of who collaborates. And what are their reasons and motivations for entering into collaborations? These questions are interrelated in the sense that the answer to the first question is used to explain the second: characteristics of agents are used as explanations for why they engage in interaction. Most of the analyses have an underlying interdependence perspective (Pfeffer & Salancik 1978, Oliver 1990, Geisler 1995) focusing on that organizations form ties to others as a way of coping with uncertainty and manage dependence on others for resources vital for their survival. Firms that demand input of scientific knowledge are likely to interact with university environments, and universities who need resources for research due to constrained public funding are motivated to form ties with firms[28].

In general, focus is put on understanding why firms interact with universities and less so on why universities form ties with firms. In terms of the first, knowledge intensity, maturity and characteristic of innovation processes are seen as relevant industrial properties (Schartinger et al 2002, Meyer-Krahmer & Schmoch 1998, Faulkner & Senker 1995, Rappert, Webster & Charles 1999, Pavitt 1984) and R&D intensity, technology centrality, size and proximity as seen as firm characteristics, influencing the propensity for interaction (Vedovello 1997, Santoro & Chakrabarti 2002, Schartinger et al 2002, Faulkner & Senker 1995, Mansfield 1991, Arora & Gambardella 1990, Santoro 2000). In general the following pattern is expected: Firms that are large (as measured by number of employees), R&D intensive (as measured by share of revenue used on R&D) and engage in radical innovation processes (as measured by patents) are dependent on input of scientific knowledge, and as a result, are more motivated to enter into collaborative R&D with universities. Moreover, firms who have internal R&D capacity in a permanent R&D lab and have university trained scientists on staff are likely to be more dependent on new knowledge and interact more with universities.

[28] As discussed in chapter 2, this assumption does not hold empirically. Universities, departments and individual academics that mostly interact with firms are usually not the most "dependent" on additional research funding. Rather industrial funding for research flows mainly to departments and individuals who also have public funding This concentration of resources is known as the "Matthew effect" in science (Merton 1968)

In this study, the data collected indicate that the firms involved in R&D collaborations are large, for the most part R&D intensive and internationally oriented firms. This finding largely corresponds to the research literature and other relevant data sources (NFR 2005b). Also several of the firms that most of the interviewed researchers interact with have corporate R&D labs and, according to the respondents, a long tradition for interacting with university environments.

What is interesting is that several researchers in both chemistry/material science and economic/administrative science interact with the same companies. This could indicate that the firms that have a tradition for interacting with universities in knowledge areas of high relevance to them, extends this collaboration strategy to other business areas. Further data collection is needed to address this issue. On the other hand, surveys of interaction across knowledge fields indicate that some academic fields like economics and IT interact with many different economic sectors (Schartinger et al 2002), and in a sense are more general collaboration partners than others.

But the data collected also indicate that even though the firms in several cases are the same, the researchers experience the firms' motives for forming a tie as different. Some see the firms' motives as related to problem solving in a core technology/competence where others identify development of new and uncertain technologies or more general competence development as motivation for tie formation. As seen in chapter 6, how related the collaborations were to the firms' core technology/competence seem to be a relevant dimension of interdependence. Gulbrandsen & Larsen (2000) find that firms dominantly collaborate with public research institutions in non-core technologies. This has also been investigated by Santoro & Chakrabarti (2002) who find that the size of the firms and technology centrality interact with respect to how and why they collaborate with universities. Large firms collaborate with universities as to gain access to ancillary competence in non-core areas and smaller firms collaborate with universities for problem solving and competence building in core business areas. Although size of firms has not been a central focus in this analysis, the firms involved with the researchers interviewed are all large. The data collected indicate that the firms involved interact in both core and non-core areas.

In terms of universities (institutions, disciplines and individual academics are very often not discerned), resource dependence is seen as a driving force behind forming ties to industry (Slaughter & Leslie 1997) but since there is a high degree of differentiation between academic fields with respect to industrial funding (as seen in chapter 5), disciplinary characteristics like size,

visibility and particularly reputation/prestige are used to explain propensity for interacting with firms by disciplines and individual academics (Schartinger et al 2002). The interview data indicate that access to additional resources for research is the dominant reason for why the researchers form ties with firms. Resources are not for personal gain but for strengthening and extending research activities, predominantly through providing funding for students and equipment. This finding is corroborated by several other studies of UI interaction (Meyer-Krahmer & Schmoch 1998, Gulbrandsen & Larsen 2000, Nimtz, Coscarelli & Blair 1995, Waagø 2001, Santoro & Gopalakrishnan 2000, OECD 1999). However, the data from this study indicate that it is not only access to resources from firms that the researcher see as a central motivation, but that through interacting with firms they can get easier access to public funding. This could indicate that that the largely reactive resource dependence interpretation as motivating tie formation from universities should be questioned, as interacting with firms is better seen as a proactive strategy to manage dependence on public funding which is increasingly distributed on a competitive basis. This strategic aspect is also stressed by Slaughter & Leslie (1997) in their analysis of academic capitalism, and in the original resource dependence theory. And also fits much better with the empirical findings that business/industry funding is concentrated in research environments that already enjoy public support.

Since, as seen, most collaborative R&D projects are, for the most part, not related to core technologies in the firms and the university environments are not dependent on resources from firms, the extent to which ties are formed due to experienced interdependence is questionable. The role external triggers play seems to be particularly relevant for explaining tie formation. As posed in the analytic framework in chapter 3, when partners experience less interdependence, external agents can trigger tie formation, if the interactors experience dependence on the triggering agent. The data suggests that this is a highly relevant dimension for understanding universities' motivations, but is also relevant for understanding firms' reasons for forming collaborative R&D projects. The data suggest that when projects are related to development of new and uncertain technologies or more general competences outside the core business of the firm, availability of public funding seems to trigger formation of collaborative R&D projects. Risk reduction and sharing of the cost burden seem to be important for firms when the relevance of the project for the firm is uncertain. The risk reduction motive has also been emphasized by others (Bonaccorsi & Piccaluga 1994, Faulkner & Senker 1995, Rappert, Webster & Charles 1999). And in Norway, Gulbrandsen & Larsen (2000) find that access to public funding through collaborative R&D programs in the NFR and EU is seen as a motivation by firms to collaborate with universities. Evaluations of the Norwegian research council's programs for user-initiated research also show

that according to firms, public funding is central in realizing R&D projects. 66% percent of the firms that had received funding from the NFR claimed that this support was vital for initiating the project, and 23 % claim that it was important for initiating R&D collaboration. In general, they find that the effect of public funding is higher for research than development projects (Hervik, Bræin & Bergem 2004).

In terms of the second research question – *why are collaborative R&D projects initiated?* – the theoretical and empirical analyses indicate that R&D collaboration projects are formed mainly between large and knowledge intensive firms and particular academic fields close to business and industry. Funding stream data, surveys of firms and university staff, and interview studies of interacting firms and researchers show that UI interaction in the form of collaborative R&D projects is concentrated in certain academic fields (notably technology fields) and firms in R&D intensive industries. In Norway chemical industry, metal industry and oil/gas are industries with a relative high propensity for interaction (NFR 2005b), and similar concentration patterns are also found in other countries (Schartinger et al 2002). This seems to indicate that interdependence stemming from the need for knowledge by R&D intensive firms and need for resources for research by university research environments motivates firms and universities to form collaborations. At the same time, it has also been found that many firms do not form collaborations related to core technologies and that access to public funding triggers formation of R&D collaborations. Data also suggest that researchers are not dependent on firms for research funding, but that many see collaborative research as a strategy to increase public funding for research. The data collected here indicates that in many of the cases firms and universities form collaborative research projects because opportunities for funding emerge, and since they have established social and cognitive ties they are able to form collaboration projects when opportunities emerge.

10.4 Tender ties – experiences of collaboration

The data indicate that for the majority of the respondents interacting with firms in collaborative R&D projects is experienced as positive but also challenging. There also seem to be a connection between how ties are formed and how interaction is experienced. In the analytic framework, the perspective that collaborations formed between parties with previous contact and shared a cognitive repertoire would be experienced as more positive than collaborations formed without such prior contact, was posed. This perspective was based on both social capital analyses (Nahapiet & Goshal 1998, Uzzi 1997) and cognitive capacity analyses (Nooteboom 1999; 2002,

Cohen & Levinthal 1990, Rogers 2003), and indicates that prior ties give interactors resources beneficial for exchange. Both cognitive resources (joint understanding, language and code) and relational resources (trust, familiarity, norms of reciprocity) were addressed. In particular, cognitive resources were seen as central due to the characteristics of knowledge exchange.

In line with this perspective, the data analysis indicates that collaborative R&D projects that were formed using previous contacts, established in university and reinforced through previous collaboration projects like small scale student projects, seem to be experienced as more positive and less difficult. But as seen in chapter 7, a few of the collaboration projects were formed without prior contact and they, on the other hand, were experienced as more negative and challenging, particularly related to perceived cultural differences between firms and universities. Lack of prior experience and cognitive distance seem to create discrepancy between expectations, which are high since need for new knowledge was the reason for why they were formed, and what the collaboration process delivers.

This could indicate that relational resources like trust and familiarity lubricate collaboration processes, making them run more smoothly. Further, that cognitive proximity contributes to a positive exchange experience and sharing of knowledge. Other research also corroborates this interpretation. Investigating collaboration between scientists in scientific alliances, Shrum, Chompalov & Genuth (2001) find that although trust is not associated with higher performance, trust is associated with less conflict. Mora-Valentin, Montoro-Sanches & Guerras-Martin (2004) investigated what contributed to success in collaborative projects between firms and research institutions in Spain, and find that previous cooperative experience has a positive influence on success (measured by partners' satisfaction and continuity of the relationship), as do trust and commitment. Porac et al (2004) expected that prior collaboration experience and similar professional qualifications and disciplinary background would be positive for knowledge sharing in scientific alliances, but found that human capital heterogeneity is associated with higher performance but not with assessment of success.

However, the data also indicate that some of the collaborative projects that were formed using previously established contacts, but where the strategic need for the knowledge by the firm was experienced as less, are also experienced as challenging. They seem to be particularly susceptible to contact loss due to external changes. It is quite common for the interviewed researchers to experience that the firms reorganize, and in several of the cases, this leads to a loss of contact person for the university group they collaborate with. Since personal contacts are very central for forming ties

and cognitive proximity central for exchanging knowledge, loss of contact person is experienced as negative, since it entails a breakdown in communication. This is experienced as more problematic for the economic/administrative science respondents than for the chemistry and material science respondents, probably due to differences in organizational anchoring and institutionalization. The anchoring and contact loss concepts contributed to refining the understanding of tie formation processes, highlighting the opportunity driven dimension of tie formations. This again led to a reconceptualization highlighting the integrated character of tie formation between firms and research environments, which matches the data and makes theoretical sense.

In terms of the third research question – *how researchers experience interaction in collaborative R&D projects?* – the theoretical and empirical analysis indicates that collaborative R&D projects formed through previous personal contacts are experienced as more positive and with stronger expectancy of further continuation. However, the rationale for why ties were formed is also relevant for understanding researchers' experiences. How central the R&D collaboration is for the firm, as reflected in its motives and commitment, seem to have a clear relation to experiences of contact loss and its felt implications on the knowledge exchange process. Projects formed based on both previous contact and experienced need, are experienced as more positive overall. Projects that have been established only with previous contact or strategic need are seen as less positive and with less expectation of continuance. They also seem to meet more challenges associated with the issues of cultural differences and/or contact loss.

10.5 An integrated framework for understanding tie formation behavior between firms and universities

The analytic framework and the perspectives developed from analyzing and integrating different theoretical perspectives on knowledge exchange and interorganizational relationships, highlighted that both resources and opportunities for collaborating stemming from embeddedness in networks, and inducements due to demand for resources, would be central aspects for understanding tie formation. As indicated in the conceptual model in chapter 3, the double arrow between knowledge networks and tie formation motives indicates an assumed relationship between them, and further that both aspects would be relevant for forming ties. The nature of the relationship was unknown, in the sense that expectations about how opportunities and inducements would be connected in given tie formation processes were unclear. As seen in chapter 3 presenting research on alliance formation

(Ahuja 2000, Gulati 1995, Gulati & Gargiulo 1999, Larson 1992, Eisenhardt & Schoonhoven 1996), both social networks and strategic needs (embeddedness and interdependence) are seen as relevant and integrated explanations for alliance formation. But where some researchers highlight that strategic needs explain tie formation and social networks determine whom organizations interact with (Ahuja 2000), other claim that social networks provide opportunities that again generates incentives (Larson 1992).

The analysis of the data indicates, as seen above, that most of the collaborative R&D projects are formed using existing contacts, but a few are not formed this way. Also, whilst some of the projects seem to be founded on dependence based in clear strategic need for the knowledge by the firm, most are not, but rather address new or ancillary competences, and triggering agents seem to be of importance. Further, whilst several of the projects formed using established contacts were experienced as positive and continuance of the relationship was expected, some of them were not experienced in this way. Also, there does not seem to be clear differences between academic fields, as their experiences are quite similar, as indicated in chapter 9. However, by categorizing the collaborative projects according to the two main dimensions it was possible to group all of the observations, also the ones that initially did not fit the modal pattern, into four categories of tie formation processes: created, opportunity driven, needs driven and interdependence driven. The majority of the observations from both economic/administrative science and chemistry/material science fit into the opportunity driven category. As seen above, here ties are formed because there are previous connections between key agents and funding is available. A few cases from chemistry/material science fit into interdependence pattern where interaction is recurrent, and a minority of the cases fit into the needs driven category where ties are formed without prior contact, but with explicit needs. The last category "created collaboration" was added because several of the respondents that were not researchers claimed that this was their focus, stimulating collaborations between previously unconnected firms and university groups, which is also reflected in recent innovation policies (as seen in chapter 5).

Support for this interpretation is found in literature on alliance formation processes that indicate that some alliance formation processes seem to be driven by clear strategic needs; others are formed due to brokering by a triggering agent, and some by strong social relationships (Doz, Olk & Ring 2000, Ring, Doz & Olk 2005). These findings indicate that there are different forms of tie formation processes, and that different preconditions initially operate in each of them. Ring, Doz & Olk (2005) find three different tie formation patterns in their study of large R&D consortia – engineered,

emerging and embedded. These resemble the three main categories found here, but on the intra-firm level. Also, as R&D collaboration between firms and universities, which are smaller, less resource intensive and closer to basic research than large R&D consortia, opportunity driven processes seem to be particularly common. This finding is also supported by Hervik, Bræin & Bergem's (2004) evaluation on the effect of public support for R&D collaboration. The framework also accommodates differences in experiences that seems to be connected to how ties are formed. As seen, assessment of success and expectation of continuance seems to be more positive in ties formed using previous contacts than in ties formed without such contact, and tensions with respect to cultural differences is seen as less of a problem. But ties formed with previous contact but weaker inducements also seem to have particular issues in connection to contact loss and breakdown of communication.

The framework of integrating two central preconditions for forming ties have afforded some new insights into how collaborative R&D projects are formed and through that also insight into who collaborates and why ties are formed. The research literature on university – industry interaction has been very preoccupied with exploring and partly explaining why firms and universities interact, and this is often seen as a reflection of characteristics of the interactors. Thus the answer to why firms and universities collaborate is seen as a reflection of characteristics of the firms and, to lesser extent, universities who collaborate. Based in an interdependence perspective, it is maintained that large, R&D intensive firms in industries oriented towards radical innovation processes collaborate with universities, who on their part interact to get access to money for research. This assumption is in contrast to comparisons of UI interaction that indicates that although interaction is concentrated in certain sectors and academic fields, it is also distributed across many sectors and fields. Thus, it is a contradictory account of university – industry collaboration. With this contradiction in mind, a focus on how ties are formed in the context of university – industry relations was assumed to offer some new insights also into who form ties and why they do it. This integrated approach has been previously been utilized in research on firm alliance formation (Ahuja 2000, Gulati 1995, Gulati & Garguli 2000, Eisenhardt & Schoonhoven 1996), but has not been utilized in research on university – industry relations. How ties are formed has not been seen as a central research focus. For instance, Gulbrandsen & Larsen (2000, p.42) claim that: "It seems like initiation is not a central issue, because collaborative projects most often are created by the use of prior established relationships…" (author's translation). However, understanding the social mechanisms of how ties are formed actually gives a lot of insight into who form ties, why they do it, and implications for the collaboration processes. According to Ring, Doz & Olk (2005, p. 137): "Discussions of the

management of collaborative efforts generally have tended to overlook these formation processes or have treated them as homogeneous activities. This is a mistake; R&D consortia formation processes deserve attention because they affect the creation and subsequent success of collaboration". This analysis also supports this interpretation with respect to UI relationships. Consequently, to better understand and potentially improve coordination of interaction processes and performance, understanding the way ties are formed in this context, is necessary.

In terms of the overall research problem – *how can we understand tie formation between universities and firms?* – the theoretical and empirical analysis indicate that tie formation behavior can be well understood in terms of two interrelated dimensions – inducements based on interdependence, and opportunities and resources stemming embeddedness in knowledge networks. However, both theory and data indicate that it is not a linear relationship where one is 'causing' and the other 'moderating' tie formation behavior. Rather, the two dimensions seem to be related, but which focus is most central seems to be different in specific formation processes. The theoretical and empirical analyses also indicate that how ties are formed and how they are experienced are related, as seen in the performance perception, challenges identified and expectations of continuance.

Based on the theoretical and empirical analyses carried out in this thesis, the following five propositions are suggested to guide further research on tie formation behavior in the university – industry setting. Three propositions are made concerning tie formation:

- Knowledge networks facilitate formation of formal collaborative relations between firms and universities by providing opportunities and resources needed to form ties.

- Interdependence can motivate firms and universities to form ties in situations where firms experience a strategic need for scientific knowledge inputs and universities experience need for additional resources.

- However, triggering entities can motivate agents to form ties even though they do not experience interdependence, if they experience dependence on the triggering entity.

The two following propositions are made with respect to how embeddedness in knowledge networks is related interaction processes and performance in collaborative research projects:

- Collaborative research projects formed based on previously established cognitive and social ties, experience the knowledge interaction process as more positive and less challenging than collaborative research projects that were formed without such ties.

- Experience in collaborating reinforces the cognitive and social ties between the agents, which increase the likelihood of further collaboration.

This framework for understanding tie formation behavior in the university-industry context, as summarized in these propositions, should be subjected to further investigation. Therefore the implications of this framework and suggestions for further research are outlined in the next chapter. But first a reflection on the validity and limitations of the analysis is made.

10.6 A reflection on the validity and limitations of the analysis

In this final section, a brief reflection of the validity and the limitations of the analysis will be made. As discussed in chapter 4, validity in qualitative research is a multidimensional concept, and is not seen as a context independent property of methods. Maxwell (1996) further claims that validity must be seen in light of different types of understanding, and he discerns between deceptive, interpretative and theoretical validity. Since the first of these was addressed in the methodology chapter, the focus here is on the interpretative and theoretical validity. How valid are the interpretations and representations made? What shortcomings does the analysis have? Findings in a qualitative research project will always represent an interpretation based on reduction of an ambiguous material. Coding, comparison and display are central tools in this process. As seen in chapter 4, there are several potential biases that can weaken the validity of the interpretations made. Such as uncritically imposing ones framework, selecting only data that fits the emerging theory, or not paying attention to discrepant data and alternative explanations. The literature on qualitative research methodology suggests that bias in interpretation can be handled by increasing the consciousness about the interpretative framework, theoretical selection, comprehensive data treatment, and paying attention to outliers and discrepant evidence. Generally, consciousness about interpretative processes in research was seen as central.

In this thesis, reflexivity on the interpretation process was a central methodological emphasis, seen both in the idea of retroduction and the

template analysis model. The main element in the interpretation process was seen as the interfacing between the interpretative framework and the data material. This was carried out through repeated interfacing between data coding – template revisions. Moreover, in relation to the theoretical validity, confronting the emerging representations was seen as a central step in the analysis and reconceptualization processes. Comprehensive analysis of the data material, constant comparison and deliberately focusing on outliers and negative data were carried out. Due to this, the representation became more differentiated as to better grasp the complexity in tie formation processes and interaction experiences, as presented and discussed in chapter 9. The design of the study is also relevant for the validity and relevance of the findings. By exploring tie formation in two different contexts, findings can be seen as fairly robust across academic fields, particularly with respect to how ties are formed.

However, there are also several weaknesses and limitations in the design and analysis that are relevant for the validity of the findings. In terms of limitations, three issues are seen as particularly important. First of all, this study has focused on exploring project formation processes as experienced mainly by researchers. This represents a limited perspective on interaction processes in two ways – it targets only one phase in the UI interaction process and has mainly emphasized the experiences and perceptions of one group of actors. To gather detailed qualitative data about R&D collaborations demanded a clear delimitation of empirical focus. Pilot interviews attempting to cover UI relationships more generally yielded very superficial stories of interaction processes. By delimiting the focus to formation processes and exchange experiences it was possible to explore much more in detail. As to the perspectives of different parties in collaboration, steps were taken to include both administrative personnel and leaders in universities as well as industrial R&D managers, but the majority of the respondents in the interview study are researchers. But as argued in chapter 5, the respondents are highly knowledgeable about the interaction processes and the issues discussed are not controversial for the respondents. There is also a consistency in their experiences and accounts. But as to ensure more and different stakeholders' perspectives, field observations and informal interviews with industrial actors were carried out. However, this represents a weakness and this is particularly visible in chapter 6 focusing on firm inducements and motives *as perceived* by the researchers. As will be argued below, further research could improve on these limitations by addressing the levels of analysis and reporting in new ways, as well as extending the process focus.

The second limitation is also related to the choice of a qualitative study of formal R&D collaborations in two academic fields. Basically, it is a small

empirical study of collaboration projects in two academic fields, in three higher education institutions, in one small country. Consequently, the question of whether the results from this study are relevant for understanding tie formation in other academic fields, institutions and countries can be posed. Particularly the issue of the 'Norwegianness' of the findings has been raised as a critical question, indicating that a small and affluent country like Norway might be a special case. However, recent Norwegian innovation policies follow an international format and levels of industrial funding for university R&D is comparable to international levels. But the social and cognitive networks might be denser in Norway since it's a small country with few universities and few large R&D heavy firms. Even the respondents interviewed are concerned with this issue, and claim that the mechanisms in tie formation are different when forming a collaboration project with a Norwegian firm than with an international firm. Consequently, location is seen as central for tie formation behavior. However, as has been found by Schartinger et al's (2002) study of UI interaction in another small European country, Austria, UI interaction in small countries are not locally oriented, as large R&D heavy firms are national rather than regional actors. An implication of this might be that size of country and importance of regional UI interaction might be inversely related. Overall, this study has relied on little comparative data from other countries, and as a consequence it is empirically impossible to assess whether the findings are uniquely Norwegian or not. This has to be left to further research.

Thirdly, the theoretical focus on interorganizational relationships might be seen as a limitation for exploring the nature of relationships between firms and universities. A critical question that can be raised is whether concepts and theories developed for understanding formation of ties between firms are relevant for understanding relationships between firms and public organizations like universities? The choice of theoretical focus was made based on review and analysis of published research on UI relationships. This analysis indicated key analytical dimensions that were implicitly present but rarely explicated in this research literature. The analysis in this thesis was connected to the network embeddedness and interdependence concepts that are fairly general and have been used to explore and explain a tie formation in a large number of contexts. An interrelated critical issue concerns the match between levels of analysis in theory and observations. Literature on interorganizational relations as well as UI relationships in particular conceptualizes the relationship at an organizational level. But the data collected indicate that interpersonal relationships and networks are of importance for such relationships both in formation and in exchange processes. However, as discussed in chapter 4, this is not seen as an analytical "mistake". Rather the findings indicate that individuals and their

networks and ties to others are very central in interorganizational relationships.

In this chapter the main findings were discussed in light of other empirical data as well as research literature, by utilizing ”pattern matching” logic. Yin (1994) and Eisenhardt (1989) maintains that comparing findings to other data and research findings can increase the theoretical relevance. This is in line with the idea of theoretical generalization. As seen above, the findings were discussed in light of research and other data sources on UI relationships and literature on tie formation processes between organizations more generally. The key findings were corroborated by other relevant sources of data, and this increased the confidence that the emerging framework could be relevant for investigating university-industry relationships in other academic fields as well. However, as to increase the confidence in the interpretations and the relevance of the framework, further research is needed. In the next chapter, a few avenues for further research is suggested, which will be central for further exploration and testing of the interpretations made here and their relevance for research on university-industry relationships.

Chapter 11: Contributions, implications and concluding remarks

11.1 Contributions

As discussed in the introductory chapter, this study sought to make some contributions to the research literature on university – industry interaction. Thus, it is within this particular research context that the contributions and implications for further research are framed. With regard to what is seen as strengths of the study four issues are seen as contributions made in this study:

- Teasing out central theoretical perspectives and providing an integrating framework for understanding tie formation behavior in the university-industry context.
- Providing new micro-level data focusing on interaction processes, with collaborative R&D projects as an analytical focus.
- Proposing the knowledge network concept and highlighting the different types of resources available through knowledge networks and their importance in university-industry relationships.
- Comparing different academic fields as contexts for university – industry relations.

As highlighted in the introductory chapter and the literature review chapter, the research literature on UI interaction is fragmented and it is quite unclear at times what is really meant by UI interaction and consequently how we should seek to understand it. With respect to the question of tie formation behavior, as seen in chapter 2, when taking into account all relevant levels of analysis the list of characteristics found to influence propensity for interaction is long: R&D intensity of sectors and firms, the degree of radical innovations, maturity of industry, size of firms, industries and academic fields, technology centrality, location and geographic proximity, reputation, size and maturity of academic fields, as well as mobility between universities and industries. And at times the findings conflict, which suggests several paradoxes that need to be addressed. Research focusing on interaction forms is equally broad and has focused on categorizing the many different ways that universities and firms interact. Overall, a good share of the research in this area is data driven, and many studies lack discussions of the theoretical relevance of the findings or integrating perspectives.

Due to this, the ambition of this study was to tease out central theoretical dimensions that are relevant for understanding tie formation behavior in the university-industry context. The ambition was not to generate a theory of tie formation or to test such a theory, but through the combination of theoretical analysis and empirical investigation, to sort out and clarify relevant dimensions. As such, the study contributes to the research literature on UI relations by clarifying central theoretical dimensions and by connecting this topic to the broader literature on interorganizational relationships and exchange of knowledge. As seen above, the theoretical and empirical analyses indicate that tie formation behavior can be understood in terms of two interrelated dimensions – interdependence and network embeddedness. However, both theory and data indicate that this should not be seen as a linear or causal relationship, where one is causing and the other moderating tie formation. Rather, the two dimensions seem to be related, but which focus is most central seems to be different in specific formation processes. Due to this, a matrix categorizing four different tie formation processes was identified. Based on this, this thesis contributes to the research literature on UI relationships by providing a critical assessment of the underlying dependence model, suggesting instead an integrated framework emphasizing the interrelationship between motives and resources in tie formation processes and interaction experiences.

Moreover, the research literature is largely focused on characteristics of agents and their motivations, on forms of interaction and to some extent on outcomes. There is, however, a relative neglect of how interaction is actually carried out – that is, the processes of forming, developing and carrying out knowledge interaction. This might be partly due to the nature of data used by many, such as patent and publication data or (national) R&D and innovation survey data. As seen in chapter 5, the lack of micro level data on university-industry interaction distorts the present understanding of the phenomenon. Several authors comment that interaction between firms and universities is a much broader issue than what funding data or surveys reveal, because it is assumed that the majority of interactions between firms and universities are not institutionalized and occur informally. Due to this, more micro level data on knowledge interaction was required. Qualitative data was seen as particularly suitable, because the present understanding of the "micro cosmos" of knowledge interaction is poorly understood. In light of these reflections, a second contribution this study makes to the research literature on university-industry relationships is to provide insight based on micro-level empirical data about interaction processes with collaborative R&D projects as an analytical focus.

This analysis revealed that knowledge networks and resources available through informal ties are central in both formation of collaboration projects

and in interaction processes. Previously established relationships were central for the establishment of formal collaboration projects in the majority of the cases investigated. This illustrates that it is a relationship between knowledge networks, the establishment of formal R&D collaboration projects and knowledge interaction processes. As such, the contribution that the thesis makes to the literature is to further the present understanding of the micro-dynamics of UI interaction and knowledge exchange. The analysis based on micro level data indicates that collaborative R&D projects rest on a sea of informal relationships. Further, that such relationships are central in interaction processes by providing cognitive and relational resources needed for exchange of knowledge. The concept of knowledge networks was suggested as a conceptualization of the embedded character of university-industry relationships, which highlight both the relational and cognitive dimension of network ties.

In terms of methodological contributions, the research literature on collaboration between firms and universities has to a large extent focused on cross-sectional designs surveying either firms or universities. Consequently, it is a great deal of focus on variance between extent and type of interaction and tentative explanations of the observed variance. To a very modest extent has there been a focus on exploring similarities across industries, academic fields or collaboration types. And in this sense there has been a clear focus on categorization but not a lot on characterization – that is identifying key properties and dimensions of the phenomenon. To contribute to conceptual development or improvement, focusing on both understanding similarities as well as differences are important. Looking at similarities enables a focus on what is common across a set of observations, which can lead to an improved understanding of categories. With this in mind, this study sought to identify similarities by focusing on formal R&D collaborations in two academic fields that were assumed to be different in terms of relevance for industrial innovation. Since this had not been done in the literature before, a third contribution of this thesis is to focus on similarities, through theoretical sampling and exploration of different contexts. Focusing of what is similar across diverse contexts can improve conceptualizations and here it enabled a clearer identification of two conceptual dimensions of relevance for understanding tie formation between firms and universities.

Based on these three arguments, the overall contribution made is a theoretically informed and empirically grounded study of UI interaction processes based on micro level data in a comparative design. The main finding is a typology of tie formation processes and connections to interaction experiences. The strength of the typology is not the empirical case illustrations, but rather the clarification of the main theoretical dimensions that the framework embodies, and the connection between them.

The framework indicates that with respect to formation of ties between firms and universities indented to generate and share knowledge through interaction, inducements, opportunities and experiences are connected. Thus, an integrated framework for understanding UI tie formation is suggested, which can be the basis for further investigation.

11.2 Implications for further research

Based on the framework developed and the findings in this study, in relation to the state of research on university-industry relationships, several implications and opportunities for further research are seen.

Firstly, the study indicates that there is potential for generating new knowledge about university-industry relationships by further micro level studies focusing on interaction processes. As seen in chapter 5 and in the discussion of the findings above, macro level indicators such as funding data and cross-sectional surveys underestimate the degree of interaction because they gloss over the largely informal and non-institutionalized character of university-industry interaction. To gain a better understanding of the roles universities play in innovation systems and the nature of knowledge flows from universities to industry, research needs to take into account the informal nature of ties, and the link between formal collaboration projects (what is accounted for in innovation and R&D statistics) and informal ties and networks. To capture the complex and largely informal nature of linkages between industry and universities, further research on the process perspective could yield added insight. To do this, and to extend the process focus beyond the project initiation stage, further research following interactions over time is needed. Collecting longitudinal data, by following concrete R&D collaboration projects over time also after they formally end, can represent a new approach. This approach can provide further knowledge about initiation and coordination of R&D collaboration, and also about how knowledge is created and exchanged in UI collaborations. Intensive case studies following collaborative projects over time are one way to address these issues, and it would be an important point to collect data from all involved parties. It is noticeable that most research on UI interaction includes data from only firms or university researchers, which limits the perspective. Thus, rather than taking firms or universities as a level of analysis, further research should address the collaboration level of analysis. And since projects are the most common way of formally organizing collaboration, this level of analysis should be addressed in further research.

A second issue for further research concerns development of the integrated framework and further investigation of the relationship between knowledge networks, establishment of collaboration projects and exchange of knowledge. To further develop the framework, a quantitative study could provide a critical test of the relationships found in this qualitative study. The qualitative study and theoretical analysis carried out here, provide a more comprehensive basis for formulating testable propositions. Such a survey could be made at the project level of analysis, for instance by investigating all R&D collaboration projects that had received some support from the NFR. However, this would also limit the representativeness, as quite a lot of UI collaborations do not receive such support. Surveying research environments or firms are other approaches, but might not provide data that are accurate enough on project level of analysis. Investigating individual academics is possible because a register of academic staff exists, and this provides micro level data, but again this provides a one-sided perspective. But by asking each respondent to provide a name of a firm representative that had been involved in a concrete R&D collaboration project, it would be possible to generate a dyad or project register, providing information on concrete projects from both academic researcher and firm representatives. Although this would be a resource intensive endeavor, this approach would give the most comprehensive and detailed data set.

In addition to these suggested approaches for further research, it could also be possible to better utilize existing sources of data. One issue that could be addressed by utilizing existing data is to develop and test network and mobility indicators in the university – industry context. There does not currently exist any well-developed network measures between particular academic fields and industries. In terms of Norwegian data sources, the annual Norwegian graduate employment survey[29] could be analyzed at academic field/program and industrial sector levels, and thus could be used to create descriptions of knowledge network ties between academic fields and industrial sectors. Data on educational levels and mobility of R&D personnel[30] can also be used to develop network indicators. Such network indicators can be used to analyze R&D collaboration data in the national R&D and innovation statistics, which today use R&D intensity and size variables to explain propensity for interaction between firms and research environments. The aim of this would be to further develop the understanding of the preconditions for UI interaction and knowledge exchange, by making clear the embedded character of interaction and exchange. This study based on qualitative data and theoretical analysis indicates that it is a connection between knowledge networks in which firms and universities are embedded,

[29] Carried out by NIFU-STEP
[30] Carried out by SSB and NIFU-STEP

and formation of collaborative R&D projects as well as exchange of knowledge in collaborations. The further characterization and specification of the relationships between these concepts should be addressed in further research.

11.3 Implications for policy

The purpose and rationale for this research project was set in the context of recent innovation and research policies. As seen in chapter 1, recent policies aim at fostering closer collaboration between firms and universities in Norway. However, the present understanding of the preconditions for tie formation was seen as underdeveloped, as research to a limited extent has addressed preconditions for tie formation and has emphasized a few "best case" academic fields. Likewise, research has focused on the institutional arrangements of UI relationships with little attention to the actual interaction processes. As a consequence, it was argued, that further research was needed on preconditions for tie formation and knowledge exchange. With this in mind, what is the relevance of this analysis and findings for current policies?

The analysis indicates that both inducements based on dependence and resources available through networks are relevant preconditions. Recent policies also address these dimensions in terms of stimulating firm capacity building as well as stimulating network development. These policies then are aimed at stimulating both demand and opportunities for tie formation. However, the analysis provides criticism towards naïve optimism about the potential for fostering UI interaction, particularly between previously unconnected agents. The analysis indicates that forming and carrying out collaborative research projects are complicated and rely on relational and cognitive resources available through previously established ties. Moreover, that knowledge interaction also benefits from a 'felt need' for the knowledge, as reflected in a demand for knowledge and commitment to the interaction. This indicates that creation or engineering of relationships, without paying attention to such preconditions, is a risky strategy. In particular strategies that aim at fostering relationships between previously unconnected firms and universities could be vulnerable, if these firms neither have an explicit demand for, nor the resources needed to form ties as well as exchange knowledge.

Also, the findings indicate the central role of triggers like the Norwegian Research Council in bringing collaborative projects to life. For resource intensive collaborations that are not directly relevant for a firm's core technology, the existence of funding stimuli is very central for tie formation.

However, as has been observed, the opportunity driven character of tie formations also poses several challenges, particularly in relation to the commitment needed to sustain the collaborations over time. Several of the projects investigated seem to suffer from breakdown in communication, which has a negative impact on the interaction and performance. Consequently, the organizational commitment to R&D collaborations could be addressed in relation to further development of policy measures. This has implications for practice as well. The analysis reveals that there is a relationship between how collaborations are formed, how they are coordinated and organized, and perceived performance. Since most relationships are dependent on ties between key persons, coordination and implementation of collaboration projects should take into account the informal and interpersonal ties that the projects most are often founded on. As such, paying attention to tie formation processes could yield benefits for the coordination and performance of collaborative relationships.

11.4 Concluding remark

Recent Norwegian research and innovation policies put a strong emphasis on interaction between universities and industry. UI collaboration is seen as a way of strengthening innovation in the economy, by increasing the flow of knowledge across sectors and by stimulating industrial R&D investments. The latest white paper on research claims that although initiatives during the last ten years have led to increased interaction, there is still too little flow of knowledge across sectors and too little private sector investment in research and development activities in Norway. In light of this strong policy focus on interaction and collaboration, this study sought to clarify central preconditions for UI interaction by focusing on how and why collaborative ties are formed and how interaction is experienced. The overall aim was to improve the understanding of tie formation in this particular context.

The central finding in this study is that the interdependence perspective, focusing on why firms and universities collaborate by pointing to need for resources, cannot fully explain why R&D collaboration projects between universities and firms emerge. But, by also looking at the opportunities and resources available by being embedded in knowledge networks, we can make fuller sense of why universities and firms form ties, how they do it, and the challenges involved. The analysis indicates that opportunities and social and cognitive resources available through knowledge networks are central for both forming collaborative ties as well as exchange processes. This has implications for research on UI interaction, which has tended to overlook the opportunities and resources needed to form ties and carry out

knowledge exchange processes. Due to this, further process oriented research is recommended, since we know quite a lot about *why* firms and universities interact, but still very little about *how* they do it.

This study also provides critical input to current policy on university-industry relations. The analysis indicates that relational and cognitive resources are central for both forming and carrying out knowledge interactions. An implication of this is that creating new and successful collaborations between previously unconnected firms and research environments is probably difficult, as such relationships lack central resources for knowledge exchange. Formation of ties and interaction in collaborative relationships require many different resources, such as opportunities, familiarity, trust, common understanding and language, and a long-term commitment to the collaboration. This implication is particularly relevant for the policy of stimulating SMEs to collaborate with universities, and thereby increasing firms' investments in R&D. Also, a main finding in this study was to highlight the opportunity driven character of tie formation in this context, and highlighting the central role of public agencies for triggering UI relations. At the same time, opportunities without commitment represent a problem for collaboration projects. The issue of organizational commitment seems to be highly relevant for further development of policy measures and programs intended to stimulate UI interaction. This is particularly important in this context because collaborative R&D projects are based on informal relationships and are usually only loosely anchored to the firms involved. And therefore reorganizations resulting in loss of contact often have a highly negative effect on interaction. Overall, due to the many tensions and challenges involved in forming and carrying out interactions between firms and universities, collaborative R&D projects should be treated and managed as highly 'tender ties'. And due to this, both resources available through knowledge networks and organizational commitment seem to be necessary preconditions for knowledge interaction between universities and industry.

Methodological appendix

Appendix A: Contact letters

Letter to department heads in two universities (In Norwegian)

Forskningsprosjekt om kunnskapsoverføring fra universitet- og høyskolesektoren til næringslivet

Ved Handelshøyskolen BI, Center for Education Management Research (www.bi.no/cem) gjennomfører vi et NFR finansiert forskningsprosjekt om kunnskapsoverføring mellom universitet- og høyskolesektoren og næringslivet, med et særskilt fokus på samarbeid på faggruppenivå.

Vi er på nåværende tidspunkt ute etter å identifisere faggrupper innen ---- som har erfaringer med å samhandle med næringsliv gjennom å

- arbeide med forskningsprosjekt finansiert helt eller delvis med midler fra næringslivet
- arbeide med prosjekter hvor det foreligger pågående eller nylig avsluttede forskningssamarbeid med private bedrifter.
- arbeide med prosjekter hvor det er konkrete erfaringer med å overføre kunnskap til næringslivet.

Vi ønsker med denne henvendelsen å få informasjon om faggrupper ved instituttet som er aktuelle for undersøkelsen. Vi vil deretter kontakte faggruppelederne via e-post.

Med vennlig hilsen
Taran Thune, stipendiat & Anne Welle-Strand, Professor/senterleder

Norwegian School of Management, BI
Dept. of leadership and organizational management
PO Box 580, 1302 Sandvika, Norway
Tel: (+47) 67 55 71 95 / Fax: (+47) 67 55 76 78
taran.thune@bi.no
www.bi.no

Letter of participation to potential respondents (In Norwegian)

Forskningsprosjekt om kunnskapsoverføring mellom universitet- og høyskolesektoren og næringslivet

Ved Handelshøyskolen BI, Center for Education Management Research (www.bi.no/cem) gjennomfører vi et forskningsprosjekt om samarbeid og kunnskapsoverføring mellom universitet- og høyskolesektoren og næringslivet.

I forbindelse med denne studien lurer vi på om du kunne tenke deg å stille til et timelangt intervju. Intervjuet vil dreie seg om dine erfaringer fra samarbeidsprosjekter med næringslivet. Informasjonen skal benyttes til å undersøke samarbeid mellom næringsliv og universitetet innen ulike fagområder. Vi har vært i kontakt med instituttleder ved Institutt for ----- som har oppgitt at du kan være en relevant person å intervjue i denne sammenhengen.

Intervjuet vil tas opp på bånd og kan gjerne gjennomføres på ditt kontor eller en annen plass du foretrekker. Intervjuerne har taushetsplikt og informasjonen vil behandles konfidensielt. Informasjon som samles av kan gjøres tilgjengelig for inspeksjon. Resultatene av studien vil bli publisert uten at den enkelte kan gjenkjennes. Etter at prosjektet er avsluttet vil opplysningene bli anonymisert. Det er frivillig å være med og du har mulighet til å trekke deg når som helst underveis, uten å måtte begrunne dette nærmere. Dersom du trekker deg vil alle innsamlede data om deg bli slettet. Studien er meldt til Personvernombudet for forskning, Norsk samfunnsvitenskapelig datatjeneste A/S.

Med vennlig hilsen
Taran Thune, stipendiat & Anne Welle-Strand, senterleder/professor

Taran Thune
Norwegian School of Management, BI
Dept. of leadership and organizational management
PO Box 580, 1302 Sandvika, Norway
Tel: (+47) 67 55 71 95 / Fax: (+47) 67 55 76 78
taran.thune@bi.no
www.bi.no

Appendix B: List of respondents in the interview study

Respondent	Subj. field	Position
1	Ec/adm	Professor
2	Ec/adm	Professor
3	Ec/adm	PhD
4	Ec/adm	PhD
5	Ec/Adm	PhD
6	Ec/Adm	Postdoc
7	Ec/Adm	Researcher
8	Ec/Adm	PhD
9	Ec/Adm	PhD
10	Ec/Adm	Professor
11	Ec/Adm	Professor
12	Ec/Adm	Professor
13	Chem/Mat	Professor
14	Chem/Mat	Post doc
15	Chem/Mat	Professor
16	Chem/Mat	Professor
17	Chem/Mat	Postdoc
18	Chem/Mat	Professor
19	Chem/Mat	Industrial R&D manager
20	Chem/Mat	Industrial R&D manager
21	Chem/Mat	Postdoc
22	Chem/Mat	Researcher
23	Chem/Mat	Researcher
24	Gen.	University manager
25	Gen	University manager
26	Gen	Industry leader
27	Gen	University leader
28	Gen	Government leader
29	Gen	University leader

Appendix C: Interview topic guide

The interview guide for the semi-structured interviews was modified to fit different groups of respondents. But all interviews focused on the same topics, but questions were not always posed in the exact same way. The topics covered in the interviews are listed in this table.

Respondent info	▪ Short background info: Education, current position, gender, prior work experience?
Project info	▪ What does the project you are involved in do? ▪ Who are involved? ▪ Who is funding the project? ▪ Other project related info - time frame, financing etc?
Preconditions and formation	▪ Why in your opinion was the project formed? ▪ What was the motivation of each party? ▪ How did it come into being? ▪ What facilitated the formation? ▪ Who facilitated the formation? ▪ Were there any previous interactions between the parties? ▪ What roles did previous relationships play?
Interaction experience	▪ How was the interaction carried out? ▪ How would you describe knowledge exchange processes in the project you have been involved in? ▪ Who participated in the interaction from the firm and university? ▪ What do they do and what are their main roles? ▪ Would you describe the people you collaborate with as "colleagues"; and if so why or why not?
Opinions about the interaction and the future	▪ Would you describe the interaction as successful? Why or why not? ▪ And what do you think about the firms' perception? ▪ In your experience, what would you say is the biggest challenge? ▪ What of the future? Do you think you will collaborate with them again? Why or why not?

Appendix D: Coding templates

Preliminary coding template (in Norwegian)

Kode	Definisjon	Navn
Prosjekt-informasjon	Faktainformasjon om samarbeidsprosjektet	P-INFO
Fagområde	fagområde/tematisk område	P-FAG
Aktivitetsområde	Industri/sektor	P-AKTIV
Aktører	Bedrifter, fagfolk, NFR, andre aktører	P-AKTØR
Finansiering	Bilateralt, NFR finansiert, etc	P-FIN
Bakgrunn	Bakgrunnen for at prosjektet ble dannet	B
Motivasjon bedrift	Grunnene til at bedriften ønsket samarbeid	B-MOTB
Motivasjon fagmiljø	Grunnene til at fagmiljø og forskerne ønsket samarbeid	B-MOTF
Kontekst	Prosjektet som en del av en større sammenheng	B-KON
Prosjektdannelse	Hvordan oppsto prosjektet? På hvilke måter ble prosjektet dannet? Skapelsesberetningen	PD
Eksisterende bånd	Eksisterende relasjoner mellom mennesker og miljøer som ble benyttet for å skape prosjektet	PD-BÅND
Direkte	Direkte relasjoner eller tidligere samarbeid. Personlig relasjon	PD-DIRB
Indirekte	Indirekte/svake kontakter, nettverk. Ikke personlig relasjon	PD-INDIRB
Sosiale	Sosiale relasjoner, vennskap, bekjentskap	PD-SOSB
Faglige	Relasjoner av faglig art	PD-FAGB
Nyskapelse	Prosjekter som blir dannet uten noen forut historie	PD-NY
Lokale	Lokale relasjoner	PD-LOK
Internasjonale	Internasjonale relasjoner	PD-INTR
Samarbeids-prosesser	Hvordan foregår samarbeidprosessen?	SP
Møteplasser	Møter og møteplasser som tas i bruk	SP-MØTE
Deltagere	Deltagere i selve samarbeidsprosessen	SP-

		DELTA
Arbeidsfordeling/roller	Hvem gjør hva? Hvilke roller har de ulike deltagerne?	SP-ARBF
Kanaler for ksk. trans	skriftlig og muntlig kommunikasjon, møter, samlok, formell og uformelle disk, og pers. deling	SP-KAN
Opplevelsen av samarbeidet	Vurdering av samarbeidet fra det deltager-perspektiv	OS
Innfridde forventninger	Innfridde samarbeidet forventningene deltagerne hadde	OS-FOR
Utfordringer	Utfordringene som samarbeidet møtte	OS-UT
Kulturkløft	Opplevelsen av kulturelle forskjeller mellom bedrifter og universiteter	OS-KUL
Tid	Tidsrammen for prosjektet, når prosjektet skal levere, tid til utvikling, kortsiktighet versus langsiktighet	OS-TID
Fokus/dybde	Dybden på problemløsningsaktivitetene, følge problemstillinger i detalj versus kortsiktig problemløsning	OS-FOK
Åpenhet	Formidlingskultur versus eierskap og beskyttelse av IP	OS-ÅP
Videreføring	Ser deltagerne for seg at samarbeidet skal videreføres, videreutvikles	OS-VID
Forklaringer av suksess/mangel på suksess	Deltagernes vurdering av hvorfor prosjektet fungerte eller ikke fungerte	FS
Interne	Forklaringer som dreier seg om det indre livet i prosjektet	FS-INT
Eksterne	Forklaringer som dreier seg om utenforliggende forhold	FS-EKST
Puzzles/surprises		?

Final list of codes (in Norwegian)

QSR N6 Full version, revision 6.0.
Licensee: Unregistered.

PROJECT: Tarans prosjekt, User Taran, 15:55, 3 May, 2006.

REPORT ON NODES FROM Tree Nodes
Depth: ALL
Restriction on coding data: NONE

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(1 2) /Base data/Subject fields
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(1 2 2) /Base data/Subject fields/Kjemi/matvit
(1 3) /Base data/Samarabeidspartner
(1 4) /Base data/Posisjon
(1 4 1) /Base data/Posisjon/Professor
(1 4 2) /Base data/Posisjon/Forsker
(1 4 3) /Base data/Posisjon/Leder
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(1 5 1) /Base data/Finansiering/NFR
(1 5 2) /Base data/Finansiering/Bilateral
(1 5 3) /Base data/Finansiering/begge
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(2 2 1 2) /Motivasjon/Motivasjon fagmiljø/Access to resources/Other resources
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(2 2 5) /Motivasjon/Motivasjon fagmiljø/Symbol for kvalitet
(2 2 6) /Motivasjon/Motivasjon fagmiljø/Arbeid til studentene
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(2 3 1) /Motivasjon/Interdependence/Ksk.intensitet bedrift
(2 3 2) /Motivasjon/Interdependence/Kjerneteknologi
(2 3 3) /Motivasjon/Interdependence/Ressursavhengighet U
(2 4) /Motivasjon/Trigget
(3) /Prosjektdannelse
(3 1) /Prosjektdannelse/Direkte bånd
(3 2) /Prosjektdannelse/Indirekte bånd
(3 3) /Prosjektdannelse/Faglige bånd
(3 3 1) /Prosjektdannelse/Faglige bånd/Tidligere prosjektsamarbeid
(3 3 2) /Prosjektdannelse/Faglige bånd/Vennskap/bekjentskap

(3 3 3) /Prosjektdannelse/Faglige bånd/Faglig renommé
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(5) /Opplevelsen av samarbeidet
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(5 2 3) /Opplevelsen av samarbeidet/Utfordringer/Tekniske og ressursproblemer
(5 3) /Opplevelsen av samarbeidet/Problemhåndtering
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(5 4) /Opplevelsen av samarbeidet/Endinger underveis
(5 4 1) /Opplevelsen av samarbeidet/Endinger underveis/Tap av kontakter
(6) /Framtiden
(6 1) /Framtiden/Videreføring
(6 2) /Framtiden/Avslutning
(6 3) /Framtiden/Uformell videreføring
(7) /Forklaringer på suksess/mangel på suksess
(7 1) /Forklaringer på suksess/mangel på suksess/Interne
(7 2) /Forklaringer på suksess/mangel på suksess/Eksterne
(8) /Forankring
(8 1) /Forankring/Konsernforankring
(8 2) /Forankring/Person/gruppe forankring

Bibliography

Adler, P. & Kwon, S.-W. (2000): ”Social capital: The good, the bad and the ugly”. Reprinted in Lesser, E.L. (ed.) (2000): *Knowledge and social capital.* Boston: Butterworth-Heinemann

Ahuja, G. (2000): “The duality of collaboration: Inducements and opportunities in the formation of interfirm linkages”. *Strategic management journal*, Vol. 21, 317-343

Allen, T. J. (1977): *Managing the flow of technology*. Cambridge, Ma: The MIT press

Almeida, P. & Kogut, B. (1999): ”Localization of knowledge and the mobility of engineers in regional networks”. *Management science*, Vol. 45, No. 7, July

Alvesson, M. & Skjöldberg, K. (2000): *Reflexive methodology. New vistas for qualitative research*. London: Sage

Amesse, F. & Cohendet, P. (2001): ”Technology transfer revisited from the perspective of the knowledge-based economy”. *Research policy*, vol. 30 pp- 1459-1478

Andersen, S. (1997): *Case studier og generalisering. Forskningsdesign og strategi*. Bergen: Fagbokforlaget

Anderson, M. S. (2001): “The complex relations between the academy and industry. Views from the literature”. *The journal of higher education*, Vol. 72, No. 2, March/April

Arora, A. & Gambardella, A. (1990): “Complimentarity and external linkage: The strategies of the large firms in biotechnology”. *Journal of industrial economics*, Vol. 38, No. 4

Baert, P. (2005): *Philosophy of the social sciences. Towards pragmatism.* Cambridge: Polity Press

Barnes, T., Pashby, I. & Gibbons, A. (2002): ”Effective university-industry interaction: A multi-case evaluation of collaborative R&D projects”. *European Management Journal*, Vol. No.

Becher, T. & Trowler, P.R. (2001): *Academic tribes and territories. Second edition.* Buckingham UK: Open University Press

Bell, D. (1976): *The coming of post-industrial society. A venture in social forecasting.* New York; Basic Books

Biglan, A. (1973): “Relationships between subject matter characteristics and the structure and output of university departments”. *Journal of applied psychology*, Vol. 57, No. 3

Blackman, C. & Segal, N. (1991): “Access to skills and knowledge: managing the relationship with higher education institutions”. *Technology analysis and strategic management*, Vol. 3, No. 3

Blumer, H. (1954): "What is wrong with social theory?" *American sociological review*, vol. 18 (1954): 3-10

Bonaccorsi, A. & Piccaluga, A. (1994): "A theoretical framework for the evaluation of university – industry relationships". *R&D Management*, Vol. 24, No. 3

Bourdieu, P. (1986): "The forms of capital". In Richardson, J. G. (ed): *Handbook of theory and research for the sociology of education.* New York: Greenwood

Bouty, I. (2000): "Interpersonal and interaction influences on informal resource exchanges between R&D researchers across organizational boundaries". *Academy of Management Journal*, Vol. 43, No. 1

Boyatzis, R. E. (1998): *Transforming qualitative information. Thematic analysis and code development.* Thousand Oaks, Ca: Sage

Bozeman, B. (2000): "Technology transfer and public policy: a review of research and theory". *Research Policy*, Vol. 29, pp. 627-655

Breschi, S., Malerba, F. & Orsenigo, L. (2000): "Technological regimes and Schumptereian patterns of innovation". *The Economic journal*, 110 (April), 388-410

Burrell, G. & Morgan, G. (1992) [1979]: *Sociological paradigms and organizational analysis*. Aldershot: Ashgate publishing

Carayannis, E.G., Alexander, J. & Ioannidis, A. (2000): "Leveraging knowledge, learning, and innovation in forming strategic government-university-industry (GUI) R&D partnerships in the US, Germany and France". *Technovation*, Vol. 20 (pp. 477-488)

Carayol, N. (2003): "Objectives, agreements and matching in science-industry collaborations: reassembling the pieces of the puzzle". In *Research Policy*, Vol. 32, (pp. 887-908)

Carlsson, B. & Stankiewicz, R. (1991): "On the nature, function and composition of technological systems". *Journal of evolutionary economics*, Vol. 1, pp. 93-118, 1991

Castells, M. (1994.): "The University System: Engine of Development in the New World Economy". In *Revitalizing Higher Education*, edited by Salmi, J. & Verspoor A. M. 1994. Oxford: Pergamon Press

Castells, M. (1996): *The Rise of The Network Society*. Volume I of The *Information Age: Economy, Society and Culture*. Oxford: Blackwell Publishers.

Chalmers, A. F. (1982): *What is this thing called science?* 2nd ed. Milton Keynes: Open University Press

Cohen, W. M. & Levinthal, D. A. (1990): "Absorptive capacity: A new perspective on learning and innovation". *Administrative science quarterly*, Vol. 35, pp. 128-152

Cohen, W. M., Nelson, R. & Walsh, J. P. (2003): ”Links and impacts: the influence of public research on industrial R&D”. In Geuna, A., Salter, A. & Steinmueller, W. E. (2003): *Science and innovation. Rethinking the rationales for funding and governance.* Cheltenham, UK: Edward Elgar

Coleman, J. S. (1990): *Foundations of social theory*. Cambridge, Ma: The Belknap Press of Harvard University Press

Cowan, R., David, P. A. & Foray, D. (2000): “The explicit economics of knowledge codification and tacitness”. *Industrial and corporate change*, Vol. 9, No.2

Crabtree, B. F. & Miller, W. J. (1999): “Using codes and code manuals. A template organizing style of interpretation”. In Crabtree, B. J. & Miller, W. L. (eds): *Doing qualitative research. Second edition.* Thousand Oaks, Ca.: Sage

Cresswell, J. D. (2003): *Research design. Qualitative, quantitative and mixed methods approaches.* Second edition. Thousand Oaks, Ca.: Sage

Crotty, M. (1998): *The foundations of social research: meaning and perspective in the research process*. London: Sage

Cyert, R. M. & Goodman, P. S. (1997): “Creating effective university-industry alliances: An organizational learning perspective”. In *Organizational dynamics*, Spring 1997

Dalen, M. (2004): *Intervju som forskningsmetode: en kvalitativ tilnærming.* Oslo: Universitetsforlaget

Dasgupta, P. & David, P. A. (1994): “Toward a new economics of science”. *Research Policy*, Vol. 23, pp. 487-521

Dearing, J. W. (1993): “Rethinking technology transfer”. *International Journal of Technology Management*. Vol. 8. Nos 6/7/8

Denzin, N. K. & Lincoln, Y.S. (1994): *Introduction: Entering the Field of Qualitative Research.* In Denzin, N. K. & Lincoln, Y.S. (eds): *Handbook of qualitative research*. Thousand Oaks, Ca: Sage

Doz, Y. L. (1996): “The evolution of cooperation in strategic alliances: Initial conditions or learning processes?” *Strategic management journal*, Vol. 17: 55-83

Doz, Y. L., Olk, P. M. & Ring, P. S. (2000): ”Formation processes of R&D consortia: Which path to take? Where does it lead?” *Strategic management journal*, Vol. 21: 239-266

Easterby-Smith, M., Thorpe, R., Lowe, A. (2002): *Management research.* London: Sage

Edquist, C. (1997): “Systems of innovation approaches – their emergence and characteristics”. In Edquist, C. (ed): *Systems of innovation. Technologies, institutions and organizations*. London: Pinter

Eisenhardt, K. (1989): ”Building theories from case study research. *The academy of management review*, Vol. 14, No. 4

Eisenhardt, K. M. & Schoonhoven, C. B. (1996): ”Resource-based view of strategic alliance formation: strategic and social effects in entrepreneurial firms”. *Organization science*, Vol. 7, No. 2

Etzkowitz, H. & Leydesdorrf, L. (1997*): Universities and the global knowledge economy*. London: Pinter

Etzkowitz, H. & Leydesdorff, L. (2000): “The dynamics of innovation: from National Systems and “Mode 2” to a Triple Helix of university-industry-government relations”. *Research Policy*, Vol. 29, 2000

Etzkowitz, H. et al (2000): “The future of the university and the university of the future: evolution of ivory tower to entrepreneurial paradigm”. *Research Policy*, Vol. 29, 2000

European Commission (2005): *Annual Innovation Policy Trends and Appraisal Report. Norway 2004-2005*. Available at: http://trendchart.cordis.lu/reports/documents/Country_Report_Norway_2005.pdf

Faulkner, W. & Senker, J. (1995): *Knowledge frontiers: Industrial innovation and public sector research in biotechnology, engineering ceramics and parallel computing.* Oxford: Clarendon Press

Freel, M. S. (2003): “Sectoral patterns of small firm innovation, networking and proximity”. *Research policy*, Vol. 32: 751-770

Fujisue, K. (1998): “Promotion of academia-industry cooperation in Japan – establishing the “law of promoting technology transfer from university to industry” in Japan”. *Technovation*, Vol. 18, Nos. 6/7

Geisler, E. (1995): “Industry – university technology cooperation: a theory of inter-organizational relationships”. *Technology analysis and strategic management*, Vol. 7, No. 2

Geisler, E. (2001): “Explaining the generation and performance of intersector technology cooperation: A survey pf the literature”. In *Technology analysis and strategic management*, Vol. 13, No. 2, 2001

Gephart, R. (1999):”Paradigms and research methods”. *Research Methods Forum*, Vol. 4, summer 1999, Academy of management, research methods division

Gibbons, M. et al (1994): *The new production of knowledge. The dynamics of science and research in contemporary society.* London: Sage

Glaser, B. & Strauss, A. (1967): *The discovery of grounded theory : strategies for qualitative research.* New York: Aldine de Gruyter

Granovetter, M. (1973):”The strength of weak ties”. *The American Journal of Sociology*, Vol. 78, No. 6: 1360-1380

Granovetter, M. (1985):”Economic action and social structure: The problem of embeddedness”. *American Journal of Sociology*, Vol. 91, No. 3: 481-510

Granovetter, M. (1992):"Problems of explanations in economic sociology". In Nohria, N. & Eccles, R. (eds.): *Networks and organizations: Structure, form and action*. Boston: Harvard Business School Press

Gulati, R. (1995): "Social structure and alliance formation patterns: A longitudinal analysis". *Administrative science quarterly*, Vol. 40, No. 4: 619-652

Gulati, R. & Gargiulo, M. (1999): "Where do interorganizational networks come from?" *The American journal of sociology*, Vol. 104, No. 5: 1439-1493

Gulbrandsen, M. & Larsen, I. M. (2000): *Forholdet mellom næringslivet og UoH sektoren – et krevende mangfold*. Rapport 7/2000: NIFU

Gulbrandsen, M. (2003): "Forskning, kunnskap og økonomisk vekst: universitetet som aktør i innovasjonssystemet". I Larsen, I. M. & Stensaker, B. (red): *Tradisjon og tilpasning. Organisering og styring av universitetene*. Oslo: Cappelen

Hansen, M. T. (1999): "The search-transfer problem: The role of weak ties in sharing knowledge across organizational subunits". *Administrative Science Quarterly*, Vol. 44: 82-111

Harmon, B. et al (1998): "Mapping the university technology transfer process". *Journal of business venturing*, Vol. 12, pp. 423-434

Hervik, A., Bræin, L. & Bergem, B. G. (2004): *Resultatmåling av brukerstyrt forskning. Anslag til samfunnsøkonomisk nytte/kostnadsanalyse av brukerstyrt FoU.* Høgskolen i Molde: Møreforskning

Johnson, B. Lorenz, E. & Lundvall, B.-Å. (2002): "Why all this fuss about codified and tacit knowledge?" *Industrial and corporate change*. Vol. 11, No. 2: 245-262

King, N. (2004): "Using templates in the thematic analysis of text". In Cassel, C. & Symon, G. (2004): *Essential guide to qualitative methods in organizational research.* London: Sage

King, N. (2005): *What is template analysis?* Available at: http://www.hud.ac.uk/hhs/research/template_analysis/whatis.htm (24.02.06)

Kirat, T. & Lung, Y. (1999): "Innovation and proximity. Territories as loci of collective learning processes" *European urban and regional studies*, Vol. 6, Nr. 1: 27-38

Kirk, J. & Miller, M. L. (1986): *Reliability and validity in qualitative research* Beverly Hills, Calif.: Sage Publications

Kvale, S, (1996): *Interviews. An introduction to qualitative research interviewing*. Thousand Oaks, Ca.: Sage

Larson, A. (1992): "Network dyads in entrepreneurial settings: a study of the governance of exchange relationships". *Administrative science quarterly*, Vol. 37, Nr. 1: 76-104

Lazzarini, S. G. & Zenger, T. R. (2002): *The strength of churning ties: a dynamic theory of interorganizational relationships.* Paper presented at the 2002 Academy of Management conference

Lesser, E. L. (2000): ”Leveraging social capital in organizations”. In Lesser, E.L. (ed.): *Knowledge and social capital.* Boston: Butterworth-Heinemann

Leydesdorff, L. & Etzkowitz, H. (2001): “The transformation of university-industry-government relations”. *Electronic Journal of Sociology*. 5, 4 [iuicode:http://www.icaap.org/iuicode?1.5.4.1]

Lieberson, S. (2000): ”Small N’s and Big Conclusions: An Examination of Reasoning in Comparative Studies Based on a Small Number of Cases”. In Gomm, R., Hammersley, M. & Foster, P. (eds). *Case study method.* London: Sage

Liebeskind, J. P.; Oliver, A. L.; Zucker, L.& Brewer, M. (1996): “Social networks, learning and flexibility: Sourcing scientific knowledge in new biotechnology firms”. *Organization science*, Vol. 7, No. 4, July-August

Lincoln, Y.S. & Guba, E.G. (2000): “Paradigmatic controversies, contradictions and emerging confluences”. In Denzin, N. K. & Lincoln, Y.S. (eds): *Handbook of qualitative research.* Thousand Oaks, Ca: Sage

Lundvall, B.-Å. (ed) (1992): *National systems of innovation. Towards a theory of innovation and interactive learning.* London: Pinter

Malerba, F. & Orsenigo, L. (2000): ”Knowledge, innovative activities and industrial evolution”. *Industrial and corporate change*. Vol. 9. No. 2: 289-314

Mansfield, E. & Lee, J. Y. (1996): “The modern university: contributor to industrial innovation and recipient of industrial R&D support”. *Research Policy*, Vol. 25, pp. 1047-1058

Mansfield, E. (1991): “Academic research and industrial innovation”. *Research Policy*, Vol. 20, pp. 1-12

Marstein, E. (2003): *The influence of stakeholder groups on organizational decision-making in public hospitals.* Norwegian School of Management, Series of Dissertations, Nr. 2 – 2003

Maxwell, J. A. (1996): *Qualitative research design. An interactive approach*. Thousand oaks, Ca.: Sage

Merton, R. K. (1968): “The Matthew effect in science”. *Science*, Vol. 159, No. 3810, Sept. 1968, pp. 56-63

Meyer-Krahmer, F. & Schmoch, U. (1998): “Science-based technologies: university-industry interactions in four fields”. *Research policy*, Vol. 27, pp. 835-851

Meyerson, E. (2000): “Human capital, social capital and compensation: The relative contribution of social contacts to managers’ incomes”. In

Lesser (2000): *Knowledge and social capital. Foundations and applications.* Boston: Butterworth-Heinmann
Miles, M. B. & Huberman, A. M. (1994): *Qualitative data analysis. An expanded sourcebook*. Second edition. Thousand Oaks, Ca.: Sage
Miotti, L. & Schwald, F. (2003): "Co-operative R&D: why and with whom? An integrated framework of analysis". *Research Policy*, 32, 1481-1499
Mjøset, L. (2005): "Can grounded theory solve the problems of its critics?" *Sosiologisk tidsskrift* [Journal of sociology]. Vol. 13, Nr. 4, 2005
Mora-Valentin, E. M. (2000): "University-industry cooperation: a framework of benefits and obstacles". In *Industry and Higher Education*, June 2000
Mora-Valentin, E. M. (2002): "Co-operative relationships. A theoretical review of co-operative relationships between firms and universities". *Science and public policy*, Vol. 29, No. 1, pp. 37-46
Mora-Valentin, E. M., Montoro-Sanches, A. & Guerras-Martin, L. A. (2004): Determining factors in the success or R&D cooperative agreements between firms and research organizations". In *Research Policy*, Vol. 33 (pp. 17-40)
Morgan, G. & Smircich, L. (1980): "The case for qualitative research". *Academy of Management Review*, Vol. 12, No. 4, 491-500
Mowery, D. C.; Nelson, R. R; Sampat, B.N. & Ziedonis, A. A. (2001): " The growth of patenting and licensing by U.S. universities: an assessment of the effects of the Bayh-Dole act of 1980". *Research policy*, Vol. 30, pp. 99-119
Nahapiet, J. & Ghosal, S. (1998): "Social capital, intellectual capital and the organizational advantage". *Academy of management review*, Vol. 23, Nr. 2: 242-266
NFR (2003): *Det norske forsknings- og innovasjonssystemet – statistikk og indikatorer. 2003*. Oslo: Norges Forskningsråd
NFR (2005a): *Det norske forsknings- og innovasjonssystemet – statistikk og indikatorer. Delrapport 1, mai 2005: FoU i universitets- og høyskolesektoren i 2003*. Oslo: Norges Forskningsråd
NFR (2005b): *Det norske forsknings- og innovasjonssystemet – statistikk og indikatorer. Delrapport 3,august 2005: FoU og innovasjon i næringslivssektoren i 2003.* Oslo: Norges Forskningsråd
NFR (2006): *Det norske forsknings- og innovasjonssystemet – statistikk og indikatorer. 2005*. Oslo: Norges Forskningsråd
NHD (2003): *Fra Ide til Verdi. Regjeringens plan for en helhetlig innovasjonspolitikk.* Oslo: Nærings- og Handelsdepartementet
NHD (2005): *Regjeringens innovasjonspolitikk. Tilstandsrapport*. Oslo: Nærings- og Handelsdepartementet
Nickols, F. W. (2000): "The knowledge in knowledge management". In Cortada, J.W. & Woods, J.A. (Eds) *The knowledge management*

yearbook 2000-2001 (pp. 12-21). Boston, MA: Butterworth-Heinemann.
Nimtz, L. E., Coscarelli, W. C. & Blair, D. (1995): "University – industry partnerships: Meeting the challenge with a high tech partner". *SRA Journal*, Fall
Nooteboom, B. (1999): "Innovation, learning and industrial organization". *Cambridge Journal of Economics*, Vol. 23, pp. 127-150
Nooteboom, B. (2002): *Learning and innovation in organizations and economies.* Oxford: Oxford University press
NOU 2000:14 *Frihet med ansvar. Om høgre utdanning og forskning i Norge*. [Freedom with responsibility. On higher education and research in Norway] Oslo: Statens forvaltningstjeneste
NOU 2000:7 *Ny giv for nyskaping. Vurdering av tiltak for økt FoU i næringslivet.* [A new start at innovation. Assessment of new measures for increasing industrial R&D] Oslo: Statens forvaltningstjeneste
NOU 2001:11 *Fra innsikt til industri. Kommersialisering av forskningsresultater ved universiteter og høgskoler.* [From insight to industry. Commercialization of research from universities and colleges] Oslo: Statens forvaltningstjeneste
OECD (1999): "Trends in university – industry research partnerships". *STI Review*, No. 23
Olaisen, J. (1991): "Plualism or positivistic trivialism: Important trends in contemporary philosophy of science". Nissen, H.-E., Klein, H. K.& Hirschheim, R. (eds): *Information systems research*: Contemporary approaches and emergent traditions. North-Holland: Elsevier Science Publishers
Oliver, C. (1990): "Determinants of interorganizational relationships: Integration and future directions". *The academy of management review*, Vol. 15, Issue 2
Ot. Prp. Nr. 67 (2001-2002): *Om lov om endringer i lov av 17. april 1970 nr. 21 om retten til oppfinnelser som er gjort av arbeidstakere.* Available at: http://www.odin.dep.no/kd/norsk/dok/regpubl/otprp/045001-050003/dok-bn.html
Ot.prp. nr. 40 (2001-2002) *Om lov om endringer i lov 12. mai 1995 nr. 22 om universiteter og høgskoler og lov 2. juli 1999 nr. 64 om helsepersonell.* Available at: http://www.odin.dep.no/kd/norsk/dok/regpubl/otprp/045001-050002/dok-bn.html
Owen-Smith, J. & Powell, W. W. (2001): "Careers and contradictions: Faculty responses to the transformation of knowledge and its uses in the life sciences". *Research in the sociology of work*, Vol. 10, pp. 109-140

Patton, M. Q. (2002): *Qualitative research & evaluation methods. 3rd edition.* Thousand Oaks: Sage

Pavitt, K. (1984): "Sectoral patterns of technical change: Towards a taxonomy and a theory". *Research policy*, Vol. 13, 343-373

Pfeffer, J. & Salancik, G. R. (1978): *The External Control of Organizations: A resource dependence perspective.* New York: Harper & Row Publishers

Polanyi (1983) [1966]: *The tacit dimension*. Reprinted by Doubleday, Gloucester Massachusetts

Polanyi, M. (1969): *Knowing and being*. London: Routledge

Porac, J. F. et al (2004): "Human capital heterogeneity, collaborative relationships, and publication patterns in a multidisciplinary scientific alliance: a comparative case study of two scientific teams". *Research Policy*, Vol. 33 (pp. 661-678)

Portes, A. (1998): "Social capital: Its origins and applications in modern sociology". *Annual Review of Sociology*, Vol. 24. Reprinted in Lesser, E.L. (ed) (2000): *Knowledge and social capital*. Boston: Butterworth-Heinemann

Powell, W.W, Koput, K. W. & Smith-Doerr, L. (1996): "Interorganizational collaboration and the locus of innovation: Networks of learning in biotechnology". *Administrative Science Quarterly*, Vol. 41, pp. 116-145

Ragin, C. (1987): *The comparative method. Moving beyond qualitative and quantitative strategies.* Berkley, Ca.: University of California Press

Ragin, C. (1992): "Casing" and the process of social inquiry". In Ragin, C.C & Becker, H. S. (eds): *What is a case. Exploring the foundations of social inquiry.* Cambridge: Cambridge university press

Ragin, C. (1994): *Constructing social research*. Thousand Oaks, Ca.: Pine Forge Press

Rappert, B., Webster, A. & Charles, D. (1999): "Making sense of diversity and reluctance: academic – industrial relations and intellectual property". *Research Policy*, Vol. 28, pp. 873 – 890

Remø, S. O. et al (2004): *Governance of the Norwegian innovation policy system. Contribution to the OECD MONIT project*. Rapport 6/2004. Oslo: NIFU STEP

Richards, L. (2005): *Handling qualitative data. A practical guide*. London: Sage

Ring, P. S. & Van de Ven, A. H. (1994): "Developmental processes of cooperative interorganizational relationships". *Academy of management review*, Vol. 19, Nr. 1: 90-118

Ring, P. S., Doz, Y. L. & Olk, P. M. (2005): "Managing Formation Processes in R&D Consortia". *California Management Review*, Summer 2005, Vol. 47 Issue 4, p137-156

Rogers, E. M. & Bhowmik, D. K. (1970): "Homophily-Hetrophily: Relational concepts for communication research". *The Public opinion quarterly*, Vol. 34, No. 4: 523-538

Rogers, E. M. (2003) [1980]: *Diffusion of innovations*. 5th Edition. New York: The Free Press

Rubin, H. & Rubin, I. (1995): *Qualitative interviewing. The art of hearing data.* Thousand Oaks, Ca.: Sage

Sahal, D. (1981): "Alternative conceptions of technology". *Research policy*, Vol. 10: 2-24

Sandefur, R. L. & Laumann, E. O. (1988): "A paradigm for social capital". *Rationality and society*, vol. 10, No. 4: 481-501. Reprinted in Lesser, E.L. (ed) (2000): *Knowledge and social capital*. Boston: Butterworth-Heinemann

Santoro, M. D. (2000): "Success breeds success: the linkage between relationship intensity and tangible outcomes in university – industry collaborative ventures". *The journal of high technology management research*, Vol. 11, No. 2

Santoro, M. D. & Chakrabarti, A. K. (2002): "Firm size and technology centrality in industry – university interactions". *Research Policy*, Vol. 31, pp. 1-18

Santoro, M. D. & Gopalakrishnan, S. (2000): "The institutionalization of knowledge transfer activities within industry – university collaborative ventures". *Journal of engineering and technology management*, Vol. 17, pp. 299-319

Saxenian, A. L. (1994): *Regional advantage*. Boston: Harvard University Press

Schartinger, D.; Rammer, C.; Fischer, M.M & Fröhlich, J. (2002): "Knowledge interactions between universities and industry in Austria: sectoral patterns and determinants". *Research Policy*, Vol. 31, pp. 303-328

Schofield, J. W. (2002): "Increasing the generalizability of qualitative research". Huberman, A. M. & Miles, M. B. (2002): *The qualitative researcher's companion*. Thousand Oaks, Ca.: Sage

Seale, C. (1999): *The quality of qualitative research*. London: Sage

Shrum, W., Chompalov, I. & Genuth, J. (2001): "Trust, conflict and performance in scientific collaborations". In *Social studies of science*, Vol. 31, No. 5

Silverman, D. (2000): *Doing qualitative research. A practical handbook.* London: Sage

Simonin, B.L. (1999): "Ambiguity and the process of knowledge transfer in strategic alliances". *Strategic management journa*l, Vol. 20, pp. 595-623

Slaughter, S. & Leslie, L. (1997): *Academic capitalism*. Baltimore: Johns Hopkins University Press

Slaughter, S. & Rhoades, G. (2004): *Academic capitalism and the new economy*. Baltimore: The Johs Hopkins University Press

Smeby, J.-C. (2001): *Kunnskapens kognitive og sosiale strukturer. En teoretisk og empirisk studie av fagforskjeller ved universitetene.* Rapport 8/2001. Oslo: NIFU

St. Meld. Nr. 39 (1998-1999): *Forskning ved et tidsskille* [Research at the beginning of a new era] (White paper)

St. Meld No. 27 (2001-2002): *Gjør din plikt – Krev din rett. Kvalitetsreform av høyere utdanning* [Do your duty demand your rights. Quality reform of higher education (White paper)

St. Meld. Nr. 20 (2004-2005): *Vilje til Forskning* [Commitment to research]. (White paper)

Stake, R. E. (2000): "The case study methodology in social inquiry". In Gomm, R., Hammersley, M. & Foster, P. (eds). *Case study method.* London: Sage

Stehr, N. (1994): *Knowledge societies*. London: Sage

Strauss, A. & Corbin, J. (1998): *Basics of qualitative research. Techniques and procedures for developing grounded theory. Second edition*. Thousand Oaks, Ca.: Sage

Szulanski, G. (2000): "The process of knowledge transfer: A diachronic analysis of stickiness". *Organizational behavior and human decision processes*. Vol. 82, No. 1: 9-27

Tashakkori, A. & Teddlie, C. (1998): *Mixed methodology: combining qualitative and quantitative approaches*. Thousand Oaks, CA: Sage

Tashakkori, A. & Teddlie, C. (eds) (2003): *Handbook of mixed methods in social & behavioral research.* Thousand Oaks, CA: Sage

Teece, D. J. (1986): "Profiting from technological innovation: implications for integration, collaboration, licensing and public policy". *Research Policy*, Vol. 15, 285-305

Teknologibedriftens Landsforening (2004): *TBLs FoU- og innovasjonsrapport 2004*. Oslo: TBL

Uzzi, B. (1996): "The sources and consequences of embeddedness for the economic performance of organizations: The network effect". *American sociological review*, Vol. 61, No. 4: 674-698

Uzzi, B. (1997): "Social structure and competition in interfirm networks: the paradox of embeddedness". *Administrative science quarterly*, Vol. 42, No.1: 35-67

Vedovello, C. (1997): "Firms' R&D activity and intensity of the university – enterprise partnership". *Technological forecasting and social change*, Vol. 58, pp. 215-226

Von Hipple, E. (1994): "Sticky information" and the locus of problem solving: Implications for innovation". *Management Science*, Vol. 40, No. 4, April 1994

Waagø, S. J. et al (2001): *The role of the university in economic development.* Trondheim: NTNU

Walton, J. (1992): "Making the theoretical case". In Ragin, C.C & Becker, H. S. (eds): *What is a case. Exploring the foundations of social inquiry.* Cambridge: Cambridge university press

Winter, S. (1987): "Knowledge and competence as strategic assets". In Teece, D. (ed): *The Competitive Challenge – Strategies for Industrial Innovation and Renewal.* Cambridge, MA.: Ballinger

Yin, R. K. (1994): *Case study research. Design and methods*. 2nd edition. Thousand Oaks: Sage

Zander, U. & Kogut, B. (1995): "Knowledge and the speed of the transfer and imitation of organizational capabilities: An empirical test". *Organization science*, Vol. 6, No. 1, Jan-Feb 1995

Web resources

- European commission The European Trend Chart on Innovation website: Country page Norway. Available at: http://trendchart.cordis.lu/tc_country_list.cfm?ID=14
- NIFU STEP R&D statistics. Available at: http://www.nifustep.no/norsk/innhold/statistikk/fou_statistikkbanken
- Norwegian research and innovation system statistics (NFR). Available at: http://www.forskningsradet.no/servlet/ContentServer?cid=1113847748963&pagename=ProgNett%2FPage%2FHovedSide&pageid=1113847748963&siteid=1113847729138
- Soria Moria declaration (government platform). Available at: http://odin.dep.no/filarkiv/260512/regjeringsplatform.pdf
- Template analysis resource pages: http://www.hud.ac.uk/hhs/research/template_analysis/whatis.htm