Research Collaboration and Knowledge Transfer in University-Industry Links

An empirical study of research collaboration and knowledge transfer between the University of Bergen and industrial companies

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Thesis for the Master of Technology Management Programme
NTNU, NHH, MIT Sloan

Master of Technology Management

Acknowledgement

This study has been conducted on commission of, and with support from, my employer, the University of Bergen. The University wanted to gain more systematic knowledge about its contact with industry in the Bergen area. As I am working as a Deputy Director for research and strategy at the Faculty of Mathematics and Natural sciences, it was therefore a natural choice to select the theme about university-industry links for this final master thesis at the Master of Technology Management Programme (MTM). This thesis would, however, not have been accomplished without the help of many persons who deserves my gratitude.

First of all I want to thank Kjell A. Sælen, the Director of the Faculty of Mathematics and Natural Sciences, and my supportive leader for many years. I will also thank Kristen Haugland, the Director of the Research Department at University of Bergen. Without their immediate (and economic) goodwill I would most probably never have had the courage to apply for admission to the MTM Programme. Secondly, I want to thank my supervisor Tor Fredriksen, Head of department at the Department of Strategy and Management at The Norwegian School of Economics and Business Administration. Tor has been an enthusiastic and instructive supervisor and without him gently pushing me, this final thesis would perhaps never have been completed in my busy everyday life. Also Tove Krokstad and Frode Heldal at the MTM administration have been most service minded and supportive. My local mentor and supervisor professor and Vice Dean, Geir Anton Johansen has provided me with help and for valuable discussions on the topic. My friends, and colleagues, lecturer Åshild Lunde and professor Rein Aasland have been helpful with advice on language and how to structure the document. It was certainly needed and is most appreciated. I will also thank all the 16 friendly respondents for sharing their valuable experience and time. For me the interviews were both a pleasure and a lot of learning. Finally, I must thank my dear family; my husband Amund Måge and my children Synve Elisabeth and Sindre Johannes. They were (almost) always understanding and supportive although I have been constant behind my computer the last couple of months. Amund has also at any time been ready to help me, both as a discussion partner and as a constructive critic. We are now looking forward to what’s left of the skiing season this year…..

Bergen, 26.03 2008

Randi Elisabeth Taxt

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List of abbreviations

BTO	Bergen Technology Transfer Office AS
ILO	Industrial Liaison Officer
ILP	Industrial Liaison Programme
IP	Intellectual Property
IPR	Intellectual Property Rights
IS	Innovation System
LRD	K.U. Leuven Research & Development
MIT	Massachusetts Institute of Technology
NIFU STEP	Studies in Innovation, Research and Education
NRC	The Norwegian Research Council
NTNU	Norwegian University of Science and Technology
OCR	Office of Corporate Relations
PDMA	Product Development and Management Association
PRO	Public Research Organisation
R&D	Research and Development
SME	Small and Medium Enterprise
SMES	Small and Medium Enterprises
UiB	University of Bergen
UIL	University-Industry Links

‘What's most important for us is that Harvard stays great and get even greater.
If Harvard succeeds in doing that, we will be fine’

Mayor Thomas Menino of Boston, US (2004)

1 Introduction

1.1 Background

Innovation[1] is closely linked to the human urge to always seek new and more efficient ways of doing things. In terms of national economies both innovation and productivity are shown to be influenced by the characters and learning processes between producers, users, suppliers and public authorities (Porter, 1998). In the, past policies to foster innovation were inspired by linear innovation models with focus on passive diffusion of science and technology into industrial firms. More recently, the policy is influenced by 'best practice models' of interactive innovation derived from high tech- and well performing regions (Dodgson, Gann and Salter, 2002). The innovative capacity is however not uniformly or randomly dispersed in geography. The more knowledge-intensive the economic activity, the more geographically clustered it tends to be (Asheim and Gertler, 2005). It is observed that creating and maintaining various forms of industry-science relations positively affects innovation performance, especially in terms of knowledge transfer (Agrawal, 2001). Universities are in this respect widely cited to play an important role as a source of new knowledge and they constitute a prominent part of the overall national and regional innovation systems (Lundvall and Johnson 1994, Nelson 1993; Etkowtiz and Leydesdorff 1997).

A wide variety of relation mechanisms, knowledge transfer and other interactions for academy and industry exists, with systematic differences between industrial sectors and scientific disciplines (Cohen, Nelson and Walsh, 2002). University-industry links[2], and the impact they have on innovation has, for a long time, been an object of research in management, economics and organisational sciences. Further extensive studies on the mechanisms and distribution of patents, licensing and graduate mobility have been conducted in order to measure the results and output of research based innovation. Recently, focus has

[1] In this thesis the term innovation is used for product innovations as well as process innovations. Product innovations are new – or better – material goods as well as new intangible services. Process innovations are new ways of producing goods and services. They may be technological or organisational (Edquist, 2005).

[2] The term university-industry links (UIL) are used to include all types of links between public research organisations (PRO's) and industry. PRO's are defined as research organisations that are funded mainly by government, i.e. universities, public research laboratories, research institutes etc. (Perkman and Walsh, 2006).

shifted to research topics associated with more non-explicit, or tacit, knowledge[3]. How the industrial companies get in contact with the relevant academic institutions and individual researchers, how they actually interact and collaborate with each other and how they gain and utilise knowledge from each other is, however, under-researched and remain unclear in many respects (Agrawal 2001; Perkman and Welsh, 2007).

The University of Bergen (UiB) is the third largest university of Norway and is expected to play an important role as a generator of new knowledge for the society. The University of Bergen recognises this role and states in its *Strategic Plan* for 2005 – 2010[4]:

'Long-term high-quality basic research leads to commercially viable ideas, the establishment of knowledge enterprises and the transfer of competence to established businesses. Cooperation with the business sector will increase the University's access to external research funds, give researchers new perspectives on their research and increase the competence and competitiveness of the businesses involved.'

To promote research based innovation, University of Bergen is also planning to, according to the *Strategic Plan*, strengthen subject areas with a potential for commercial development and improve long-term institutional collaboration. Further the University of Bergen wants to exploit the opportunities in the areas of activity affiliated with its academic communities and serve as a driving force in regional development, interact with knowledge-intensive industry and form long-term alliances with the business sector.

The University of Bergen has a clear goal of being a well renowned research university and is emphasising the need for academic freedom within their social responsibilities, as formulated in the *Strategic plan* (2005):

'The basic research, research-based teaching and the development of academic disciplines are among the university's most important tasks. The freedom to engage in knowledge-based and critical

[3] As described by Michael Polanyi (1956), tacit knowledge is knowledge that people carry in their minds. Often, people are not aware of the knowledge they possess or how it can be valuable to others and it can therefore be difficult to access. Tacit knowledge is considered important because it provides a context for creating new ideas and sharing experiences. Effective transfer of tacit knowledge generally requires extensive personal contact and trust (more about tacit knowledge in section 2.3.).

[4] http://regler.uib.no/regelsamling/show.do?id=130

elucidation of important areas and problems in our society is crucial to its existence. […]. Academic freedom will be used to generate research and provide first-rate education and to make a socially useful and relevant contribution to the advancement of knowledge. Our modern society is more research-based than ever before. Consequently, we are increasingly dependent on research and knowledge and the universities have a much greater societal responsibility than might be apparent from the general debate about these institutions.'

In 2005, the University of Bergen did, together with six other research institutions in Bergen, establish Bergen Technology Transfer AS (BTO)[5], for facilitating commercialisation of research in the Bergen area. In addition, several other companies are established in connection with the University of Bergen, like Sarsia Innovation[6], Innovest AS[7] and Forinnova AS. All these companies are set up to find, develop and finance research-based concepts to create businesses and research based commercialisation processes.

There are, however, indications that the Bergen, and its surrounding region, has rather week interactions between research institutions and local enterprises (Fredriksen and Grønhaug, 1996; Berrefjord, Thomassen and Dinesen, 2005; Vatne, 2008). This includes the University of Bergen, which is sometimes said to be indistinct, and perhaps even uninterested, when it comes to contacts with local industries, service companies and public organisations (Isaksen, 2005, Tessem, 2006). A question of whether this could affect the Bergen Region's ability to develop into a knowledge-based and innovative region has been put forward. A political desire to facilitate the innovative capacity of the City of Bergen and the University of Bergen is however expressed (Berrefjord, Thomassen and Dinesen, 2005; Bergen Chamber of Commerce, 2006 and 2008; Grønmo. Bergsvik and Haaland, 2006; Grønmo, 2006).

The Faculty of mathematics and natural sciences at the University of Bergen is the faculty at the University with the most extensive external funding and contact with industry. While knowledge about public funding sources like The Research Council of Norway and The European Research Programmes is good at a faculty level, awareness of potential private contributors is more limited. In this respect the faculty has stated a goal to increase the contacting surfaces with surrounding industry and in this respect it is required to gain more

[5] http://www.bergento.no/
[6] http://www.sarsia.com/
[7] http://www.innovest.no/

knowledge about how scientists collaborate with local industrial partners (The Faculty of Mathematics and Natural Sciences, 2005; Johansen, 2007).

1.2 Purpose of the study

Although university-industry contacts involving patents, commercialisation and human mobility are well studied, the actual mechanisms of contact patterns and knowledge transfer within the industry-academy border are under-researched. More research is therefore wanted on this field (Agrawal, 2001; Fagerberg; Mowery and Nelson, 2005). Links and relations between universities and industrial companies are good targets for investigating the role of universities in regional innovation systems. This study aims to gain a deeper knowledge in the features of collaborating patterns, knowledge transfer and the type of research conducted in university-industry links. The study further aims to shed light on the University of Bergen, and especially the Faculty of Mathematics and Natural sciences, as a source of new knowledge for the neighbouring society.

1.3 Questions to be addressed

Within the purpose of the study the following questions will be addressed:

1. How do university researchers and their industrial partners collaborate within the university-industry links?

2. How does the knowledge transfer take place between university researchers and their industrial partners?

3. Can any novel results and/or spin offs[8] from the university-industry links be identified?

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[8] A spin-off is a new, or improved, product formed unintentionally as a result of a production or research process, or an organisation or entity formed by a split from a larger one, or as a new company formed from a university research group or business incubator (wikipedia.com, The PDMA Glossary for New Product Development: http://www.pdma.org/library/glossary.html

1.4 Disposition of the thesis

This thesis has the following disposition:

Chapter 1 contains the introduction, the background of the study and research questions stated.

Chapter 2 contains an overview of the theoretical context considered relevant for the questions addressed. Theories about tacit knowledge, as explained by Polanyi (1956) and Nonaka and Takechu (1995), are used to discuss the mechanisms of knowledge transfer. Donald Stokes book, *The Pasteur's Quadrant* is further used as a background for the discussions about the role of research in research-based innovation. Some other important studies and aspects considered relevant for the questions addressed and discussion of the results, is also given in this chapter.

In chapter 3, The Method, premises for the choice of the qualitative approach, and the criteria for selection of data sources, is presented.

Chapter 4 presents the results of the study. In this chapter the results and findings are grouped according to the questions of the interview guide. The results are illustrated by an extensive use of quotes from the respondents.

In chapter 5 the main findings are discussed in light of the theories chosen and of other relevant research within the field. This chapter also contains some practical examples relevant for the discussion.

Chapter 6 summarises and concludes the main findings in order to address the questions set up in section 1.3. In addition some aspects about the study, method and results are discussed. Finally possibilities for further studies are suggested.

In the end of the thesis the references are listed. The guide used in the interviews, and the form used for reporting key information about the projects, are presented in an appendix (in Norwegian).

2 Theoretical Context and Previous Research

Innovation related processes are thoroughly described in research, in fields of studies like management, economics of innovation and organisation. In these studies patents and commercialisation processes has been commonly studied, describing the role of universities, and other public research organisations, in innovation systems. Recently, however, the relevance of inter-organisational and social networks for innovation processes are more and more rooted in the knowledge creation as a more socially embedded process.

The questions addressed in section 1.3 cover two main areas of research: ‘knowledge transfer’ and ‘the role of research in innovation’. Two known theories were therefore chosen as most relevant for this study. The theory of tacit knowledge, as first described by Polanyi (1956), and further brought into the realm of corporate innovation by Nonaka and Takechu (1995), was considered very useful for explaining mechanisms behind knowledge transfer within university–industry links. The second theory was developed by Donald E. Stokes in his book *Pasteur’s Quadrant* (1997) and is relevant for discussing the role of (basic) research in research-based innovation.

These two theories will be supplemented by relevant research within the field. Status and research on various forms of university-industry links and different kinds of channels for knowledge transfer are outlined in section 2.1.2 and the geography of innovation is shortly reviewed in section 2.5.

This chapter starts, however, with defining the innovation and innovation systems.

2.1 Defining innovation

The role of innovation in economic and social changes has recently been more highlighted and the research in the field has proliferated. This is especially the case within the social sciences and business research. The term innovation is commonly used both for product innovations as well as for process innovations. Product innovations are defined as new – or better – material goods or new intangible services. Process innovations are new ways of producing goods and services, technological or organisational (Edquist, 2005). An important distinction must be made between inventions and innovations. As pointed out by Fagerberg (2005), invention is the first occurrence of an idea for a new a product or a process, while innovation is the first attempt to carry it into practice. Whether an innovation is considered successful depends considerably on market need. Sometimes inventions and innovations are closely linked, sometimes there are years, maybe decades, of time lag between them (Rogers, 1995). While inventions can be carried out anywhere and by anyone, innovations usually take place within firms, larger organisations and within certain geographical regions (Fagerberg 2005; Svedeberg 1991). In order to transform an invention to an innovation a company, or a public enterprise or the organisation needs many types of knowledge's, skills and capabilities. Very often these capabilities are found outside the organisation itself (Teece, Pisano and Shuen, 1997; Edquist, 2005; Asheim and Gertler, 2005). The innovation process is therefore complex and is depending on many factors working simultaneously, commonly termed an *innovation system (IS)*. An *innovation system* is defined as all important economic, social, political organisational, institutional and other factors that together influence the development, diffusion and use of innovation (Edquist, 1997).

A product or process innovation is termed *discontinuous*, or *disruptive*, if an innovation changes the marked totally and establishes new consumption patterns that previously not existed. Examples include microwave ovens and the cellular phones. A new product, or process, that that significantly changes behaviours and consumption patterns in the marketplace are usually called a *radical innovation*. Radical innovations are generally involving new technologies. An innovation that improves a product or a process, but produces neither a behaviour change, nor a change in consumption patterns, is called an *incremental innovation*. (Utterbach, 1994; PDMA, 2008).

2.2 The role of research in innovation

Many studies show that public research organisations play an important role as a source of fundamental knowledge, skilled personnel and technological inventions in most systems of innovation (Cohen, Nelson and Walsh; 2002, Edquist, 2005; Mowery and Sampat, 2005). This thesis discusses the role of universities in innovation systems with emphasis on the role of research, research capabilities and knowledge transfer. Many theories and models are set up trying to explain innovation, innovation systems and the role of (basic) research in these systems. In the following sections of this chapter the two most relevant theories chosen for this thesis will be briefly outlined.

However, first the term research and revelopment (R&D), and the different types of research activities covered by this term, are defined.

2.2.1 Defining Research and Development

According to the widely used - and cited - *Frascati Manual* provided by the OECD (2002) the term research and development (R&D) are defined as follows:

"Research and experimental development (R&D) comprise creative work undertaken on a systematic basis in order to increase the stock of knowledge, including knowledge of man, culture and society, and the use of this stock of knowledge to devise new applications.'

The *Frascati Manual* further states that the term *Research and Development* covers three activities: *basic research*, *applied research* and *experimental development*:

"*Basic research* is experimental or theoretical work undertaken primarily to acquire new knowledge of the underlying foundation of phenomena and observable facts, without any particular application or use in view. *Applied research* is also original investigation undertaken in order to acquire new knowledge. It is, however, directed primarily towards a specific practical aim or objective. *Experimental development* is systematic work, drawing on existing knowledge gained from research and/or practical experience, which is directed to producing new materials, products or devices, to installing new processes, systems and services, or to improving substantially those already produced or installed. R&D covers both formal R&D in R&D units and informal or occasional R&D in other units.'

In this thesis the definitions of the different research activities as stated in the *Frascati Manual* are the used. But, as further outlined in this chapter, these definitions are perhaps too limited in order to explain the activities and mechanisms for research collaborations within the university-industry links. Additional frameworks are therefore needed to explain the role of research in innovation.

2.2.2 The Mode 1 and 2 concept and the Triple Helix Model

A known conceptual framework that has been used to explain the role of academic research in the industrial society is the Mode 2 term put forth in 1994 by Michael Gibbons and his colleagues in the book *The new production of knowledge: the dynamics of science and research in contemporary societies*. In this book, devoted to explore changes in the mode of knowledge production in contemporary societies, it was argued that a more interdisciplinary, pluralistic and networked innovation system has evolved in the last part of the 20th century. This was in contrast to the previous system which was an academic and purely investigator-initiated knowledge production, by Gibbons termed the Mode 1. Mode 1 was explained as highly discipline based and did carry a clear distinction between basic and applied research. Mode 2, on the other hand, was described as generated within the context of application and it was interdisciplinary. According to Gibbons the Mode 2 concept did evolve from Mode 1 and do exists continuously alongside it. The knowledge in the Mode 2 concept was described to be, in many respects, linked to the humans involved rather than thorough codified knowledge. Practical skills and tacit knowledge was therefore considered highly valued. Above all, success was defined very differently in Mode 2 than in Mode 1. Usefulness and efficiency was considered important in Mode 2 in contrast to the more traditional ones of scientific excellence, like peer review evaluations, in Mode 1 (Nowotny, Scott and Gibbons, 2001).

Another conceptual framework for analyzing the role of universities and public research, and especially within national innovation systems, is *The Triple Helix Model,* introduced by Etzkowitz and Leydesdorff in 1997. The model stated that the university can play an enhanced role in innovation in increasingly knowledge-based societies by taken on entrepreneurial tasks. The Triple Helix metaphor did refer to the dynamic interaction between the government, academia and industry to explain innovation, the development of new technology and knowledge transfer. Etzkowitz and Leydesdorff stated further - in a follow up article from 2000 - that the common objective of the model was to realise an innovative environment consisting of university spin-off firms, different initiatives for knowledge-based economic development, and strategic alliances among various types of firms, government laboratories, and academic research groups. According to Etzkowitz and Leydesdorff these arrangements were often encouraged, but not controlled by government, whether through new instruments, incitements, direct or indirect financial assistance.

2.2.3 Pasteur’s Quadrant

An important framework being frequently used to explain the role of basic research in innovation is the one Donald E. Stokes introduced in his book *Pasteur’s Quadrant* in 1997. This theoretical framework will be the one used as a foundation for further discussion of the results and the questions addressed in section 1.3.

Donald E. Stokes, at the time dean of the Woodrow Wilson School of Public and International Affairs at Princeton University, wrote a book providing a provocative new way of looking at the relationship between science and technology. The main purpose of the book was to analyse, criticise, and eventually rethink the linear model of the relationship between science and technology that was put forward by Vannevar Bush in his famous report *Science, the Endless Frontier* (Bush, 1945). Bush, as the director of the Office of Scientific Research and Development in US President Truman’s administration, was late in the World War II asked to prepare a report on the role of science in peacetime. This report became a major influence on science policy in the post-World War II period - not only in the US - but in the whole global research community. Bush's produced a linear model of science and technology which was based on two fundamental postulates:

1. Basic research is performed without thought of practical needs or ends
2. Basic research is the pacemaker of technological progress.

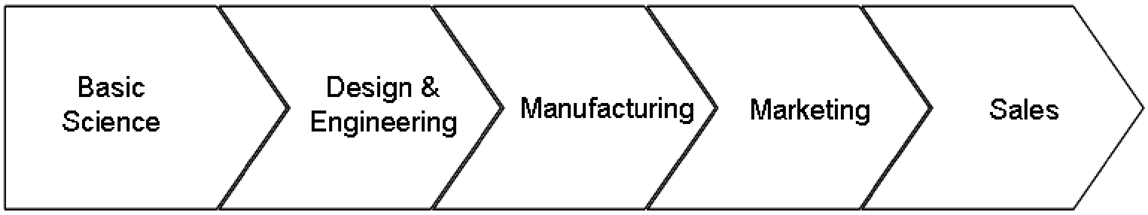

Figure 1. The linear model of innovation according to V. Bush, The Science Push Mode (Dodgson, 2002). Source: Prof. K. Lakhani, Harvard Business School.

According to Bush, large investment in basic research would - as a direct consequence - in the end inevitably filter down into industrial applications and also finally sale (see Figure 1). In this respect the Bush’ model of innovation did, in many ways, resemble the Mode 1 concept (se section 2.2.2).

Bush's linear model influenced the way people viewed the relationship between science and technology for fifty years. Stokes, on the other hand, argued that the rationale behind Bush's linear model arose from the classical ideal of knowledge for its own sake, which had been institutionalised in American and European universities. He claimed further that Bush's model did not reflect the actual practice of science and technology in society in the post-cold war period, where most of the basic research was done with applications in mind. Stokes believed now it was time to rethink the Bush' model.

Stokes did - in his book – pay particular attention to the work of Louis Pasteur (1822-1895). Louis Pasteur was a 19th-century biologist and chemist whose work in microbiology opened up several new scientific fields important for industries ranging from wine to silk. According to Stokes, Pasteur's research within microbiology was both basic and applied at the same time. Stokes postulated further that Pasteur's work was not possible to explain within the context of Bush linear model, where basic research was placed at one end and applications at the other (see Figure 1.) Pasteur's research, being both basic and applied at the same time, would rather have to be represented by two locations on the line, one close to the basic end and one close to the applied end. In this way Stokes was transforming Bush's one-dimensional model into a two-dimensional and more dynamic model, which much better described the type of research activity done by Pasteur (see Figure 2).

Quest for fundamental understanding	Yes	Pure Basic Research (Bohr)	Use Inspired Basic Research (Pasteur)
	No		Pure Applied Research (Edison)
		No	Yes
		Consideration of use	

Figure 2. Types of Research according to Stokes

In Stokes model four types of quadrants were set up and the relations between them described (see Figure 2). Niels Bohr (1885-1962), working with the understanding of atomic structure and quantum mechanics, was used as an example of pure basic and curiosity driven research with no particular use in mind (upper left quadrant). Stokes was then using Pasteur as an example of use inspired basic research (upper right quadrant). The lower-right quadrant represented applied research that had not focus on a quest for fundamental understanding, such as the work done by Thomas Alva Edison Edison (1847-1931). The lower-left quadrant was not empty, but represented pure descriptive studies like taxonomy, i.e. bird watching. According to Stokes such studies could be a precursor of research in the other quadrants. Stokes indicated that research based innovations usually takes place in Pasteur's quadrant, and to some degree in Edison's, quadrant. Stokes stated further that Pasteur's quadrant deserved more attention from both the research and policy communities and this framework is now widely used to explain the role of research in research based technological innovation (Price and Behrens, 2003; Tushman and O'Reilly, 2007).

There are many good examples of important research that can be understood by Pasteur's' quadrant. As a result of collaboration between basic research scientists at Harvard and DuPont, a project investigating the role of genes in cancer served as foundation for ongoing scientific discovery and translation, innovation and economic growth within the field of cancer therapies. The Harvard Oncomouse was thus a dramatic example of a dual discovery explained by Pasteur's Quadrant (Murray 2006; Hanahan, Wagner and Palmiter, 2007). Another remarkable example is the two rivalling consortia which almost simultaneously published rough draft sequences of the human genome in 2001 (Lander et al., 2001; Venter et al., 2001). This process involved complex collaborative networks consisting of many academic institutions and industrial firms. Strikingly collaborative patterns were also found between rivals, both among companies and academic institutions (Powell and Grodal, 2005).

Although the immediate role of basic sciences is most prominent in innovation processes in disciplines' such as biotechnology, pharmaceuticals and perhaps computer science, it has been shown that the role of basic research is also very important in other sciences (Cohen, Nelson and Walsh 2002). The effect on industrial sciences in disciplines such as physics and mathematics may, however, were often expressed through applied sciences and engineering fields suggesting a considerable time lag between basic research, novel discoveries, inventions and the industrial innovation process (Cohen, Nelson and Walsh 2002; Mowery and Sampat 2005).

Stokes was an important critics of Bush' linear model, but generally most models explaining innovation are now gradually moving towards more open and network based view of innovation (Dodgson, Gann and Salter, 2002). This is explained by the fact that companies to a lesser extent can afford to rely entirely on their own research. Instead they must collaborate more intensively with public research institutions and they are buying, or licensing, processes or inventions (i.e. patents) from other companies (Dodgson, Gann and Salter, 2002, Powell and Grodal, 2005). In contrast, closed innovation refers to processes that limit the use of internal knowledge within a company and make little or no use of external knowledge (Christensen, Olesen and Kjær, 2005). In the 21st century, an even more open collaborating model is emerging, based on distributed networks. This model describes how knowledge, creativity, learning and communication can be sources of innovation. New ways of communication and problem solving are occurring across organisational borders both within firms and between firms and research institutions. Furthermore, Dodgson and his colleagues describe that innovation and research and development strategies in this realm are better formulated and implemented within firms. In addition, firms move from investments in research and development to what is called 'connect and develop' and finally; the number of actors investing in research and development is increasing. In this landscape companies carry out their innovations by collaborating with outside partners, from whom they learn, transfer or in-source components of the new knowledge. As mentioned above, collaborative patterns are also found between rivals, both among companies and academic institutions in such distributed networks (Lakhani, 2006).This inter-organisational cooperation and networking has been referred to as distributed innovation (Coombes and Metcalfe, 2000; Huston and Sakkab, 2006; Lakhani, 2006).

2.3 Knowledge Transfer - Explicit and Tacit

As mentioned earlier the role of knowledge transfer is very central to the innovation processes and a central topic in this thesis. An important distinction is drawn between explicit and tacit knowledge (Cowan, David and Foray, 2000). Explicit knowledge is defined as highly codified and is expressed through blueprints, manuals, recipes, scientific publications etc. In contrast tacit knowledge lacks such codification. Michael Polanyi (1891-1976), a known scientist and philosopher formulated the concept that human beings frequently know a good deal more than we can express verbally (Polanyi, 1956). In literature this is usually expressed by Polanyi's famous words, 'We know more than we can tell.' He termed this phase of knowing as *tacit knowledge*. Tacit knowledge comprises a range of conceptual and sensory information and images that can be brought to bear in an attempt to make sense of something. The fact that we use our senses and images when we pass on this kind of knowledge, contributes to the conclusion that much knowledge is passed on by non-explicit means. Apprenticeship in terms of observing a master, and then practicing under the master's guidance, is often used as a good example on how to pass on tacit knowledge effectively. Nonaka and Takeuchi was perhaps the first who brought the concept of tacit knowledge into the realm of corporate innovation in their famous book *The Knowledge Creating Company* (1995). The two researchers cited the example of Mitsushita's development of the Home Bakery (the world's first fully automated bread-baking machine for home use) on how tacit knowledge can be converted to explicit knowledge. The designers couldn't perfect the dough kneading mechanism in the machine. Then a software programmer apprenticed herself with the master baker at Osaka International Hotel and then gained a tacit understanding of kneading. Finally, she conveyed this information to the engineers.

The example stated above illustrates the embedded nature of tacit knowledge, often referred to as 'sticky' and many studies point out the relatively ease of transferring explicit knowledge in contrast to tacit knowledge. Codified knowledge is easily dispersed at a low cost but the likelihood that such knowledge would lead to innovation is lower (Von Hippel, 1998). The increasing focus on topics associated with tacit knowledge transfer in the literature suggest that this is a central issue in terms of the firms ability to utilise university channels of knowledge effectively (for a review see Agrawal, 2001 and Powell and Grodal, 2005). Tacit knowledge is frequently associated with a firm's *absorptive capacity*, first introduced by Cohen and Levinthal (1990) and confirmed by Cockburn and Henderson in 1998. The term is now prevalent throughout the knowledge transfer literature and refers to a firm's ability to recognise, assimilate and apply new scientific information for its innovation and new product development. It is, however, important to bear in mind that when the knowledge become too 'sticky' the degree of difficulty and the cost of transfer is high. The greatest value may be derived when knowledge and novel ideas are transmitted without too much difficulty (Powell and Grodal, 2005).

2.4 University-industry links

As mentioned earlier, collaboration across organisational boundaries has become more commonplace in innovation systems in order to pool or exchange knowledge, skills and other resources. In fields where the scientific or technological progress is developing rapidly, no single firms have the capabilities to stay on top of all areas necessary in order to bring significant innovations to the market (Powell and Grodal, 2005). Research and development is no exception and in every sector an increased reliance on external sources of research and development, notably from universities, consortia and government labs, has been observed globally (OECD, 2002). This shift from closed to more open innovation systems has further resulted in various attempts to describe and characterise the links between academic communities and industrial firms. An overview of types and features of such links, along with a review of different channels of knowledge transfer within these links, are presented below.

2.4.1 Types and features of links between universities and industry

Pavitt (2005) has, in his work on innovation processes, managed to extract the most typical characteristics of university industry links emerging from the literature and - according to his study - there are three common features of university-industry links:

1. The importance of personal and often informal contacts
2. A university research activity that is useful to industrials is often valued by academics and a high proportion of industrially significant research is publicly funded.
3. The practical benefits of most university research emerge from processes that are roundabout and indirect, often carried out by graduates trained by leading researchers.

Perkman and Walsh (2007) have, on their side, supplemented this with a comprehensive survey of peer reviewed empirical articles where they have identified the most common types of university-industry links seen in innovation systems. Perkman and Walsh have presented these various types in a recent review article and they are listed in Table 1 below.

Table 1. The nature of various types of university-industry links according to Perkman and Walsh (2007)

Research partnerships	Inter-organisational arrangements with the objective to pursue collaborative R&D (most often co-funded by public sources).
Research services	Activities commissioned by industrial clients including contract research and consulting.
Academic entrepreneurship	Development and commercial exploitation of technologies pursued by academic inventors through a company they (partly) own.
Human resource transfer	Multi-context learning mechanisms such as training of industry employees, postgraduate training in industry, graduate trainees and secondments to industry, adjunct faculty.
Networks	Formation of social relationships and networks at conferences, etc.
Commercialisation of property rights	Transfer of PRO-generated intellectual property (such as patents) to firms, e.g. via licensing.
Scientific publications	Use of codified scientific knowledge within industry.

According to Perkman and Walsh (2007) research partnerships, such as joint ventures and public funded user oriented research, are defined as activities that are characterised by a high degree of complementarities between their academic and industrial applicability. This means that output from the collaborative projects can be used freely or modified for academic papers. The industrial partners do benefit from the collaboration, but usually steers clear of negotiating the actual scope of the research. Research services such as contract research and academic consulting are, on the other hand, undertaken by academic researchers under the direction of industrial clients and tend to be less exploitable for academic publications. Activities within these two types of university-industry links are however often classified differently by institutions and will often be practiced simultaneously.

Although several additional frameworks have been suggested in order to conceptualise the different kind of links between public research organisations, such as universities and industries (see Perkman and Walsh, 2007, for an overview). Common to all these frameworks, however, is their inability to grasp the socialised relations such as learning and transfer of non-codified, or tacit, knowledge. Wenger (2000) did define the social learning as a process that facilitates the sharing and creation of knowledge through, and within, social relationships such as groups of individuals and across organisations. As described above in section (2.3), tacit knowledge, and other forms of socialised relations and learning, have been shown to be important for the innovation processes and closely related to a firm's *absorptive capacity*. The ability to share, and transform, knowledge is conducted through various channels where most are classified as tacit. The next section will give an overview of the various types of channels for knowledge transfer within the university-industry links, and their impact.

2.4.2 Channels of knowledge transfer

Many studies have been conducted in order to explore the characteristics of different channels through which knowledge is transferred from public research organisations such as universities to industry (Agrawal 2001; Cohen, Nelson and Walsh, 2002; Cockburn and Henderson 1998; Agrawal and Henderson, 2002). The channels under consideration in these studies include generally some subset of publications, patents, consulting, informal meetings, recruiting, licensing, research partnerships and other forms of joint ventures, research contracts and personal exchange. Common to all these studies are that the channels considered to be most important for the industry are, with exception of consulting, those often associated with open science such as publications, conferences and personal contact. In this respect publications and reports are being the most dominant (Cohen, Nelson and Walsh, 2002). Furthermore these channels are rather decentralised in nature and do not reflect typical formal institutional links.

Different kinds of industries of value the various channels differently. Cohen and his colleagues (2002) found that almost a third of industrial projects made use of research findings from public research and over a fifth made use of instruments and techniques. Schartinger et al (2002) showed that technical sciences and manufacturing industries intensive in research and development, tend to use direct research cooperation, while service industries and social and economic sciences rest more on personal mobility and training related interactions. By analysing patent and paper collaborations Agrawal and Henderson (2002) found that those firms which take advantage of patented innovations rarely are those taking advantage of published knowledge and that biotechnological and pharmaceutical industries are shown to have gained important advantages from patents and licence agreements in contrast to other industries. Biotechnology is also shown to draw more directly from basic research (Cockburn and Henderson, 1998). However, respondents from this industry still rated research publications and conferences as more important sources of information (Cohen, Nelson and Walsh, 2002). Within this context it is, however, important to mention that the direct impact of public research on innovation processes has been shown to less important than sources of knowledge lying more directly in the vertical chain of production and sale, including suppliers, buyers, users and the firms own manufacturing operations (Cohen, Nelson and Walsh, 2002; von Hippel 2005).

Research on university-industry links has traditionally focussed on the quantitative studies on the transfer of intellectual property rights, often termed IPR or just IP[9]. Recent studies, however, show a more multifaceted nature of links and relations between industry and universities, and the relevant importance of other knowledge channels have been highlighted (Agrawal, 2001, Cohen et al., 1998 and 2002). A consensus is emerging in the literature that patents are only moderately important for the innovation process, and that relationship-based mechanisms are exceeding them in terms of relevance (Agrawal, 2001, Fagerberg, Mowery and Nelson, 2005, Perkman and Walsh, 2007). Recent research further suggest that firms with a more open strategy for their research and development collaborations will tend to benefit more from university research (Chesbrough, 2006; Laursen and Salter, 2004; Lakhani, 2006).

[9] The term ‘intellectual property’ (IP) or ‘intellectual property rights’ (IPR) is a legal field that covers creations of the mind such as musical, literary, and artistic works; inventions, patents, copyrights, trademarks and database rights etc. The term intellectual property (IP) is sometimes used as something separate from intellectual property rights (IPR). In such cases, the term IP means the (abstract) product of the intellect and the term IPR means a legal right covering IP. The term IP is also used to denote things for which no explicit legal right is provided. An invention can be protected by a patent. An original work of authorship is protected by copyright. A distinctive product name can be registered as a trademark. But for instance, a domain name or a trade secret can be considered IP but there is no separate legal right to protect these. Hence they cannot be called IPR. Sources: *Wikipedia* and *Ius Mentis – Law and technology explained*

2.5 The geography of innovation

A growing body of studies argues that a geographical area with success in terms of innovation and economic growth depends increasingly upon its ability to produce new and improved products or processes. In this innovation-based value creation, it is further claimed that tacit knowledge is the most important element (Lundvall and Johnson, 1994; Agrawal, 2001; Asheim and Gertler, 2005). When everyone has relatively good access to explicit knowledge, the creation of unique capabilities and products depends on the production and use of tacit knowledge (Asheim and Gertler, 2005). The skills required for effective knowledge transfer is interactive and collective and takes place across organisational borders. The actors thus need to have a shared understanding of local codes and social learning on which collective tacit as well as embedded codified knowledge is based (Lam, 2000). In this pattern of knowledge sharing spatial proximity is the key. Further the 'sticky' nature of tacit knowledge and complex social assets is believed to be an important explanation why successful regions and innovation systems such as the *Route 128 Biotechnology cluster* in the Boston area, *Silicon Valley* in Cakifornia and *Baden-Würtberg's regional networked innovation system* in Germany are so difficult to imitate by others (Asheim and Gertler, 2005).

As mentioned in the introduction, universities are widely cited to play an important role as a source of new knowledge and constitute a prominent part of the overall national and regional innovation systems (Lundvall and Johnson, 1994; Etkowtiz and Leydesdorff 1997). Within research intensive industries, such as biotechnology, it has been shown that the formation-rate of research-based start-up companies is higher in the regions where defined *star scientists*[10] live and work (Zucker and Darby, 1996, Agrawal, 2001). These star scientists were found both within the companies and at public research organisations, and a high degree of co-publication was registered between them. These studied thus confirmed the work of Cohen and Levinthal (1994) on absorptive capacity and showed that knowledge intensive companies, with open research collaboration within the company, increase the innovation capacity of local innovation system (Agrawal 2001; Asheim and Gertler. 2005).

[10] "Star Scientists' are defined as highly productive scientists in terms of publications, citations and other results valued by the academic society (Agrawal, 2001).

In this chapter the innovation processes and innovation systems have been defined according to recent literature. Furthermore the role of research, and especially basic research, in innovation processes has been illustrated in the realm of Stokes book *Pasteur's Quadrant* (1997). The knowledge transfer between universities and industries are believed to be of a highly socialised nature and tacit knowledge, as explained by Polanyi (1956), is exceeding explicit knowledge as important for innovation processes. Furthermore a firm's innovation capacity depends on its absorptive capacity. The skills required for effective knowledge transfer are interactive and collective and takes place across organisational borders. The embedded and 'sticky' nature of tacit knowledge and social assets is believed to be an important explanation why some regions are more successful in innovation than others and why they are so difficult to copy.

3 Method

Universities are regarded to be important sources of new knowledge into all kinds of businesses, industries and public organisations. The empirical part of the study will, in the following two chapters, deal with methods and results. The results will finally be analysed and discussed in terms of knowledge transfer and the role of basic research in innovation processes.

3.1 Choice of method

The first step in the choice of method was to find out whether a quantitative or a qualitative approach was most suitable in order to answer the research questions.

According to Grønmo (2004) there are four different aspects that distinguish qualitative and quantitative studies:

- Analytical descriptions versus static generalisations
- Flexibility versus structure
- Proximity and sensitivity versus distance and selectivity
- Relevance versus precision

A questionnaire distribution was considered as a research option because it could cover the entire population of industrial funded research projects at the faculty. Such a method would in gain valuable information about the existing contact points with industry in a structural manner. In other words, a questionnaire is a good tool for generalisation. An important aspect of this thesis was to investigate knowledge transfer between researchers at the university and their industrial partners. Knowledge transfer within innovation systems is, according to the chosen theory of Polanyi and Takechu and Nonanka, described to be of an embedded and ‘sticky’ nature and difficult to transfer directly. Further, channels for knowledge transfer between universities and industries are classified as tacit or non-codified (see section 2.4.2). Another questions stated in this study was whether basic research, as described by Stokes (1997), is important in the research partnerships. The definition of basic versus applied and developmental research is by no means clear and can be understood differently by individuals. An analytical and descriptive approach would, in this respect, be a better method in order to grasp individual experiences, describing the knowledge transfer within the research partnerships, collaboration patterns and the role of basic research. In addition an important motivation for this study was to gain new knowledge about university-industry links, both at an organisational level for the University of Bergen and at a personal level for the author working within the field. Proximity to the data sources was therefore desirable. This proximity would in turn secure certain sensitivity towards the data sources in order to follow up with additional questions about definitions (i.e. basic research), actions; interactions events and reflections etc. Flexibility during the data collection was in this manner required. A quantitative approach with a questionnaire was therefore considered too static and superficial for the research questions and theoretical framework stated in this study. A typical method for qualitative studies is the use of semi structured interviews. According to Kvale (1996), the research interview is a conversation that has a structure and a purpose. The questions are not predefined, but a scheme or a guide for the interview is normally used. Semi structured interviews was therefore chosen as a method for the empirical part of the study. In the interview guide, however, a small quantitative element was included when the respondents were asked to rank the most important channels for knowledge transfer (see also section 3.3). This was considered adequate in order to discuss the results within the context of the important work of Cohen and his colleagues (2002) on the influence of public research on industrial research and development.

3.2 Selection of projects and respondents

This study investigates university-industry links at the Faculty of Mathematics and Natural Sciences at The University of Bergen and their industrial partners. The study aims to shed light on knowledge transfer, collaboration patterns and nature of research conducted within stated projects. In innovation systems university-industry links are important as well as in service industries, public organisations and technological companies, but in this study industrial companies within science and technology were chosen as targets for the investigation. This was mainly done to limit the selection, but also because these kinds of companies were considered most relevant for the research activities at the Faculty of Mathematics and Natural Sciences.

Research project co-financed by private companies was considered a suitable framework for identifying appropriate respondents[11] for the study. A list with all the private research projects at the faculty was therefore extracted from the university's economy system. In addition, all departments at the faculty were asked to give information about user-driven research projects funded by the Research Council of Norway. These projects are required to have one or more companies in the consortium and are considered important for funding university-industry links in Norway (The Research Council of Norway, 2006). The following criteria were then used to select the research projects most suitable for identifying respondents able to elucidate the research questions:

- The project had to be at least half way through the project period assuring the respondents had enough relevant experience from work within university-industry links
- The project should have a formal contract
- The project should preferably have an industrial partner localised in the Bergen area

Relevant projects were selected based on the criteria above. In addition some of the projects were chosen based on suggestions from the University department leaders. It was aimed to reflect the scientific discipline presented at the faculty and different types of industrial partners in the final selection of projects.

Ten projects were selected based on the criteria above. Collaboration patterns and mechanisms for knowledge transfer are important questions in this study. Respondents from both the University of Bergen and from the industrial partners were picked from each project. Scientific experience was an additional important criterion for selecting the respondents from the university and they were - in all cases - identical with the project leader. In most cases the respondents were asked by telephone whether they would participate in the project. Respondents from the university were always contacted first. They did in turn suggest possible respondents from the industrial partner. In most cases these industrial respondents were persons working within research anddevelopment, not directors or other managers.

[11] In this context the term respondent is used as a data source responding to certain questions and this response will shape the data collected. Respondents can be asked about meanings, actions, events, reflections etc. (Grønmo, 2004).

Respondents from the industry were sometimes contacted by the author – along with a recommendation from the university respondent - sometimes by the university-respondent's themselves. All the respondents were e-mailed information about the project (see Appendix I) and they were guaranteed full confidentiality. A final approval of participation in the study was done in agreement with both the project leader from the university and the industrial partner. Three of the projects were, based on a total assessment, not considered adequate for the study. Of the ten projects initially chosen, a selection of seven projects was therefore set up as a basis for data collection.

3.3 The interview situation

Two interviews were conducted for each project. In order to get important and relevant information an additional interview was conducted for two of the projects. From the seven projects a total of 16 semi-structured interviews were conducted and used as data sources for the empirical part of the study.

According to Kvale (1996) the research interviews is not a conversation between equal partners because the researcher defines and controls the situation. The author of this thesis is deputy director for research and strategy at the faculty and has knowledge about external funding, research strategy and external collaboration. This could, in theory, create a tension in the interview situation where the respondents could perceive the interview rather as an inquiry than a research interview. It was therefore important for the author to seek the respondents in their own environment and to assure full anonymity. All, but one, interviews were conducted as a personal conversation and lasted from one to two hours. One interview was done by phone. For non-Norwegian speaking respondents the interviews were done in English. A guide for the interview was used. This interview guide was centred on the research questions formulated in section 1.3 (see Appendix II), but not seen by the respondents. The interview guide contained the following key questions:

1) How was the contact patterns and research collaboration in the project?
2) What type of research was conducted in the project?
3) Was formal competence, like master- and PhD-degrees, of any significance for the work conducted and results achieved in the project?
4) Where there any novel results or spin offs from the project?

Question 2 was formulated mainly based on the Frascati-definition of research outlined in section 2.2.1, *basic-*, *applied-* and *experimental and developmental research,* but with the limitations described. The respondents were given these definitions during the interview. In question 4, the respondents were asked to grade the results from the project on a scale from fundamental or disruptive innovation in one end to incremental in the other end of the scale as defined in section 2.1.

The respondents were during the interview, asked to rank the five most important channels for knowledge transfer based on a list out of ten (see Appendix II): personal contact, scientific publications, open meetings, contract research, consulting, research partnerships, change of personnel, patents, licensing, new candidates from universities. Two of the respondents needed some time to think this trough and did send their ranks by e-mail after completion of the interview.

The respondents were in addition asked to list their most positive and negative experience from the project. In the end of the interview all of the respondents were, based on a general experience from possible other collaboration projects, asked to give some advice to the Bergen area on how to become a knowledge-based and highly innovative region.

The interviewer was mostly passive moderating the respondents through the interview and deliberately not stating any own opinions when questioning. It was, however, considered important to go through all the key questions in the interview guide. When something particularly interesting came up, some carefully probing to deepen the topic were conducted. Extensive notes were taken during the interviews and the interviewer was particularly aware of writing down quotes correctly. The project leaders were also asked to give some background information about the project by filling out a form before the interview. This information was not a direct part of the survey, but a tool for better understanding the scope; content and size of each project (see Appendix III).

3.4 Processing the data material

When completing the interviews, the most important quotes and regards from the respondents were put in a matrix. The main questions from the interview guide and the individual respondents constituted the columns and the rows in the matrix respectively. Horizontal analyses of respondent were made in addition to a vertical analysis were the respondents were compared against each other in a more thematic manner as according to Thagaard (2002). The respondents from the university and from the industry were distinguished during analysis of the collected data material. This distinction is, when considered prominent, reflected in the presentation of the results. All of the companies, projects and respondents are made anonymous. The quotes are therefore sometimes altered in order to ensure this anonymity. The quotes are also translated from Norwegian to English when necessary. All the individual ranks from 1-5 of the different channels for knowledge transfer were summarised in a table which again was the foundation for Figure 3, shown in section 4.3.1.

4 Results

In the following chapter the results from the study are presented. The results are grouped according to the main questions from the guide used during the interview, which in turn were set up to reflect the research questions stated in section 1.3. Interviews were conducted both with respondents from the university and from the industry. These are, when reported separately, hereafter abbreviated university-respondents and industry-respondents respectively.

4.1 The Projects – an overview

Different kind of research projects at the University of Bergen were chosen in order to study the university-industry links more throughout. The emphasis in the investigation has been the interactions between researchers at the university and their industrial partners. In addition the type of research conducted in the projects was studied and the importance of different channels for information and knowledge transfer were analysed. An overview of the seven research projects are given in Table 2 below. All the project leaders from the university were renowned professors within their field.

Table 2. Distribution of the seven projects in the study according to field of research and type of industrial partner.

Field of Research	Academic entrepreneurial companies	Entrepreneurial companies (SME**)	Large corporations	Total
Technology	1	1		2
Life Science	1		1	2
Petroleum*			3	3
Total	2	1	4	7

* Geological, geophysics and mathematical disciplines represented from UiB in the different projects
** Small and medium enteprises

4.2 Contact patterns and research collaboration

This part deals with the question 1-4 (as formulated above in section 3.3) which includes contact patterns, type of research, significance of formal competence and whether novel results and spin-offs emerged from the projects.

4.2.1 Initial contact

Early in the interview the question was asked on how the contact between the university researchers and the industrial partners was initiated in the project. All the respondents reported that they knew each other long before the initial contact for the projects were established. In all cases the initial contact was a result of an existing network typically based on former students, PhD candidates, or as a result of their own professional network. In most projects the industry-respondents were responsible for the initial contact. It must, however, be stated that in the academic entrepreneurships the university-respondents did, in periods, have positions both places. In the cases where the university-respondents were responsible for the initial contact, the projects were within life science.

One of the respondents illustrated the importance of network for imitating projects:

`We have a problem we need to solve and we have resources in our company. We want excellent competence and we know where the good scientists are. It’s all about network.`

Many of the industry-respondents did however complain about the university being passive in promoting themselves as partners in industrial collaboration:

`We have always had a very good relationship with the university, but they have never taken any initiative towards us. The university should be more active and invite to collaborate on an institutional level.`

Another industry-respondent stated:

`The academics are a bit secluded and they do rarely make contact. The research community should be more visible. We have to carry the problems to the researchers.`

4.2.2 Motivations for formalisation of contact

The formalisation of the initial contact into a final contract were by most of the respondents explained as a result of funding opportunities, either from the Research Council of Norway or from the companies themselves. Many of the respondents highlighted the importance of having a formalised contract for the research partnership and in most cases the contract was signed few months after the initial contact.

One of the university-respondents formulated the reason for getting a contract this way:

```
You must have contacts in order to get projects. In the company we
know three persons very well. They have scientific background
themselves and control the money.
```

Many of the respondents reported that good relationships and trust was important in order to close a final contract. From the industry-respondents the chance of getting in contact with experts on their field was highlighted as important:

```
From the industry it is important to get access to persons who have
focus and who has the time and knowledge to analyse the problems. We
see the researchers as a resource which can work intensively and
dedicated and has the freedom to follow the ideas.
```

Many of the university-respondents highlighted that freedom to approach the problem in an unrestricted manner also was an important motivation for finally closing the contract:

```
We have freedom from our collaborating partner – a freedom to do
what you want and go beyond the project description. This freedom
enables us to follow the problems arising during the project.
```

With few exceptions all of the respondents reported they were in contact with their partners also after the research project were completed.

4.2.3 Type of research

Most of the respondents reported that although the problems stated in the project were of applied character, an important part of the research performed was basic research. All of the projects had master- and PhD-theses included. Some of the respondents underscored that data collected from the experiments could be used as foundation for future basic research.

Some of the university-respondents put it this way:

`The problems to be addressed were applied, but the research conducted was basic and did go directly to the heart of the research conducted in our group.`

`There is a lot of basic research, but with the aim of getting a product to the market. In developing the method and algorithms we do basic research, but when we develop the prototype we do applied research.`

`We get ideas for further research through the collaboration with the company. In turn we use these ideas and apply for funding from the Norwegian Research Council.`

The industry-respondents reported that the research included elements of basic research, but the problems to be addressed were of either applied or developmental character:

`The research was applied, but we did some new things not documented before.`

`There were elements of basic research, but the research conducted was applied.`

`The research done in the company is applied, but the one conducted by our partners at the university is pure basic research.`

4.2.4 Formal competence

Most of the persons working on the research projects had a master- or PhD-degree. Some of the projects did also have technical staff engaged. Many of the respondents reported that the projects were suited for master thesis, for student summer jobs or short-time project contracts. Furthermore many of the projects had PhDs doing most of the actual research, often funded by the Norwegian Research Council. All of the respondents highlighted the importance of a scientific background in order to understand the problems and develop adequate methods and equipments. Two of the industry-respondents put it this way consecutively:

`Scientific background and formal competence is beyond doubt important for the project. It is important for the creativity, the development and the implementation of the project. Finally it is important for the ability to grab the opportunities.`

`You have to be able to write and present your data to colleagues and partners. In other words you must know the discipline.`

One of the university-respondents formulated the necessity of formal competence this way:

`The level of knowledge is very high. You need to have extensive disciplinary expertise and skills. You must be certified for the job.`

4.2.5 Results and spin-offs

Most of the respondents reported that the results from the project were radical in the meaning it could change the way of doing things within a certain field; technology, etc. (see definitions in section 2.2.1 and how these were presented for the respondents in section 3.3). Some of the respondents reported on rather fundamental, or disruptive, results and products which eventually could alter a whole industry. Many of the respondents added, however, that the impact of their results was depending on developments within the market constraint.

Many of the respondents reported spin-offs from the projects, several in form of new companies others in form of alternative fields of utilisation of the products.

Some of the respondents reported that the project was meaningful to work with:

> You are given the opportunity to do your best and at the same time given the opportunity to disseminate your knowledge and skills to the community. This is perhaps the most enjoyable project I have ever done!

Most of the respondents did tell that the project had increased their professional network. From the industry-respondents the response was rather clear:

> The project has contributed to a larger professional network for me, especially with the scientific community and with international expertise within the field. Also other companies are interested in the results.

> I have established a broad contact with various companies. It is not only domestic companies, but also international companies of high quality and public organisations. The projects include lots of travel for me.

Also the university-respondents reported on an increased network, especially with the industry. Some of them were however a bit reluctant as to whether the project actually increased their scientific network.

4.3 Channels for knowledge transfer

This sections reports results from the part of the interview where the respondent's were asked to range the five most important channels for knowledge transfer based on a list of 10 different channels (se the questions listed in section 3.1). The respondents were also asked to give their reasons for ranking the two most important channels.

4.3.1 The importance of the different channels

All of the respondents were, during the interview, asked to rank five of the most important channels for knowledge transfer. Figure 2 shows how the different channels were ranked by the university-respondents and industry-respondents respectively.

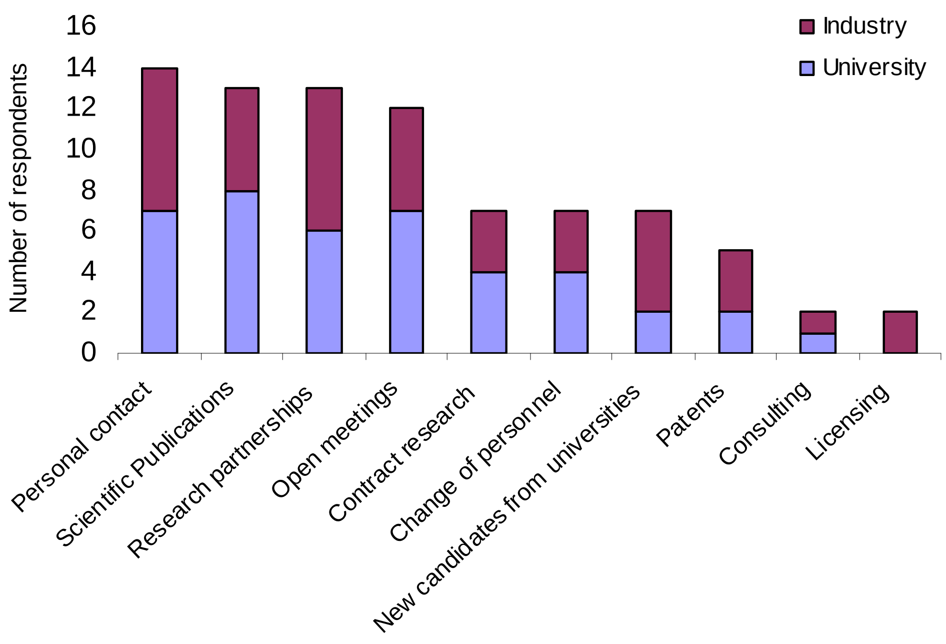

Figure 2. Different channels for knowledge transfer ranked by the respondents from the university and industry.

As shown in Figure 2 informal contact and scientific publications are ranked as the most important channels for knowledge transfer. Many of the respondents also listed research partnerships, in terms of project collaboration, and open meetings as important. Patents, consulting and licensing were considered less important as channels for knowledge transfer. No major differences between the university-respondents and industry-respondents can be drawn from the collected data material.

In the following some interesting observations about the most important channels for knowledge transfer are referred.

4.3.2 Personal contact

Personal contact was considered very important by close to all of the respondents. Many of the respondents did say it was important to know the persons with whom they collaborated. They highlighted conditions such as the importance of a close dialogue, of trust and of frequent communication with their partners. Some of the respondents claimed that without knowing their partners for many years the project wouldn't be realised.

`It is crucial for our collaboration that we trust each other. It takes time to build trust.`

`Our competence is tightly woven into each other when we carry out the project. Frequent contact is therefore important and necessary.`

`Strong ties between the company and the research group at the university is crucial. We need discussions on a daily basis.`

`Informal contact is necessary and in this case the long time relationship gave us the most effective impact and contacting surfaces with the company.`

`You need a comprehensive contact with your partners in order to detect congruent field of interest. Within these fields you are able to approach the novel problems.`

`You must know the people you work with. You avoid misunderstandings, you can be more direct in your dialogue and you do not need to explain all the time.`

4.3.3 Scientific publications

Many of the respondents highlighted scientific publications as a very important channel for knowledge transfer. In this respect predominance from the university-respondents can be vaguely perceived based on the interviews.

Also many of the industry-respondents reported that scientific publications had considerable significance:

`The production from the PhDs in the project gives us insight about the project in a structural way. When we are asked to give comments on drafts it gives us valuable information about the scientific problems and about the experiments conducted. We must actively contribute with our knowledge and the scientific publications are in this way produced in tight collaboration with the researchers.`

`The publications from our collaborative scientific communities at the universities give us a special insight into the field which we are working.`

For the university-respondents, the freedom to publish without restriction was prominent and by many stated that this was very important for their contact with industry:

`Everything is public; the company does not put any restrictions on publications. No secrets.`

4.3.4 Research partnerships

A certain level of formality was highlighted as important by most of the respondents. Without economical resources or commitment to a contract, the collaboration was reported likely to become without liability. Research partnerships were therefore considered as a crucial channel for knowledge transfer:

`Without any research partnerships, there would be no significant contact.`

Research partnerships are important. Without any money, no results would emerge.

The research partnerships frame the collaboration, also when it comes to economy.

In order to get the collaboration in the project working, we are depended on a formalised contract. We need get access to equipment, personnel and other necessities.

4.3.5 Open meetings

Open meetings in the form of conferences, work shops etc. were by many of the respondents reported as an important channel for knowledge transfer. Most of the projects had open work shops several times a year, where all the persons working on the project came together, sharing theirs results, their experience and their problems. In this way the work shops functioned as meeting point where the partners share their knowledge and solve problems. Open meetings and work shops were by most of the respondents clearly distinguished from the more formal project meetings where progress, economy and other administrative issues were on the agenda. The project meetings did often include corporate leaders, department leaders or other managers and the scientific problems were not discussed in detail. These meetings were therefore considered limitary in scientific knowledge transfer.

4.3.6 Human resource transfer

Quite many of the respondents reported that human resource transfer such as personnel exchange and new candidates from the university had a notable effect on the knowledge transfer. Most of the projects included master and PhD students, which were regarded as crucial for the scientific progress in the project. In many cases candidates from the university got jobs in the company after completion of their thesis. Consequently these candidates in turn became responsible for much of the contact with the university. One of the industry-respondents supervising master students explained his experience with human mobility this way:

We are supervising master students. At first I did this as a favour of my former supervisor at the university, thinking by myself it would be a lot of work with little in return for me. However these master students are quite useful. They make me check important details I otherwise would have missed. This is in turn increasing my own knowledge.

4.4 Experiences

In the end of the interview the respondents were asked to bring about some of their most important experiences from the project, both positive and negative.

4.4.1 Positive experiences

Most of the respondents did highlight the project collaboration as a very positive experience. A vast majority of the respondents, both from the university and industry, highlighted a good relationship with their collaborative partners as the most positive factor in the partnership.

We have had an excellent atmosphere in this project. No confrontations and good results.

Our collaborative partners from the university were very flexible. The project did evolve over time and everybody handled changes in scope and demands very well. We did trust each other and the atmosphere was very good.

The collaboration with the company was beyond doubt the most valued quality factor in this project. Without their goodwill this project would have been impossible to work through. They posses a degree of far-seeing and tolerance you rarely meet at the university.

Some of them also mentioned that geographical proximity affected the teamwork in a positive way, as illustrated by this quote:

The project has been accomplished in a very contented way. Very good people are working on the project and the relationships are excellent. We are localised on the same floor in the same building and are able to solve conflicts at an early stage. Everybody has been willing to bend down in discussions in order to find the best solution for the project.

Some of the respondents' also highlighted freedom to publish, and other forms of academic freedom, as the most positive experience. See also section 4.2.2 on this topic.

4.4.2 Negative experiences

The respondents divided themselves into two distinct groups when they were asked to highlight the most negative experiences in the project collaboration: 'Cultural differences' and 'Problems with patenting and commercialisation'.

4.4.2.1 Cultural differences

Some of the respondents reported that when pressure for deliverables started to build up in the project, the cultural differences started to emerge. For a distinct group of respondents this was reported as the most challenging factor in the collaboration. From the industry-respondents the academic culture and the university as an unstructured partner was pointed out as particularly problematic as illustrated by the following quotes:

When approaching important deadlines in the project, a lot of work emerged and we experienced problems getting deliverables from the university on time. Sometimes we really wondered whether the university did realise their contractual obligations. Most probably the anticipation was vague from the beginning. The project did also grow during the project period and the project leader at the university had a vast work load.

You have to hire an employee to take care of each professor. They live in their own world where deadlines don't exist. It is totally unimportant for them in their everyday life. Science and technology is important for them, but the market's needs seem unimportant.

There were two departments from the university involved in the project. The university was not coordinated internally and acted like two different organisations. This was especially difficult in order to plan and prioritise resources, equipment and personnel in an effective way when doing experiments.

We did have some argument about data and openness of such; even this was regulated by contract. The university must in the future be aware of their role as a contract partner and ensure all the persons dedicated to the project know their rights and limitations. This was not the case in this particular project and individuals were allowed to act as they had no responsibility towards the contract.

In addition the industry-respondents did express, to a certain degree, concerns about the foundation of the projects internally in their own company. An especially concern was expressed on how company managers did lack an understanding about the importance of research partnerships and the need for long term funding of such. This concern can be illustrated by quotes from the following two industry-respondents:

The understanding of a throughout and independent review of the problems is not very prominent internally. The problems are simplified and the importance of research underestimated. This situation should be improved.

Every year I have to fight for funding of the project internally in the company.

The respondents from the university were concerned about the total work load in the project and how this reduced their possibility to do their own curiosity-driven basic research:

This was a prestigious project for the company. Promises about freedom to follow the problems arising during the project was forgotten as the pressure build up for deliverables. The project was very time consuming for me and our contract partners showed little understanding for the academic culture. I will not do this again – there was not enough in it for me……

The publications from the projects are not of high academic impact and the project is time consuming leaving less time doing my own research. It is important to balance time between contract research and curiosity-driven basic research.

Some of the respondents from the university did also express some concern about the capacity at the university of handling projects with certain demands for deliveries:

It was a great pressure. A capacity problem emerged and an acute shortage of competence and personnel occurred. The university is not built for this.

4.4.2.2 Patenting and Commercialisation

Many of the university-respondents did report that they early in the project phase had turned to central offices at the University of Bergen, to Bergen Technology Transfer Office (BTO) or other companies within the supportive apparatus, for help and service in getting their results patented or commercialised. The university-respondents were not satisfied with the kind of help they received during this process. It was even claimed that the involvement of the university either had delayed the project or given competitors unnecessary advantages. Here expressed by some of the respondents:

We did send an application for a patent on our discovery to the university, but we never received an answer. We then contacted BTO resulting in the University of Bergen as an organisation waiving all rights to Intellectual Property. Finally we put an invitation for a tender and our present industrial partner responded. They are now responsible for filing the patent. This delay, caused by the University of Bergen, did give our closest competitor an opportunity to publish results before us; publications which in turn weakened our rights to the novel discovery.

The Research Department at the University of Bergen did send us to Forinnova AS in order to commercialise our prototype, but Forinnova failed completely in their effort to help us. The result is that

Forinnova now owns 1/3 of the shares in the company without giving us anything in return.
We did initially contact BTO for help, but they judged the project as strange and irrelevant. Now, when patenting and licensing are mentioned, they are interested. I consider this attitude odd related to BTO's stated mission.

Also the industry-respondents reported on significant problems concerning patenting and commercialisation:

We were very inexperienced and were caught in all traps possible along the path for commercialise our product. There have been a number of embarrassing meetings with possible interested parties both nationally and internationally. We had also meetings with the supportive apparatus for commercialisation in the Bergen region like Sarsia, BTO and Iris in order to get help and support. But they are highly unprofessional and do not by any means understand what we need. Their bureaucratic procedures will kill all initiatives from research based commercialisation. We do not want to have anything to do with them.

4.5 General advice from the respondents to the Bergen region

The respondents were finally asked what kind of general advice they would give to the Bergen region on how to promote more research-based innovation. A vast majority of the respondents - both from the industry and from the university - were clear in their feedback that the Bergen region were lacking relevant meeting places where representatives from the various industries, commerce, public sector and academic society could meet. Most of the respondents were also very clear in their advice to the University of Bergen that it should become more visible in the community and market its candidates and research more offensively:

The university has never taken any initiative. They should become more visible and invite the industry to collaborative projects.

UiB should market their PhD-candidates in a more offensive way. Academics should be more visible and should be perceived as useful by the society. We (the academics) are not fully integrated in the society. We should be more open and visible. In this way the society will eventually value basic research as important and necessary.

The university has to be more visible and recognise its responsibility for creating arenas where university scientists and representatives from the industry can meet. Few companies make use of research in their developmental processes. Even fewer are willing to pay for university R&D. This makes the industries isolated, fragmented and afraid of healthy competition. The companies conceal their discoveries from each other preventing useful knowledge transfer. Norway as a nation is loosing on this strategy.

A portal for the research activity in the Bergen area should be set up.

Another important piece of advice from many of the respondents was towards investors and venture capital firms working towards businesses and research institutions in the Bergen area:

Norway is one of the richest countries in the world but is still not willing to invest in high risk projects. There exists a huge potential, but no one will invest……

In Western Norway venture capital and industrial and commercial development are too much biased towards the petroleum activity. Other kind of companies does not have a fair chance. You must to be willing to think about other topics than oil. The conditions must improve!

In summary, the results of this study shows that all the industry-university links studied was a result of long lasting relationships. Furthermore, is formal competence and basic research are both important for communication and scientific progress in the projects. Basic research is conducted in all the projects and the channels for knowledge transfer considered most important by the respondents are the ones often associated with tacit knowledge. Most respondents were in total very satisfied with the project collaboration, but some cultural differences were reported. Also patenting and commercialisation seem to cause some frustration for the respondents. The Bergen region is lacking relevant meeting places to create productive university-industry links and the University of Bergen is strongly recommended to become more visible and market the candidates coming from the institution more extensively. An overview of some of the most prominent observations and results from this chapter are summarised in table 3 below.

Table 3. An overview of some of the most prominent observations and results drawn from the interviews

Respondents	Contact patterns	Type of research	Formal competence	Channels for knowledge transfer	Novel results/ Spin-offs	Increased network	Positive experiences	Negative experiences	Piece of advice
Common	Long term and personal relationships was crucial for initiating research partnerships. Frequent contact was important for the progression in the project.	Problems stated in the project was of applied character. Much of the research done at UiB were basic research.	Formal competence and scientific background was considered important in order to understand the problems and to communicate between organisational and cultural borders in the project.	Personal contact, scientific publications, research partnerships, open meetings and channels for human mobility were considered most important.	Most results from the projects were considered radical, or with a potential for becoming radical, in the market	Most of the respondents reported on professional increased network as a result of the project collaboration	The good relationship and atmosphere in the project collaboration.	Cultural differences	The Bergen region is lacking relevant meeting places for research communities and relevant industry
	Formalisation of the contract was often a result of funding opportunities. Formalisation was important for implementing the project.		Most of the persons doing research at the project were PhD-, or master students on both the university and industrial side of the UIL. They were considered important in order to establish a joint research platform between university and industry.		There were spin-offs in terms of other products or establishment of new companies in connection with the projects			Patenting and commercialisation	UiB should market themselves in a more offensive way, both the candidates and as a potential partner for industry
university-respondents	Freedom to approach the problem in a unrestricted manner was important for formalisation of the project.	New problems and data collected from collaboration with industry could later be used as foundation for own curiosity driven basic research (new projects with other funding sources like NRC).		Scientific publications were valued slightly more by the university-respondents.		Increased network towards industry were experienced, but an increased academic network were not reported.	Freedom to publish and freedom to follow new problems arising during the project period.	Total work load and restricted freedom to publish and to perform basic research	The academics should become more visible and show how research is important for the society
industry-respondents	With exception of projects within life science, industry was responsible for the initial contact			Patents and licensing seemed more valued by the industry-respondents.		The project did in general result in larger professional network for the industry-respondents.	Get access to dedicated and highly competent people with the ability to solve complex problems.	UiB as an unorganised project-partner.	UiB should become more visible. A research portal for industry were suggested.

5 Analyses and discussion

In this chapter the key findings from the empirical part of the study will be discussed within the contexts of the selected theories and previous research. Some known examples from other universities will also be added as a part of this discussion. Firstly, it will be discussed whether the contact and collaboration patterns analysed in this study corresponds with the features of the university-industry links described in the literature. Secondly, the role of basic research in the university-industry links analysed will be discussed in the context of Stokes theory *Pasteur's Quadrant* (Stoke, 1997). The meaning of knowledge transfer between the university and industry will be analysed in context of the reported findings from this study. Finally, some aspects about the visibility of the University of Bergen in the region and management of intellectual property rights will be discussed based on the feedback from the respondents.

5.1 Features of university-industry links

5.1.1 Personal contacts, communication and trust

One of the most important features of the university-industry links described in this study is the strong emphasis on personal contact, often in the form of long lasting relationships such as former students, former fellow students and scientific colleagues. Thus the findings of this study are in accordance with Pavitt (2005) who showed that personal, and often informal contact, is one of the three most common features of university-industry links (see section 2.4.1). According to Schartinger et al. (2002) personal interactions like face-to-face communication will build up social capital such as trust, a joint 'language' and a joint research culture. In this respect social capital facilitates the exchange of information and knowledge because communication proceeds relatively smoothly. As pointed out by a vast majority of the respondents in this study, a good relationship with their collaborative partners was highly valued. In this respect, the importance of a close dialogue, trust and of frequent communication with their partners, were highlighted.

Many of the respondents reported that formal scientific competence, combined with human resource transfer, was important for the communication and contact patterns. As mentioned earlier, building up social capital in research relationships is important and in order to assure this capital a common scientific platform or joint research culture has to be formed. The results from this study show that involvement of master- and PhD candidates seem to facilitate communication between university and industry and thus strengthen both the social capital and learning. This could in turn indicate that forming a social platform in research collaborations, and the need of formal competence on master- and PhD-level, is important on both sides of the university-industry links. Pavitt (2005) also recognised such a feature of university-industry links in his study, where he stated that the practical benefits of most university research emerged from processes that were roundabout and indirect, often carried out by graduates trained by leading researchers (se section 2.4.1). In addition, according to Cohen and Levintahl (1990), an organisation's absorptive capacity will depend on the absorptive capacities of its individual members, which in turn will build on prior investment in the development of its individual absorptive capacities. In other words, a firm should strive to increase competence in-house, both in form of recruitment strategies and an in form of education of existing employees. Therefore, like individuals' absorptive capacities, organisational absorptive capacity will tend to develop cumulatively. A firm investing in competence such as master- and PhD-candidates, will gradually increases their ability to communicate effectively with research communities, thus increasing a firm’s ability to form joint research, or social, platforms with research organisations. Investment in highly educated competent employees from universities, together with a willingness to invest in basic research, will consequently increase a firm’s absorptive capacity. And the other way around; university researchers will more easily learn to interpret industrial problems into scientific questions when there exist a common social and communication platform. It is however important to bear in mind that Cohen and Levinthal state that a firm's absorptive capacity is not simply the sum of the absorptive capacities of its employees; it is also dependent on organisational factors. This is most probably also true for universities. It is, however, not a question stated in this project.

An interesting observation from the data material is that, in most cases, the projects were first initiated from the industry. Cohen, Nelson and Walsh J.P. (2002) showed that knowledge from public research was not very important when new research projects were suggested in industrial firms. Public research was, on the other hand, shown necessary in order to solve the problems stated. Cohen et al. (2002) reported, however, some important differences between different kinds of industries. While manufacturing industries stated that public research was almost unimportant in suggesting new projects, it was reported from industries such as petroleum and semiconductors, that public research was moderately important. Industries within life sciences, like the biotechnological and pharmaceutical companies, reported that public research was relatively important as a source for new project ideas. It is worthwhile to mention that in the study presented in this thesis, researchers at the university were responsible for the initial contact for projects within life science. I all other types of fields the industry-respondents were responsible for the initial contact. The objective of this study is, however, not to investigate possible differences between field of research and type of industries. In order to do such analyses a larger and more quantitative approach is needed. It is, however, important to bear in mind, when investigating university-industry links that certain differences exist within scientific fields and types of industries. Differences in how public research is valued and utilised internally also exist between different kinds of companies like academic start-ups, small, medium enterprises (SMES) and large companies (Agrawal, 2001).

This study indicates that while the initial contact and planning of the projects were depended on long term personal relationships, formalisation in form of a contract was quickly accomplished when the projects were finally defined and funded. Research partnerships were also reported as one of the most important channels for knowledge transfer by the respondents of this study. One of the main reasons was that a certain formality was required to commit the partners to the project. This is in accordance with a previous study of Bonaccorsi and Piccaluga (1994), where they described that the formalisation of interactions between universities and industries is an approach for ensuring a sufficient level of trust and for reducing uncertainty.

5.1.2 The role of basic research

In this study basic research was performed in all the projects although they were conducted with a superior goal for a future benefit for the companies involved. As outlined in section 2.2.3, Donald Stokes stated that a considerable amount of the basic research was done with consideration of practical use in mind (Stokes, 1997). Stokes further claimed that research can be of both applied and basic character at the same time, using Louis Pasteur as an example. Furthermore Pavitt (2005) showed that a lot of university research considered useful for the industry, is also valued by the academic society (se section 2.4.1). This study confirms the theory of Stokes. In addition this study supports Pavitt's work by showing that collaboration with industry can give university researchers relevant problems for their own curiosity-driven basic research in return. Radical results and spin-offs emerge from most of the projects analysed in this study. Cohen and Levinthal showed, in their break-through article from 1990, that research investments in firms created a capacity to assimilate and exploit new knowledge. Further Cohen and Levinthal described how applied sciences generally had a lower impact on firms R&D-

intensity than basic research, suggesting that basic science had a greater impact on a firm's absorptive capacity than applied science. It is difficult, however, to draw any direct conclusions supportive of Cohen and Levinthals findings based on the results of this study, but it points in the same direction.

It is, however, worthwhile to bear in mind that many of the respondents from the university pointed out the importance of keeping a balance between the research done in collaboration with the industry and their own basic research. The scope and purpose in research done in industrial partnerships were reported to be somewhat different than the scope in pure basic research. Thus, research done in collaboration with industry did not give the same amount of results valued by the scientific community. In addition, many of the respondents, both from the university and from the industry, pointed out that when the pressure for deliverables started to build up in the project, many of the good intensions in the project concerning openness, freedom to follow interesting problems, and publish results, were reduced. The general impression was that while the industry partners were concerned about the marked needs, the researchers at the university did only care about the research and technology.

This cultural gap is general and described in the literature. Different organisational culture such as motivational factors, time and market orientation are found to negatively effect the formation and development of university-industry links (Plewa, 2007). Negative perceptions of market orientation in universities, internal structures, bureaucracy and the researchers' individualistic way of working have been identified as factors potentially hindering university industry relationships. Plewa (2007) did, however, also find that recognising the role of individuals, their passion and experience were important for overcoming the identified barriers.

Much can be learned from universities known to handle their industry relations well, while maintaining as successful research universities. The Massachusetts Institute of Technology (MIT) is a university in Boston especially famous for its extensive collaboration with industry resulting in many break-through discoveries. According to MIT's past President Charles Vest (Brown, 2005):

'The continuing rise in collaborative relationships between MIT and corporations is based on a synergy of basic research efforts and long term commitments by industry.'

Thus MIT is typically operating within Pasteur's quadrant in their university-industry links which, in turn, is resulting in innovation and industrial and commercial development. According to Brown, MIT is recognising the quality of their faculty and has a very professional apparatus for taking care of the university-industry relations; The Industrial Liaison Programme (Brown, 2005, Hammersia, 2006). The Catholic University of Leuven is another university typically fostering successful university-industry links. Like MIT, Leuven has

'…a dual incentive mechanism to maintain a balance and healthy tension between striving for scientific excellence and gearing this excellence towards application and innovation (van Dun, 2006).'

Leuven has also, like MIT, an effective professional apparatus taking care of the university-industry relations; The Industrial Liaison Programme *K.U. Leuven Research & Development*, LRD (Debackere and Veugelers, 2005; van Dun 2006).

5.2 Knowledge transfer and the importance of tacit knowledge

As mentioned in the introduction universities are said to be important sources for new knowledge into the society. An important goal for this study was to investigate how knowledge transfer occurs between the University of Bergen and its industrial partners. Universities are, however, not only a source of knowledge, they are also recipients thereof. Different channels for knowledge transfer between universities and industries are therefore considered important. In this study the respondents rated channels like 'informal meetings' and 'scientific publications as the most important channels for knowledge transfer. 'Research partnerships' and 'open meetings' were considered almost as important while 'contract research' and channels for human mobility like 'new candidates' and 'personnel exchange' came out as medium important. With the exception of contract research, all of these channels are valued as important by the scientific community it self and are also the ones associated with open science. These finding are consistent with the most cited work of Cohen, Nelson and Walsh (2002) described in section 2.4.2.

With the exception of scientific publications, the channels described above are classified as non-codified or tacit channels for knowledge transfer while scientific publications are classified as an explicit channel (Schartinger et al., 2002). The respondents did, however, report that working with co-authored scientific publications was a result of extensive team-work including meetings and informal discussions. In this process a great deal of tacit knowledge becomes transferred between the partners in the project. Scientific publications are in this respect facilitating a lot of knowledge transfer in a non codified way. Cockburn and Henderson (1998) has shown that firms connected to the open science community and being actively involved in sharing research results, engage in research collaboration and co-author on publications, and are also shown to be more innovative than firms conducting a more close innovation policy (as described in section 2.4.2). Furthermore such investments in research and development are necessary for increasing a firm's absorptive capacity as discussed above in section 5.1.

Patenting, consulting and licensing were considered less important as channels for knowledge transfer by the respondents. These channels are typically classified as explicit or codified knowledge. This study, together with previous research, is confirming that technology transfer, in terms of patents and other university-generated intellectual property (IP) are only moderately important for the innovation process and relationship-based mechanisms are in fact exceeding them in relevance (Agrawal 2001; Cohen, Nelson and Walsh, 2002; Perkman and Walsh, 2007). The shift of impact from explicit to tacit knowledge in research based innovation is thus described in literature and supported by this study.

5.3 Management of intellectual property rights

The aim of this study was to examine collaboration patterns, the mechanisms of knowledge transfer and the role of (basic) research within university-industry links. The more classical themes of technology transfer like patents and licensing, as well as intellectual property policy within universities was not on the agenda for this study. However, from the interviews it emerged that patenting and commercialisation were considered important taking into account the relatively strong response on these matters. Both the university-respondents and industry-respondents reported that patenting and commercialisation processes were one of their most negative experiences in the project. Most of the respondents recognised their own lack of competence with this aspect and turned to the supportive apparatus for help. However the respondents experienced that the help they received was often irrelevant and inadequate. Bergen Technology Transfer Office, Forinnova AS or Sarsia Innovation have not been consulted in order to account for their part of the story. It is therefore beyond the scope of this thesis to discuss the validity of the experiences reported by the respondents. In this context it should be noted that Bergen Technology Office was established as late as January 2005, meaning they were a very young organisation when the incidents reported by the respondents were taking place. Furthermore it is of importance that the legislation in Norway also is rather new (Ministry of Education and Research, 2002). Many of the actors within this area could therefore have expectations beyond possible service that should be provided by such a supportive apparatus. Evaluation of Technology Transfer Offices has been done other places in Norway and the results are to some degree consistent with the experiences reported by the respondents in this study. The evaluation of NTNU Technology Transfer Office, recently done by NIFU STEP, revealed that the elucidations and strategic decisions for establishment of the NTNU Technology Transfer Office were inadequate. Furthermore the evaluation report showed that the most important results of commercialisation of public funded research was the generation of new ideas for research and the contribution to new research contracts with industry. The results in terms of patents, license agreements and spin-offs companies were rather few (Spilling, Gulbrandsen and Hansen, 2006).

It is a common characteristic that universities support innovation in industry primarily through the production of deliverables for commercialisation like patented discoveries. In many ways policy instruments set up to facilitate university industry collaborations are based on a misunderstanding of the roles played by universities in regional and national innovation systems. As mentioned several times in this thesis, relationship-based mechanisms for knowledge transfer and networking are now replacing the traditional concept of technology transfer as important for the innovation process. In addition research collaboration done in terms of open research has been shown to foster more innovation than collaboration in a more closed environment (Christensen, Olesen and Kjær, 2005, Fagerberg, Mowery and Nelson, 2005, Evans, 2006, Lakhani, 2006). This should in turn affect how universities formulate their intellectual property policy. In most industrial countries, policies attempting to stimulate patenting and licensing by universities and public research organisations are modelled on the *Bayh-Dole Act*, passed in the US in 1980. This act was set up as an instrument for getting universities more engaged in innovation. However, the effects of *Bayh-Dole Act* are in, many respects, unclear. Critics claim that when universities seem to patent more, the overall quality and effect on innovation seems untraceable (Mowery and Sampat, 2005, Economist, 2005). MIT, perhaps the worlds leading when it comes to ways in developing innovative approaches to industrial research and development, recognizes that the primary university business is to educate and to perform research. Ann M. Hammersia, Senior Intellectual Property Counsel at MIT put it this way: 'Universities love IP but it really doesn't drive the decisions within the institution'. MIT is not trying to maximise it financial return on intellectual property, but is instead - with the help of its IP-model - trying to get the technology developed and out to the public. MIT policy also requires that all research results must be publishable (Brown, 2005, Hammersia, 2006).

5.4 The University of Bergen as a source of new knowledge

5.4.1 University of Bergen in the region

As outlined in section 5.2 knowledge-based innovation is believed to be highly dependent on transfer of tacit knowledge and social learning processes and is therefore often regionally based. Universities, and their most cited researchers, are further thought to play en important role in regional based innovation systems. Results from this study are in agreement with these theories. Many of the respondents also mentioned geographically proximity with their partners as important for the collaboration. Such proximity was said to be necessary for frequent personal contact as well as for conducting experiments effectively.

A concern for weak interactions between research and industry, affecting the region of Bergen’s ability to adjust into knowledge based and innovative region, has been put forward from different parties within industrial and commercial development. In section 1.2 this concern is outlined as a part of the purpose for this study. Many of the respondents, both from the industry and from the university, emphasise how invisible and passive the University of Bergen has acted in order to initiate contact and foster research collaboration with industry. This study is thus in many ways supporting the concern expressed above. There are also reasons to believe that this is not only true for industrial companies, but also for companies within service, business and public organisations. As explained in the introduction there is, however, a broad political desire to facilitate the innovative capacity of the City of Bergen, including the university itself. The radical results and various spin-offs reported from the projects in this study indicate that the research community at the University of Bergen has a lot to offer to local, national and international, industry. If the University of Bergen, together with other research institutions in Bergen and the local industry, could take more effectively advantage of such a potential this would most probably result in a significant increase in the knowledge-based innovation.

Universities often establish separate organisations dealing with applied research in order to shield core activities such as education and basic research. In Bergen the most notable example is Unifob AS, a non profit organisation owned by the University of Bergen and serving as ‘a primary tool and preferred partner for conducting externally funded research and development projects[12].' Norway has in general, compared to other OECD-countries, a relative large sector of public funded research institutes with a common mission to bridge the gap between academy and industry (Ministry of Education and Research, 2005, NIFU STEP, 2008). In context of the theory of tacit knowledge and research based innovation in *Pasteur's Quadrant*, this study indicates that increased direct contact between university researches and industrial companies would lead to more research based innovation. An intervention of a transitional link like a research institute could thus be considered unnecessary. However, the distributed nature of new innovation processes described in section 2.2.3 can now call for specific forms of governance structure, extending across firms, research institutes and university boundaries, such as loosely coupled innovative networks. White papers and cooperative models developed for academy and industry interactions seem however surprisingly often to be constructed based on older principles like the linear model postulated by Vannevar Bush (see section 2.2.3). In addition, the idea of fundamental basic research, in the context of industrial innovation, is often viewed as paradoxical and not very relevant by the industry (Gulbrandsen, 2006). This is also expressed by the industry-respondents in this study when reporting a lack of understanding importance of research in innovation at a managerial level in the company.

5.4.2 Visibility and professionalism of the University of Bergen

At the end of the interviews the respondents were asked whether they had any specific advice on how Bergen could become a more knowledge-based innovative region. As outlined in section 4.5 a vast majority of the respondents did report that Bergen is lacking relevant meeting places where industry and university could meet and identify common interests. Many of the respondents further claim that they lack information on where to find relevant research communities which could contribute to solve their problems. In this respect much can be learned from universities successful in their industry-university contact.

At MIT many of the interactions between industry and MIT researchers are facilitated by the *Industrial Liaison Programme* (ILP). The programme is run under the Office of Corporate Relations (OCR), is the largest of its kind, and has played a key role in MIT's success in linking corporations with relevant on-campus research efforts into long-term research collaborations.

[12] Unifob AS, 2006: http://www.unifob.uib.no/about/

According to Karl Coster, Director of OCR, the Industrial Liaison Programme, facilitates the process of getting a dialog going (Brown, 2005). MIT describes the process as follows[13]:

'Each Industrial Liaison Officer (ILO) consults regularly with ILP members to match their corporate needs with relevant MIT faculty and resources. As a veteran of MIT's inside track, your ILO has earned the respect and responsiveness of MIT faculty. And, armed with a deep understanding of your industry, your ILO is ideally positioned to be an effective advocate for your company's needs and goals within MIT.'

The Industrial Liaison Programme is also responsible for research briefing for larger groups and a large number of seminars and conferences are hosted each year. The Industrial Liaison Programme is not instead of, but in addition to MIT Technology Transfer Office.

The Catholic University of Leuven also has an industrial liaison programme, the *K.U. Leuven Research & Development* (LRD). Unlike the *Industrial Liaison Programme* at MIT, the *KU Leuven Research & Development* consists of central multidisciplinary staff supporting researchers in technology transfer. In addition the research divisions at The Catholic University of Leuven are embedded in via matrix structures in university 'virtual organisations'. In these virtual organisations groups of researchers (from different faculties or departments) can cluster their research, commercial-industrial and exploitation activities.

MIT and Leuven have organised their industrial liaison offices and technology transfer offices quite differently. However, common to the two universities, is the recognition of having a body facilitating contact between industry, commerce and public organisation with relevant researchers at the university. Such contact is, however, personal in nature and often informal. Such a body, or service, is lacking at the University of Bergen. Some of these tasks are taken care of by Bergen Technology Office, Sarsia Innovation, Forinnova AS etc, but within the university, however, no such address can be reached by possible external research partners. Based on the feedback from the respondents, such an address is obviously wanted.

[13] http://ilp-www.mit.edu/display_page.a4d?key=H1

6 Conclusions

This study has been conducted in order to gain a deeper understanding of the relationships between universities and their industrial partners leading to knowledge based innovation. Based on the research questions stated in section 1.3, the collaboration in university-industry links has been analysed with emphasis on the role of research and knowledge transfer. Different and different kind of channels, or mechanisms, for knowledge transfer has been investigated and the role of universities in regional innovations systems has been discussed. In addition questions were asked if formal competence had any significance for the collaboration between universities and industries and whether any novel results or spin offs was emerging from the projects.

6.1 Main findings

The most prominent findings in this study are:

1. Basic research is important for university-industry links. Industries investing in basic research appear to draw more heavily from university research and university researchers collaborating with industries are given relevant problems for their own curiosity research in return.

2. Tacit, or non-codified, channels for knowledge transfer are exceeding explicit or codified channels, like patents and licensing, as important for knowledge based innovation. The channels for knowledge transfer with highest rank in university industry links are the channels often associated with open science, they are most valued by the research community themselves and are classified as tacit and, or non-codified.

3. Informal and long-term relationships between university researchers and their industrial partners seem to be an important trigger for establishment of university-industry links. Formalisation of a contract, social relationships, frequent communication and trust are in turn crucial for the progression in the projects. Formal competence in terms of master- and PhD candidates is crucial for establishment of communication platforms between the research communities and their industrial partners.

4. The radical results and various spin offs reported from the projects studied indicates that the University of Bergen has a lot to offer to local, national and international industry. But, the University of Bergen is not sufficiently visible for potential collaborating partners outside the academic society. The institution also appears not to market its candidates in an efficient way.

In this study all the respondent's value basic research as important for the activity and most of the projects finally ended up with radical results and commercially interesting spin-offs. The study did, however, reveal that under pressure for deliveries basic research is losing impact in the collaboration with industry. As discussed above, the theory of Stokes (1997), Cohen and Levinthal (1991), among others, strongly supports the impact of basic research in industrial innovation. Universities worldwide, known to be successful in innovation and radical discoveries, like MIT and Leuven, typically value the synergy of basic research efforts, scientific excellence and long term commitments by industry. In addition they provide a successful and professional apparatus within the university taking care of the university-industry relations. This culture could be taken on more actively by the University of Bergen.

The University of Bergen has emphasised in its *Strategic Plan* its responsibility towards the society. In addition, the university emphasise that cooperation with the business sector will increase the university's access to external research funds, give researchers new perspectives on their research and increase the competence and competitiveness of the businesses involved. The university focuses, however, on the goal of being a renowned research university with first rate education and the importance of academic freedom of such. This, and previous studies, indicates that universities taking common scientific goals and values within basic research into long terms relationships with industries will lead to valuable knowledge transfer. In turn this will create radical results and spin offs contributing to research based increased innovation. This is, however, dependent on the universities prioritising contact with industry, and other external collaborative partners, in a proactive way.

This and other studies in the field, points in the direction of an emerging open and distributed innovation system. In addition the shift from explicit to tacit knowledge in research based innovation is described in literature and supported by this study. This shift in discourse should in turn affect how policy makers think and act when they design new instruments and incentives for research-based innovation. They should seek to understand and foster the new emerging networks responsible for novel discovery and innovation. Rethinking incentives and adaptation for research-based innovation should in future become an important issue both nationally, locally and at an institutional level.

This study, along with other recent studies, reveals in addition that the supportive apparatus for patenting and commercialisation is still in an early phase of establishment in Norway. Expectations and roles need therefore to be more clarified. In addition the users need probably more general information about the help and service they can be expected to be provided.

Establishment of an industrial liaison office at the University of Bergen could be helpful in order to meet some of the expressed need for information, meeting places and coupling between industry and university communities in the Bergen area. It is, however, important to bear in mind the shift of impact from explicit to tacit knowledge in research based innovations and the transition from closed to more open innovation systems. Such an office should therefore work complementary to, and in close collaboration with, other supportive and facilitating organisations within the field of technology transfer in Bergen. Especially Bergen Technology Transfer Office is perhaps the most important and closest collaborative partner in this context.

6.2 Advice to the Bergen Region

Based on the main findings in this study, known theories and previous studies, the following advice are given to the University of Bergen and firms in the Bergen area on how to become a more knowledge-based innovative region:

1. The University in Bergen should foster a culture where the synergy of basic research efforts, scientific excellence and commitments with industry is more valued than today.

2. An office for external relations, like an industrial liaison office, could be established at the University of Bergen. Such an office should, by its highly scientific competent people holding industrial know-how, be responsible for creating meeting places and couple industry with relevant research communities within the university. In addition such an office should be responsible for shaping the IP-policy at the university. These tasks cannot be outsourced to external organisations.

3. Firms in Bergen could, on their side, invest more extensively in research and long term relationships with the academic society in Bergen than they do today. This could be investment in research partnerships, education and sponsoring university activities such as laboratory projects, participating in research consortia doing basic research, attending scientific meetings, among others.

4. Knowledge-based industrial firms should strive to increase the formal competence within the company by increasing the number of masters and PhDs employed. This would in turn facilitate a common social communication platform with the research communities. In this way the industrial firms would increase their absorptive capacity and most probably become more innovative over time.

In conclusion, both the Bergen region and the University of Bergen should take into account the mayor of Boston's advice to Harvard University about 'staying great as a research university'. The University of Bergen should seek to create in house incentives towards this goal, like incentives to publish in well renowned publishing channels and give support for star scientists and research groups of high quality. It is however important to bear in mind that fostering a culture to create collaboration with industry is not contradictory but inclusive, for a well renowned research university. Industrial firms should, on their hand, seek to collaborate with the best scientists at the university by bringing their problems to them. They should in this respect avoid the short term solutions, but slowly trying to bridge the academy –industry cultural gap by increasing their absorptive capacity. For the Bergen region long term research collaboration between academic organisations and industrial firms should become an important part of the strategy towards becoming an attractive knowledge-based and innovative region.

6.3 Some aspects about the study, methods, data material and results

This study is based on a qualitative approach in order to analyse the university-industry links at the University of Bergen. The study is thus not intended to be a quantitative approach where distinct hypotheses are set up for testing. In stead a set of research questions were formulated in order to operational the purpose stated for the study. These research questions were in turn used as a fundament for the interview guide. The method used was a semi-structured interview where data materials from 16 interviews were analysed. The author of the report did personally perform the interviews in a field where she had professional interests and even own opinions. Several of the respondents were also, to various degrees, known by the author. This could bias the respondents' answers. The author was, however, aware of the situation and aimed to act objectively and professionally during the interview focusing on the respondents and their experiences. In addition it was emphasised during the interview that all information was confidential, it would be made anonymous and used for this report only.

Qualitative research involves in-depth studies of human behaviour and the reasons that govern human experiences and behaviours. It would therefore be incorrect to draw any general conclusions based on the material. Patterns and relations between different kinds of categories and thematic are, however, analysed and discussed. Quotes from the respondents are used quite extensively in the presentation of the results in order to explain and support the key findings, but no systematic distinction is made between the university-respondents and industry-respondents in the presentation of the results. To some extent differences between these groups are highlighted when considered necessary. Separating the two groups of respondents could maybe have been more distinct in the methodical approach, i.e. by the use of a separate guide for the interviews. However, the number of respondents is quite small and a more systematic separation of the groups could lead into a generalisation and causality of the results perhaps not supported by the data material as a whole.

6.4 Further studies - suggestions

As mentioned in the introduction, the mechanisms of research collaborations and knowledge transfer are under-researched, at an international and, especially, at a national level. Based on the main results from this study, and in the context of known theories and previous research, some suggestions for further studies can be made:

Firstly, it could be worthwhile to consider a more quantitative study of selected features of university-industry links. Such a study could test the main findings from this study. The study could be extended to the University of Bergen as a whole and cover collaborative projects in a broader range of industries, businesses and even public organisations.

Various problems should be addressed and several hypotheses could be the subject for testing such as mechanisms for knowledge transfer in the university-industry links, differences between scientific fields and type of industries, spin-offs, human mobility etc.

Secondly, based on the experiences from the respondent from this study it could also be worthwhile to evaluate how the supportive apparatus within technology transfer, intellectual property management and commercialisation are functioning towards their missions in Bergen. Such a study should have emphasis on expectations and roles of the different actors operating within technology transfer and commercialisation.

Finally, a broader study of innovation systems in the Bergen region, involving all the research institutions, several types of industries, businesses and public organisations could be worthwhile to set up. Such a study should address the amount of science-industry links in the region per industry, mechanisms for knowledge transfer as well as potentially innovative spin-offs and products.

References

Agrawal, A. (2001). *University –to-industry knowledge transfer: literature review and unanswered questions*. International Journal of Management Reviews. 3: 285-302

Agrawal, A. and Henderson, R.M. (2002). *Putting patents in context: Exploring knowledge transfer from MIT*. Management Science, 48(1):44-60

Asheim, B. and Gertler, M.S. (2005) *The Geography of Innovation: Regional Innovation Systems*. The Oxford Handbook of Innovation, Oxford University Press

Bergen Chamber of Commerce (2006). *Tema: Buisness Region Bergen*. Info nr 4. http://www.bergen-chamber.no/uploads/BN_Info4-2006.pdf

Bergen Chamber of Commerce (2008). *Entreprenørskapsdagen Grow'08, Konferanse om nyskaping i bergensregionen.* http://www.bergenscenarier.no/?news=26&PHPSESSID=c1de1ae304aca00171a1ed46c07adf8c

Berrefjord, O., Thomassen, L. and Dinesen, A. (2005). *Bergenscenarier 2020, Samlet rapport Fase 1 og Fase 2*. Bergen Chamber of Commerce and Industry

Bonaccorsi, A. and Piccaluga, A. (1994). *A theoretical framework for the evaluation of university–industry relationships*. R&D Management, 24 (2):229–247.

Brown, E. 2005. *The MIT experience*. ABB Review: 2/2005.

Bush, V. (1945). *Science the Endless Frontier*. *A report to the President on a Program for Postwar Scientific Research.* United States Government Printing Office, Washington

Christensen, J. F., Olesen, M.H. and Kjær, J. S., (2005). *The industrial dynamics of Open Innovation - Evidence from the transformation of consumer electronics* Research Policy, 34: 1533-1549

Chesbrough, H.W. (2006). *Open Innovation: a new paradigm for understanding industrial innovation*. In Chesbrough, H.W., Vanhaverbeke, W. and West, J. (ed.), *Open Innovation: researching a new paradigm*. Oxford: Oxford University Press.

Cockburn I. and Henderson R. (1998). *Absorptive capacity, coauthoring behaviour, and the organization of research in drug discovery*. Journal of Industrial Economics, XLVI (2): 157-182

Cohen, W.M. and Levinthal, D.A. (1990). *Absorptive capacity: a new perspective on learning and innovation*. Administrative Science Quarterly, 35: 128-152

Cohen, W.M., Florida, R., Randazzese, L. and Walsh, J. (1998). *Industry and the academy: uneasy partners in the cause of technological advance*. In Noll, R.G. (ed.), *Challenges to Research Universites*. Wahsington DC: Brookings Institute Press.

Cohen, W.M., Nelson, R.R. and Walsh J.P. (2002). *Links and Impacts: The Influence of Public Research on Industrial R&D*. Management Science, 48: 1-23

Coombs, R. and Metcalfe, S. (2000). *Organizing for Innovation: Co-ordinating Distributed Innovation Capabilities*. Oxford University Press.

Cowan, R., David P.A. and Foray, D. (2000). *The explicit Economics of Knowledge – Codification and Tacitness*. In Dosi, G., Teece, D.J. and Chytry, J. (ed.), *Understanding Industrial and Corporate Change*. Oxford University Press

Debackere, K. and Veugelers, R. (2005). *The role of academic technology transfer organisations in improving industry science links*. Research Policy, 34: 321-342.

Dodgson, M. Gann, D. and Salter, A. (2005). *Think Play Do – Technology, Innovation and Organization*, 26-44, Oxford University Press US

Economist, (2005), Vol. 377 Issue 8449, Special section p3-6

Edquist, C. (ed.) (1997) Systems of innovation: Technologies, Instituttions and Organizations. London; Printer

Edquist, C. (2005). *Systems of Innovation: Perspectives and Challenges*. The Oxford Handbook of Innovation, Oxford University Press

Etzkowitz, H. and Leydesdorff L. (1997) *Universities and the Global Knowledge Economy: A Triple Helix of University-Industry-Government Relations*. Henry Etzkowitz and Loet Leydesdorff (eds.). London: Cassell Academic

Etzkowitz, H. and Leydesdorff, L. (2000). *The dynamics of innovation: from National Systems and ‘‘Mode 2’’ to a Triple Helix of university–industry–government relations*. Research Policy, 29

Evans, P. (2006). *Collaboration Rules and Innovation Strategy*. Guest lecturer, , Managing Innovation and Entrepreneurship, Course 15.351 at MIT Sloan School of Management

The Faculty of Mathematics and Natural Sciences (2005). *Forskningsstrategi for Det matematisk-naturvitenskapelige fakultet.* http://www.uib.no/mnfa/strategi/MatNatForskningsstrategi_final.pdf

Fagerberg, J. Mowery, D.C. and Nelson, R.R (ed.) (2005).*The Oxford Handbook of Innovation*, Oxford University Press

Fagerberg, J. (2005). *Innovation - A guide to the literature*. The Oxford Handbook of Innovation, Oxford University Press

Fredriksen, T.and Grønhaug, K. (1996). *Samspill mellom forskning og næringsliv i Bergensregionen*. SNF rapport nr. 77/96.

Gibbons, M. Limoges, C., Nowotny H, Schwartzman S., Scott, P. and Trow, M. (1994). *The new production of knowledge: the dynamics of science and research in contemporary societies*. London: Sage.

Grønmo, S. (2004). *Samfunnsvitenskapelige metoder*. Bergen: Fagbokforlaget

Grønmo, S. (2006). *Universitetet og næringslivet*. Chronicle in Bergens Tidende 25.10. http://www.bt.no/meninger/kronikk/article308875.ece

Grønmo, S. Bergsvik, E. and Haaland J. I. (2006). *Kunnskap for fremtiden*. Chronicle in Bergens Tidende 15.08. http://www.bt.no/meninger/kronikk/article289426.ece?service=print

Guldbrandsen, M. (2006). *Kunnskapsinstitusjonenes rolle i innovasjonssystemet*. Seminar held by *Kunnskapsdugnaden*, Oslo, 23rd of November

Hammersia, A. (2006). *Intellectual Property Considerations when Universities Collaborate with Industry*, SIP week seminar, MIT Sloan School of Management

Hanahan, D., Wagner, E. F. and Palmiter, R. D. (2007). *The origins of oncomice: a history of the first transgenic mice genetically engineered to develop cancer*. Genes & Development, 21: 2258-2270, Huston, L. and Sakkab, N. (2006): *Connect and Develop. Inside Procter & Gambles new model for innovation*, Harvard Business Review, 84, no 358-66

Isaksen, R. (2005). *Tettere samarbeid mellom UiB og næringslivet*. På Høyden 27.04. 2005. http://nyheter.uib.no/?modus=vis_nyhet&id=270405120627

Johansen, G.A. (2007). *Faglig ledelse på tvers av grenser. Momenter, tanker og innspill til debatt*. Speach at a strategi-seminar at the Faculty of Mathematics and Natural Sciences. Feburary 2007.

Kvale, S. (1996). *Interviews. An introduction to Qualitative Research Interviewing*. Sage publications, London.

Lakhani, K.R. (2006). *Broadcast Search a New/Old Approach to the Old Search Problem*, Managing Innovation and Entrepreneurship, Course 15.351, at MIT Sloan School of Management

Lam, A. (2000). *Tacit Knowledge, Organizational Learning and Societal Institutions: An Integrated Framework*. Organization Studies, 21(3): 487-513

Lander, E.S. et al. (2001). *Initial sequencing and analysis of the human genome*
Nature 409 (6822): 860-921

Laursen, K. and Salter, A. (2006). *Open for innovation: the role of openness in explaining innovation performance among U.K. manufacturing firms*. Strategic Management Journal, 27(29): 131-150

Lundvall, B.A. and Johnson, B. (1994). *The Learning Economy*. Journal of Industry Studies, 1, No 2: 23-42.

Ministry of Education and Research (2002). *Om lov om endringer i lov av 17. april 1970 nr. 21 om retten til oppfinnelser som er gjort av arbeidstakere.* Ot.prp. nr. 67, 2001-2002, godkjent i statsråd 19. april 2002

Mowery, D.C. and Sampat B.N. (2005). *Universities in National Innovation Systems*. The Oxford Handbook of Innovation, Oxford University Press

Murray, F. (2006). *Academy-Industry Boundary: Effective Strategies and Coomon Pitfalls or how to avoid the 'please protect me from corporate research sponsors*'. SIP week seminar, MIT Sloan School of Management

Nelson R.R. (ed.) (1993), *National Systems of Innovation: A Comparative Study*, Oxford University Press.

The Norwegian Ministry of Education and Research (2005), *Commitment to Research,* Report no. 20 to the Storting (2004-2005).

NIFU STEP (2008). *Report on Science & Technology Indicators for Norway 2007*. Research Council of Norway

Nonaka, I. and Takeuchi, N. (1995). *The Knowledge Creating Company*. New York; Oxford University Press

Nowotny, H., Scott, P. and Gibbons, M. (2001). *Re-thinking Science: Knowledge and the Public in an Age of Uncertainty*. Polity Press in association with Blackwell Publishers

OECD (2002). *Frascati Manual. The Measurement of Scientific and Technological Activities. Proposed Standard Practice for Surveyw on Research and Experimental Development*. Paris: Organisation for Economic co-operation and Development (OECD), page 30

OECD (2002). *Main Science and Technology Indicators*. Paris: Organisation for Economic co-operation and Development (OECD), Volume 2002/2

Pavitt, K. (2005). *Innovation Processes*. The Oxford Handbook of Innovation, Oxford University Press

Perkman, M. and Walsh, K. (2007). *University industry relationships and open innovation towards a research agenda*. International Journal of Management Reviews, 9, no 4: 259-280

Plewa, C., Quester, P. and Baaken, T. (2007). *Organisational culture differences and market orientation: an exploratory study of barriers to university industry relationships*. International Journal of Technology Transfer and Commercialisation, 5, No 4, 21: 373-389(17)

Polanyi, M. (1956). *Personal Knowledge – Towards a Post-Critical Philosophy,* Chicago: University of Chicago Press

Porter, M. (1998): *Clusters and the New Economics of Competition*. Harvard Business Review, *76(6):77-90*

Powell, W.W. and Grodal, S. (2005). *Networks of Innovators*. The Oxford Handbook of Innovation, Oxford University Press

Price R.H. and Behrens, T. (2003). *Working Pasteur's Quadrant: Harnessing Science and Action for Community Change*. Journal American Journal of Community Psychology, 31, No 3-4: 219-223

Product Development and Management Association (PDMA), (2008). *The PDMA Glossary for New Product Development*, http://www.pdma.org/library/glossary.html

Research Council of Norway (2006); *Work Description for the Programme for User-driven Research-based Innovation (BIA)*

Price, R. H. and Behrens, T. (2003). *Working Pasteur's Quadrant: Harnessing Science and Action for Community Change*. American Journal of Community Psychology, Vol. 31

Rogers, E. (2005). *Diffusions of innovations*. 4th edn. New York: The Free Press

Schartinger, D, Rammer, C., Fischer, M.M. and Frölich, J. (2002). *Knowledge interactions between universities and industries in Austria: sectorial patterns and determinants*. Research Policy, 31(3): 3030-328.

Spilling, O.R., Guldbrandsen, M., Hansen, T.B. (2006). *Evaluering av NTNU Technology Transfer*. NIFU STEP Arbeidsnotat, 36/2006.

Stokes, D. E. (1997). *Pasteur's Quadrant: Basic Science and Technological Innovation*. Washington DC: The Brokkings Institutions Press

Svedeberg, R. (1991). *Joseph Schumpeter: His Life and work*. Cambridge Polity Press

Teece, D.J., Pisano, G. and Shuen A. (1997). *Dynamic capabilities and strategic management*. Strategic Management Journal, 18, Issue 7: 509-533

Tessem, B. (2006). *Vil slå sammen it i Bergen*. IDG.no, 01.11.2006. http://www.idg.no/karriere/karrierenyheter/article30521.ece

Thagaard, T. (2002): *Systematikk og innlevelse: En innføring i kvalitativ metode* (2.utgave). Bergen: Fagboklaget

Tushman, M. and O'Reilly, C. (2007). *Research and Relevance: Implications of Pasteur's Quadrant for Doctoral Programs and Faculty Development*. The Academy of Management Journal (AMJ), 50, No. 4: 769-774

University of Bergen (2005). *Strategic Plan 205-2010 for the University of Bergen*, http://regler.uib.no/regelsamling/show.do?id=130

Utterbach, J.M. (1994). *Mastering the Dynamics of Innovation*. Harvard Buisness School Press

van Dun, P. (2006). *K.U.Leuven Research & Development: A model for exploitation of academic research*. Presentation on COIMBRA Workshop in September

Vatne, E. (2008). Professor dr.oecon. Eirik Vatne, on a telephone conversation with the author in March 2008

Venter, J.C. et al., (2001). *The Sequence of the Human Genome*. Science 16, 291. no. 5507: 1304-1351

von Hippel, E. (1998). *Economics of Product Development by Users: The Impact of 'Sticky' Local Information*. Management Science, 44: 629-44 von Hippel, E. (2005). *Democratizing Innovation*. The MIT Press Cambridge, Massachusetts London, England

Wenger, E. (2000). *Communities of Practice and Social Learning Systems*. Organization, 7(2): 225-246

Zucker, L.G. and Darby, M.R. (1996). *Star Scientists and institutional transformation: Patterns of invention and innovation in the formation of the biotechnology industry*. Proceedings of the National Academy of Sciences, 93(23): 12709-12716.

Appendix

I. Example of an e-mail to the respondents (in Norwegian)

Hei!

Jeg viser til telefonsamtale.

Som sagt tar jeg en videreutdannelse som jeg tar innenfor teknologiledelse (Master of Technology Management). Dette studiet er et samarbeid mellom NTNU, NHH og MIT (i USA). I den avsluttende oppgaven ønsker jeg å se på et felt som jeg mener Det matematisk-naturvitenskapelige fakultetet (og UiB for så vidt) burde vite mer om, nemlig samhandlingen innenfor forskning mellom akademiske miljøer og industri/næringsliv.

Her er litt generell bakgrunnsinfo om oppgaven jeg jobber med:

Forskningssamarbeid og kunnskapsoverføring mellom bedrifter og akademiske institusjoner (og annen offentlig finansiert forskning) er viktig for kunnskapsutvikling og innovasjon både på et nasjonalt og lokalt nivå. Hensikten med denne oppgaven er å undersøke kontaktmønstre og kunnskapsoverføring mellom fagmiljøer innenfor matematikk, naturvitenskap, biomedisin og teknologi (MNT-fagene) ved UiB/Unifob AS og bedrifter, hovedsakelig lokalisert i Bergensregionen. Noen sentrale spørsmål er betydningen av grunnleggende forskning for prosjektet samt hva kontakten har materialisert seg i og hvordan prosessene har foregått frem til de konkrete resultatene.

Intervjuene er berammet til ca en time og jeg bruker en såkalt løs intervju guide. Jeg vil bruke prosjektets historieforløp som struktur for intervjuet og har en del spørsmål jeg vil komme innom langs den tidsaksen. Intervjuet er imidlertid ikke lagt opp etter "spørreskjema-metoden", derav betegnelsen "løs". Mao hvordan intervjuet/samtalen forløper vil til en viss grad styre spørsmålene som stilles etter hvert. Tilsvarende vil jeg intervjue de samarbeidspartnerne du har i industrien.

Vedlagt er et skjema for noen helt generelle opplysninger om prosjektet som jeg må be deg fylle ut i forkant av intervjuet. Du trenger ikke begynne på dette før vi evt har identifisert et relevant prosjekt. Send meg gjerne noen ord på e-post om du har et eller flere forslag til mulige case-prosjekt. Jeg er også glad for annen materiale, publikasjoner etc.

Bare for å presisere vil ikke spørsmålene være av en slik faglig karakter at vi på noen måte trenger å berøre mulige konfidensielle områder (industrihemmeligheter etc.), det er som beskrevet ovenfor selve kontaktmønsteret for kunnskapsoverføring jeg er ute etter å kartlegge. All informasjon vil bli anonymisert.

Takk på forhånd for hjelpen!

Mvh
Randi E. Taxt
Underdirektør ved Det matematisk-naturvitenskapelige fakultet
Universitetet i Bergen

Mobil 41 47 92 27

II. Guide for the interview (in Norwegian)

Master oppgave – kontaktmønster og kunnskapsoverføring mellom lokale fagmiljøer ved universitetet og industri innenfor naturvitenskap og teknologi

Forskningssamarbeid og kunnskapsoverføring mellom bedrifter og akademiske institusjoner (og annen offentlig finansiert forskning) er viktig for kunnskapsutvikling og innovasjon på et lokalt nivå. Hensikten med denne oppgaven er å undersøke kontaktmønstre og kunnskapsoverføring mellom fagmiljøer innenfor matematikk, naturvitenskap, biomedisin og teknologi (MNT-fagene) ved UiB/Unifob AS og bedrifter i Bergensregionen.. Noen sentrale spørsmål er betydningen av grunnleggende forskning for prosjektet samt hva kontakten har materialisert seg i og hvordan prosessene har foregått frem til de konkrete resultatene (eller manglende sådan…).

Veiledende intervjuguide for det enkelte intervju
Selve intervjuet blir lagt opp langs en prosjekts tidsakse fra første kontakt til konkrete resultater.

1) Hvilke typer kontaktmønstre har det vært mellom forskningsmiljøet og bedriften i prosjektperioden:

- Hvordan har kontakten oppstått for dette prosjektet
- Hvor langvarig kontakt har det vært
- Hvilken type kontakt var det initialt (formell, ikke formell)
- Hvem var ansvarlig for at kontakten oppsto (enkeltpersoner, ledelse, andre)
- Når ble kontakten formalisert
- Hvilke faktorer var avgjørende for denne bestemmelsen
- Hvordan er kontakten nå (beskriv)

- Hvilken type forskning bygger prosjektet på (grunn-anvendt-utvikling)
- Hvordan har prosjektsamarbeidet foregått (fortell)
- Har det vært noen særskilte utfordringer i samarbeidet

- Hvilke typer personer har vært involvert i prosjektet
- Hvem har vært mest involvert i prosjektet
- Hvilken (formal) kompetanse har de personene som jobber på prosjektet og hvilken betydning har det

- Hva er de viktigste resultatene fra prosjektet
- Hvorfor er disse resultatene viktige
- Er det noen spin-offs[14] i prosjektet
- Hvilken grad av nyhet er det i prosjektet (fundamental, radikal eller inkrementell)
- Har prosjektet ført til økende kontaktnett for de impliserte

[14] **Spin-off**, **spin-off-effekter** eller **spin-off-produkter** er bieffekter og -produkter som har oppstått som sideresultater av et arbeid eller forskning

2) Hvilke kanaler for kunnskapsoverføring har hatt (mest) betydning for det faglige samarbeidet (rangering):

- Uformell kontakt
- Publikasjoner
- Åpne møter/konferanser
- Oppdragsforskning
- Konsulentoppdrag
- Samarbeidsprosjekter (forskningsprosjekter, brukerstyrte prosjekter)
- Personellutveksling
- Patenter
- Lisenser
- Nyansatte kandidater fra UiB

3) Hvorfor er de nevnte kanalene viktig?

4) Hva vil du fremheve som spesielt bra i prosjektsamarbeidet?

5) Hva vil du fremheve som mindre bra?

6) Hva kan gjøres fra de ulike institusjonene for å bedre samarbeidet mellom nærings- og samfunnsliv i Bergensregionen og akademiske fagmiljøer ved UiB/Unifob AS?

III. Form for information about the project (in Norwegian)

Fakta om prosjektet (innhentes på forhånd):

Prosjektets navn	
Varighet	
Samarbeidspartnere	
Økonomisk ramme (totalt)	
Finansieringskilder	
Personell involvert (årsverk, stillingskategori)	
Konkrete resultater og spin-offs som er kommet ut av prosjektet (master, PhD, publikasjoner, produkter, patenter, lisenser, nyetableringer, etc.)	

Kort beskrivelse av prosjektet (faglige problemstillinger, gjennomføring etc.)

Er det noen planer om videre oppfølging av prosjektet (nye prosjekter, annen type samarbeid o.l)?

Vedlegg: Prosjektbeskrivelse Kontrakt Etc

IV. Agreements (in Norwegian)

A) Hovedoppgave

B) Standardavtale