University-Industry Collaboration:
Systemic Interaction or
One-Way Knowledge Transfer?

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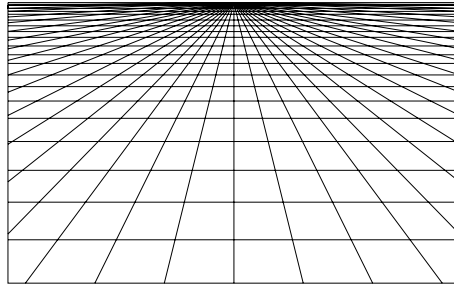
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Oslo, 1. December 2000

Hilde Røed

Synopsis

This thesis investigates university-industry collaboration in certain science-based and high technology sectors in Norway. University-industry interactions have received increased attention from both politicians, academics and industrial managers since the 1980s, and the topic seems highly relevant for research. Some argue that industry has become more "science based", and that there is no major difference between industrial and academic research in certain "new" fields of science and technology, such as computer science and biotechnology.

Types of, motivations for and obstacles to university-industry collaboration are investigated in order to find out whether university-industry collaborations in certain high technology and science based fields might be seen as mutual learning processes rather than as one-way knowledge transfers. The analysis is based on empirical data obtained through interviewees with R&D managers and university researchers mainly from the biotechnology, pharmaceutics, computer science and information technology sectors. The investigation reveals that there are numerous modes of interaction and motivations for collaboration for both academics and companies. However, access to the other parts' competence seems to be the main motivation for both parties. This suggests that companies in some sectors have so much competence that university-industry collaboration might involve knowledge exchange and mutual learning rather than one-way knowledge transfer. The findings are in accordance with modern approaches to innovation. These suggest that science and technology are highly intertwined, and that innovation takes place through systemic interaction between companies and external sources of knowledge.

Keywords: University-industry collaboration, innovation, innovation systems

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CHAPTER 1: INTRODUCTORY CHAPTER

1.0 Introduction

Rapid technological change, the emergence of new technologies such as information technology and biotechnology, globalisation and increased competition are viewed as some of the major forces influencing the world economy today. Economists pay more and more attention to the key relationship between technology and the economy, and technological change is now acknowledged as one of the major factors influencing economic growth. While economic growth used to be recognised primarily as a function of labour and capital investments, economists today focus more on technological capability and knowledge as companies' main assets. Some argue that we are entering a new "knowledge-based economy", where knowledge has bypassed capital as the most important economic resource (Lundvall, 1994; OECD, 1996).

In a world economy of fierce competition and rapid technological change, the ability to learn and thereby innovate seems to be a matter of long-term survival for companies. This realisation has lead to a profound interest in technological innovation by politicians, researchers and industrial managers alike. Researchers from different academic disciplines have been studying science, technology, and the relationship between the two. The so-called "linear" model of innovation, with its focus on radical product innovations and the importance of scientific discoveries for technological advances, has been modified in many ways. A new understanding of innovation as a complex process of interaction and learning has more or less replaced the traditional view of scientific advance as the main source of technological change.

Studies of companies' innovation processes have revealed that companies able to utilise external sources of knowledge are more likely to be successful innovators than those who are drawing upon internal competencies only. Other companies, and particularly users and suppliers, are considered important external sources of knowledge (Edquist, 1997; von Hippel, 1988; Tidd et al., 1997; OECD 1997). Universities, on the other hand, tend to be rated as rather unimportant sources of innovation by industrial managers (OECD, 1997; Nås & Ørstavik, 1988). The focus has shifted from radical to incremental innovations, and the new and more complex understanding of innovation has lead to increasing doubts about the impact of university research on technological innovation. Questions about the relevance of university research for innovation has been raised, and some argue that basic research is too abstract and far off from the real world to play a role as a source of innovation.

There are two main rationales for public support of university research. Firstly, science is assumed to have a *cultural function* related to the value of knowledge for its own sake. Science is assumed to be important as a means of satisfying human thirst for knowledge, as well as a provider of a rational view on reality. The second argument is that science has an *economic impact* on society by providing technological opportunities for industrial innovation (Kallerud, 1998). Traditionally, university research has been thought of as the driving force behind innovation and economic growth. However, the direct impact of academic research on technological innovation is not taken for granted in "modern" approaches to science and technology. Rather, economic pay-off from university research is assumed to depend on industry's ability to absorb and utilise academic knowledge for technological innovation. The realisation that science, and particularly basic science carried out mainly at the universities, does not have such an immediate and automatic pay-off as thought earlier, has lead to increasing demands for economic relevance of university research. Closer university-industry

collaboration is seen as a key to short-term economic success by some policy-makers. Hence, universities in several countries are under considerable pressure to increase the direct and short-term economic relevance of their research, and to nurture a more "entrepreneurial culture" in order to justify public support (OECD, 1998; ESTA, 1997; Etzkowitz, 2000).

The growing interest in linkage activity between universities and industry is the point of departure for this thesis. Lately, Norwegian media has paid a lot of attention to the "Mjøs"-report[1], and the future of the universities has been a focus of public debate. University-industry collaboration in Norway therefore appears as an interesting and relevant topic for research. The focus of this thesis is upon the economic dimension of university research only. This choice does not imply that the cultural dimension of university research is considered unimportant. On the contrary, cultural aspects of university research and education still seem to be acknowledged and to serve as legitimate rationales for public support of universities. However, the economic rationale is an important part of the legitimisation of a high level of public funding of academic research, and this rationale seem to be questioned nowadays. Hence, one of the interfaces between university research and the economy, namely university-industry collaboration, is chosen as a research topic.

The relations between science, technology and society have been studied with increased interest by academics from a wide range of academic disciplines, such as economics, geography, history, sociology and philosophy, amongst others. Some of these studies, which have been labelled "Science and Technology Studies", have illuminated that technology is not simply artefacts, but rather a complex phenomenon embedded within a social, political and

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[1] The commissioned report "Freedom with responsibility" (NOU 2000/14), popularly called the "Mjøs"-report, is an official report written by the Higher Education Committee on behalf of the Ministry of Education, Research and Church Affairs (Kirke-, utdannings- og forskningsdepartementet). The Higher Education Committee was appointed by Royal Decree on 30 April 1998 to undertake a study of higher education in Norway after 2000.

cultural context. This complex view of technology is one of the main pillars in modern innovation theory. University-industry collaboration seems to be a highly relevant topic for an investigation based on such an interdisciplinary approach to science and technology.

1.1 Problem formulation

Although university-industry linkages have attracted much interest by researchers from different academic disciplines since the 1980s, studies of these relations have tended to focus on quantitative measures such as number of co-patents, co-publications, patents and publications citing scientific literature etc. Data on researcher mobility, joint industry-university projects, funding of university research and number of spin-off companies also give a rough picture of some of the extent of the university-industry linkages. Some firm-level surveys have focused on more qualitative measures such as the perceived importance of the universities as sources of different kinds of information and knowledge (see e.g. Gibbons & Johnston, 1974; Schibany et al., 1999; OECD, 1997; Ørstavik & Nås, 1998). Other research topics encompass companies' motivations for collaboration as well as difficulties and barriers to university-industry interactions (see e.g. Bonaccorsi & Piccaluga, 1994; Geisler & Rubenstein, 1989; Bowie, 1994).

The studies and indicators mentioned above might provide a rough picture of the extent and nature of university-industry collaboration and give some clues about contributions from university research to industry. However, my impression is that these measures do not capture

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(Source: http://odin.dep.no/kuf/engelsk/publ/utredninger/NOU/014071-990061/index-dok000-b-n-a.html, 12.11.00).

the full range and content of university-industry collaboration. Rather, the indicators used to map knowledge flows between the public research base and industry in many ways seem to reflect a linear understanding of innovation, where the knowledge flow is supposed to be unidirectional - from the university sector to the industry. Even though there is a growing understanding of the close interactions and two-way flow of knowledge between science and technology, as well as between industry and university, studies of collaboration in science-based and high technology industry sectors seem to focus more on knowledge transfer than on mutual learning.

This thesis investigates the hypothesis that companies in certain science-based and high technology sectors today have so much competence that university-industry collaboration might be processes of knowledge exchange rather one-way transfers of knowledge. Based on modern approaches to innovation, one might further suggest that university-industry collaboration is highly influenced by personal relations and networks, that there is a rich diversity of linkage forms and motivations for linkage, and that several types of knowledge are exchanged. Based on this hypothesis about university-industry collaboration in "high technology" or "science-based" sectors as a relation characterised by mutual learning, I define the following research questions:

1. How do universities and industry collaborate?

2. Why do universities and industry collaborate?

The field of investigation is restricted in many ways. Firstly, it covers university-industry collaboration in Norway only. The study is based on information gathered from Norwegian universities and Norwegian companies. However, some of the university researchers have collaborative relations with companies in foreign countries, and some of the companies

collaborate with universities abroad. Information about such relations is also included in the study, but no information is collected directly from these foreign companies or universities. Secondly, the investigation is restricted to include collaboration within the fields of engineering and natural sciences only. Collaborations within scientific fields such as humanities, economics and social sciences are not included. The investigation is further restricted to cover areas where university-industry collaboration is expected to be most common. The interviewees are therefore selected from rather "new" fields of science and technology, such as biotechnology, pharmaceutics, materials science and computer science and information technology.

Finally, the investigation is restricted to cover universities and university-level colleges. The higher education sector in Norway also includes several state-colleges, but these are not included in the scope of this study. Since the universities and university-level colleges perform 80 % of the research in the higher education sector in Norway, I found it reasonable to exclude the numerous state-colleges from the investigation (The Research Council of Norway, 1999). For practical reasons, I was only able to select interviewees from companies located in Oslo and from the University of Oslo. Since the companies participating in my study were collaborating with different universities, I still found it reasonable to include all the Norwegian universities in the problem formulation. Some of the companies also collaborate with a few of the university-level colleges, and there seems to be no major difference in the perception of universities and university-level colleges as collaborative partners.

1.2 Research methodology

Although there is a quite a lot of theoretical literature on the linkages between industry and public research institutions such as universities, there seems to be a lack of empirical studies of university-industry collaboration. I found the existing empirical material to be insufficient in order to answer my research questions satisfactorily. As mentioned before, much of the empirical material is based on bibliographical measures such as co-publishing, co-patenting, quotations etc. This data material is not very well suited to answer my research questions, which demand qualitative and in-depth information.

To my knowledge there are no other empirical studies covering university-industry collaboration in Norway in any detail. Quite a few studies of university-industry collaboration are based on experiences from the USA and Japan, and these do not necessarily describe or explain the situation in Norway. The organisation and funding of the higher education sector varies considerably between different countries, and findings from one country do not necessarily describe and explain the situation in another country to a full extent. Because of this lack of suitable secondary material, I chose to collect my own data material in order to answer the research questions in a satisfactory manner.

The aim of this study is to investigate further *why* and *how*, rather than how often and how much, universities and industry collaborate. Hence, the empirical material consists mainly of qualitative data. In order to capture some of the diversity of university-industry collaboration and to find out to what extent the existing literature covers all the important aspects of the phenomenon, I conducted my research as an *exploratory study*. The data material was collected through fourteen semi-structured interviews with six university researchers, seven

industry R&D-managers[2], as well as an introductory interview with two employees in the university administration. The interviews lasted for about 45 minutes up to an hour and a half, and except from two cases, they were tape-recorded and typed afterwards. Since the research was exploratory, the questions were open-ended, thus providing room for the interviewees to give detailed information on the subject. I chose to give the interviewees a certain degree of discretion, in order to obtain as much interesting information as possible. Quotations and statements are therefore not directly related to any particular person or company. This prevents me from giving a very accurate description of which companies and which researchers can be linked to what views and attitudes. However, my impression is that this way of conducting the research made the interviewees more open and willing to provide information.

The qualitative data obtained in the course of this study are subjective in the sense that they reflect the respondents' personal opinions about different matters. The data material has also been subject to my analysis and interpretation, and the findings are probably somewhat flavoured by this. However, all types of research and data can be said to suffer from a certain lack of "objectivity", and this is not a problem related only to qualitative data or interview-studies. By interviewing both university researchers and industry managers, I had the chance to hear two sides of the story. I believe that this method of "triangulation"[3] provided me with a more comprehensive understanding of the phenomenon than if I had only interviewed one of the parties. Hence, the empirical investigation might provide some interesting perspectives on university-industry collaboration, seen from different points of view.

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[2] The abbreviation 'R&D' is used for 'research and development' throughout the thesis.
[3] The method used is "interviewee-triangulation", implying that a particular phenomenon is seen and investigated from different points of view (Source: lecture by Terje Grønning 07.10.99).

One should bear in mind that this study is biased towards successful collaborations. Only companies and researchers with quite a lot of experience from university-industry collaboration have been interviewed. The interviewees therefore might not be representative for the industry sectors and universities in general. However, the interviewees represent rather different institutions and fields of science and technology, and they may serve as illuminating examples of collaboration, revealing some of the important aspects and dimensions related to such linkage activity.

A problem related to the kind of study I have been undertaking, is the limited possibility of drawing statistical generalised conclusions. Although one cannot make statements about general trends based on the empirical findings, however, they might shed some light on factors and dimensions neglected in existing theoretical approaches. Explorative studies based on only a limited number of interviews can sometimes contribute to a deeper understanding of a particular phenomenon and its causes. Based on such studies, one might adjust and broaden existing theoretical perspectives and even introduce new hypotheses.

1.3 Some important concepts and definitions

The concepts of innovation can be defined in numerous ways. Definitions vary from very narrow to very broad, but they share the notion that innovation has to do with *novelty* or *change*. More specifically, technological innovations involve some degree of technological change or improvement. Tidd et al. (1997) defines innovations as a new or improved product, process or service that is introduced to the market with commercial success. Thus, innovation is a broader process than just the invention itself. Process innovations include new or changed

techniques or ways of producing and/or delivering a product or service, while product innovations involve the production of a new artefact or a change in an existing artefact or service (Tidd et al., 1997).

Traditional approaches to innovation have tended to focus on a rather narrow concept of innovation, including only product and process innovations. Later definitions also include service innovations and organisational innovations. There has also been a change in focus from radical to more incremental innovations. Radical innovations involve a great degree of novelty, while incremental innovations involve minor improvements or changes in an existing product, process or service (Tidd et al., 1997). As will be discussed further in chapter 2, modern approaches to innovation have broadened the concept of innovation, arguing that incremental innovations are important economic activities.

The concept of "collaboration" is utilised in a very broad sense in this thesis, covering university-industry interactions related to research or technological development, as long as these include some kind of effort or involvement from both parties. Hence, university-industry collaboration covers nearly all types of interactions between the two, except from pure outsourcing. Different types of university-industry collaboration are exemplified in Table 1 in Chapter 3.

1.4 Structure of the thesis

In order to find out why and how companies and universities collaborate, I have chosen to use different approaches to technological innovation as a structuring framework, as I find it reasonable to believe that technological collaboration is closely related to the innovation

activities of companies. Different economic theories of technological change are briefly introduced at the beginning of chapter two, in order to present some perspectives on the key relationship between technology and the economy. Further, the traditional and modern approaches to innovation are discussed and related to the economic theories presented. Traditional and modern approaches to innovation imply very different modes of and rationales for university-industry collaboration, and this is discussed at the very end of Chapter 2.

Chapter 3 is a discussion of the empirical material gathered through the interviews. Types of, motivations for and obstacles to university-industry collaboration are investigated and analysed. The findings are contrasted with the theoretical framework presented in Chapter 2, in order find out whether university-industry relations in the relevant sectors might be understood as:

a) one-way transfers of knowledge from university to industry, as indicated by linear approaches to innovation; or

b) mutual learning processes based on a two-way exchange of knowledge, implying a wide range of linkage mechanisms and types of knowledge flows, as indicated by modern innovation theory.

Main findings, perspectives and conclusions are presented and summarised in the final chapter.

CHAPTER 2: THEORETICAL APPROACHES TO SCIENCE, TECHNOLOGY AND INNOVATION

2.1 Technology and the Economy

Questions about the nature and causes of economic growth have been central topics in economic thinking ever since the foundation of classical economic theory by Adam Smith and other economic philosophers in the 18th century. Various factors have been taken into consideration when trying to explain the dynamics of economic growth, and one of the main controversies has been over the impact of scientific and technological advance on the economy. Numerous theoretical and empirical investigations carried out in the post-war era have supported the view that technology plays an important role in the dynamics of economic growth (Smith, 1994a). This has lead to an increasing focus on technological innovation as an essential factor for economic competitiveness.

Although technological innovation has conquered a central position in economics, traditional economic theories do not really illuminate *how* technology contributes to economic growth, or how it relates to science. The influential traditional neo-classical economic theory views technology as a factor that is produced outside of the economic sector. This view has been severely challenged from amongst others Joseph Schumpeter and his followers, who have developed a so-called "Evolutionary model of economic growth", and from several newer economists within the neo-classical economic tradition. These economists argue that technological innovation is a core economic activity that takes place mainly within the economic sector.

2.1.1 The neo-classical tradition

Traditional neo-classical economic analysis tends to focus on the state of economic equilibrium rather than on the process of economic growth. Growth processes are treated as departures from the optimal state of economic equilibrium, where the main question is the allocation of resources in order to optimise production. According to traditional neo-classical production theory, production is a function of two factors, namely capital and labour (Freeman & Soete, 1997). Technology is viewed as a factor that is exogenous to the production function. Hence, economic growth can result from an increase either in labour or in capital investments per worker. Without population growth, capital investment is the only production factor that can be accumulated.

Neo-classical economic theory is based on the assumption of perfect competition[4]. A necessary condition for perfect competition is decreasing marginal returns to each of the production factors (Freeman & Soete, 1997). Decreasing marginal returns to the production factors implies that the incremental productivity gains from increasing capital investments per worker will diminish over time and at last reach a constant value where productivity growth ceases (Fagerberg, 1994). Due to this, increasing capital investments per worker cannot be a source of long-run economic growth. Without exogenous factors, the neo-classical model thus predicts a state of long-run equilibrium where productivity growth stagnates. In other words, only factors external to the economy can cause long-run economic growth.

According to Smith (1994a), several economists in the late 1950s tried to isolate the contributions of capital investments and technological change to productivity growth (output per worker) in the U.S. economy. Amongst these was Robert Solow, who in an influential

paper from 1956 showed that the economic upheaval in the U.S. could not be explained by growth in labour and capital investments. The main part of the growth was left unexplained, and this part was ascribed to the "residual factor", which Solow labelled "technical change" (Smith, 1994a). In other words, technical change was highlighted as the most important factor influencing long-run economic growth. This result had a great impact on economic thinking.

An important aspect of traditional neo-classical growth theories, including Solow's, is that technology is viewed as exogenous to the economic system. In other words, new technologies are assumed to emerge outside of the economic system. According to this theory, the economic system adjusts to emerging technologies in order to optimise production, and companies are seen as rational actors making profit-maximising choices between different production techniques (Smith, 1994b). This view on technology diffusion as a more or less automatic process of adjustment is based on certain neo-classical assumptions about the nature of technological knowledge. These assumptions are not explicitly formulated in neo-classical economic theory, but Smith (1994b) argues that in neo-classical production theory, technological knowledge is tacitly assumed to have the following attributes:

- It is generic (technological knowledge can be widely applied among firms and perhaps among industries).
- It is codified (technological knowledge is written or recorded in another easily transmittable way).
- It is costlessly accessible (companies are assumed to face negligible or no costs when accessing this knowledge).
- It is context independent (companies have equal capabilities of utilising new knowledge).

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4 In perfect competition, each company is a price taker, which means that it cannot influence the market price. In an extreme case of perfect competition, a company will loose all its sales if it charges more than the market price (Stiglitz, J. (1996) *Economics*. New York and London: W. W. Norton.) .

This understanding of technology as codified and context-independent knowledge has important implications for technology policy. According to neo-classical economic theory, knowledge as a commodity has the characteristics of a *public good* - it is non-exclusive and non-rivalry (Hauknes, 1998). This means that companies and countries in all parts of the world are assumed to share the same pool of technology (Fagerberg, 1994). The concept of technology as a public good creates problems because it is a departure from the perfect competition-model. Technological knowledge is assumed to have positive externalities[5]. These externalities might create a problem of free riding, where companies because of the public-good nature of technological knowledge choose to copy the results of others rather than investing in the production of new knowledge. According to neo-classical economic theory, the public-good nature of technological knowledge leads to a lack of incentives for companies to innovate and invest in knowledge production.

The consequence of this might be a severe under-investment in the production on new knowledge, seen from a macro-level point of view. In other words, because of lacking incentives, the market will fail to produce an optimal amount of technological knowledge (Hauknes, 1998). Hauknes argues that this so-called "market-failure"-argument, based on the logic that the public good nature of knowledge, combined with the great amount of uncertainty and the high costs related to the production of new knowledge, provides a powerful rationale for public funding of basic research activities. This "market-failure"-argument is based on the assumption that technological innovation is an output of scientific research.

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[5] An externality arises when a company or an individual takes an action without bearing all the costs (negative externalities) or benfits (positive externalities) (Stiglitz, J. (1996) *Economics.* New York and London: W. W.

This view on science and technology and its implications for policy will be discussed more thoroughly in section 2.2.

2.1.2 Evolutionary economic theory

Evolutionary approaches to economic growth are often seen as opposed to the neo-classical tradition, although evolutionary theory and new growth theories might be regarded as complementary. The evolutionary theory of economic growth has its roots in the work of Joseph Schumpeter. Schumpeter was perhaps the first to argue that companies compete not only on prices, but also on technology, and that companies therefore engage in a continuous search for new technologies (Smith, 1994a). Rather than regarding technology as a public good and as an external factor to economic growth, Schumpeter views technological innovation as an integral part of the economy. Companies and individual entrepreneurs are seen as the main actors behind innovation processes. In other words, technology is endogenised.

While traditional neo-classical economic theory focuses on economic equilibrium, Schumpeter and his followers argue that the economy is always in a state of flux (Stiglitz, 1996). Schumpeter views economic growth as a process involving major structural change, with the processes of innovation and technology diffusion, particularly through imitation, as the major forces behind economic growth. Although Schumpeter sees technological change as a gradual, cumulative process characterised by numerous incremental innovations, economic growth is considered a discontinuous process characterised by cyclical developments. The steady process of gradual technological development is every now and then disturbed by the

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Norton.). In this case, there is a positive externality because companies and society will harvest fruits of the efforts of one company trying to increase its knowledge.

introduction of radical, new technologies. Old technologies are replaced by new and improved technologies in a process of "creative destruction" (Smith, 1994a).

According to Schumpeter, radical technological change is often characterised by "clusters" of innovations in related technologies. These lead to investment booms and hence to new cycles of economic growth (Smith, 1994a).

Schumpeter's followers have developed his approach into a so-called "Evolutionary theory of economic growth". Edquist (1997) argue that Nelson and Winter are important theorists in the evolutionary tradition. They see companies as entities creating technological diversity and novelty through elaborate search processes within the company, as well as from random processes such as accidental discoveries. Hence, innovation processes can be rather random and unpredictable in many cases. Nelson and Winter further assume that there are market mechanisms that select between various technological solutions and replace old technologies with "superior" new ones. This process of creative destruction is seen as a parallel to the "survival of the fittest" in evolutionary theory in biology.

Technological change is seen as a cumulative and incremental process that is path-dependent, since the technological opportunities facing a company are based on prior experiences (Edquist, 1997). According to evolutionary economic theory, companies are only able to identify a very limited range of technological opportunities and solutions to technical problems. The path-dependent and unpredictable character of innovation processes limits the company's ability to make calculated decisions about technology, and companies can therefore be said to have bounded rationality (Smith, 2000). They can only make choices about technology under high degrees of uncertainty. This stands in sharp contrast to the neo-classical assumption of companies acting as profit-optimising actors with perfect information about all possible production techniques.

The concept of technological knowledge in Schumpeter's theory and evolutionary approaches differs a lot from the neo-classical understanding of technology as a public good. Schumpeter and his followers view technology as having characteristics of both a private and public good. Schumpeter argues that innovators have a certain amount of time - the lead-time - before their competitors manage to imitate their novelties. In this period, innovators can experience a sort of short-term monopoly where they can have high returns to their investments. Hence, companies have incentives to innovate.

2.1.3 "New growth"-theories

As it became more and more obvious during the 1980s that Solow's model of economic growth could not explain satisfactory the actual economic development, several neo-classical economists felt the urge to come up with a new theoretical framework. The "new neo-classical growth theory" is based Solow's model of economic growth, but it departs from that model in certain ways. The most important characteristic of the approaches that have been labelled "new growth" theory is that they endogenise technological development (Fagerberg & Verspagen, 1996). These approaches attempt to capture the Schumpeterian concept of technology creation as an endogenous economic process, without leaving the neo-classical framework. Positive externalities and technological spillovers are taken into account when explaining and predicting economic growth as an endogenous process (Maurseth, 1999).

Some "new growth" theories emphasise the importance of "learning by doing". Learning leads to continuous improvements, and technological advance can thus be seen as an

endogenous process stemming from learning. The effects of learning are assumed to be external to the firm, and they can be seen as positive externalities at the aggregate level. These externalities might outweigh the decreasing marginal returns of capital investment per worker, and the result is potential for increasing returns to scale and hence new growth (Fagerberg, 1994). The "new growth" theories break with some central assumptions in traditional neo-classical economic theory, such as the view of technology as a public good. Technology is endogenised and seen partly as a private and partly as a public good.

2.2 The "Old Paradigm" in Innovation Theory

While the traditional neo-classical economic school has tended to regard technological change as a process exogenous to economic growth, evolutionary economics has provided new insights to the role of entrepreneurs within the economic sector. However, none of the economic approaches presented above give a satisfactory explanation or description of the innovation process and the relation between science and technology. These questions have been treated more specifically in the literature on innovation. The approach to science, technology and innovation that has been known as the "linear model of innovation", emerged in the 1950s. This approach, which focuses on radical, science-based innovations, has been highly influential on post-war innovation policy, particularly in the USA. The linear model of innovation is partly based on the neo-classical economic tradition.

2.2.1 The Linear Model of Innovation

The "linear model of innovation" has been very influential shaping research policy in the post-war era. In this model, innovation is recognised as a fixed, sequential process starting with scientific discovery and passing through stages of product development and marketing, ending with the successful sale of a new product in the market (OECD, 1996). The linear model of innovation has two main dimensions: Firstly, it puts great emphasis on the role of *scientific research* and its importance for technological, and thus economical, development. Secondly, this model treats innovation in a very *technocratic* manner, more or less neglecting the social and cultural dimensions of technology and innovation (Smith, 1994a). The emphasis on scientific discovery and engineering in this model seems compatible with a rather narrow definition of innovation, focusing on radical and science based innovations.

Smith argues (1998a) that there is no single "linear model of innovation". This concept rather covers a set of diffuse opinions about innovation, all however emphasising the importance of scientific discovery for innovation and the sequential nature of the innovation process. Linear approaches to innovation are based on the assumption that there exists a tight link between science and technology, as technology and engineering are viewed as applied science. Relevant knowledge for industrial production is thus supposed to be based on scientific principles that have been "translated" into technological knowledge through a sequential process with institutionally and temporally discrete phases following in a specific order (Smith, 1994a).

Innovation can be viewed as a linear process at two levels: the micro- and the macro-level (Smith, 1998a). At the micro-level, innovation is seen as a process starting with research in the R&D department of a company. An idea is born in this department, and the project passes

on to the phases of product or process development, and then to production and sale. The innovation process is characterised by separation and specialisation, with little communication between the different departments performing the different activities (Isaksen, 1997). This process is illustrated in Figure 1.
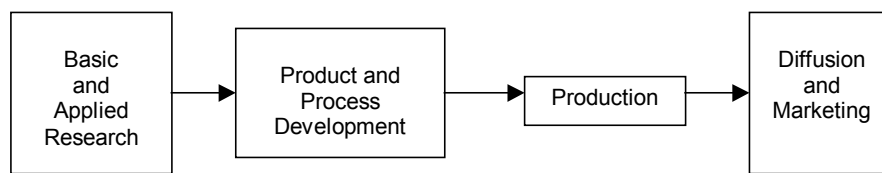
Figure 1: The linear model of innovation. Adapted from Malecki (1991).

The linear model can also be viewed as a model of technological change at the macro level. According to this view, new knowledge, produced mainly in the university sector, is being transformed into applied science in the form of technological development and engineering and utilised for innovation and economical commercialisation throughout the economy (Smith, 1998a). On both the micro- and the macro-level, the innovation is a result of a "science-push", where scientific discovery is seen as the major driving force behind innovation.

The linear model of innovation is based on a technocratic view on innovation, where technological change is considered only in terms of new technical products and processes. Technological innovation is seen as a process where research results are being transformed

into products and processes through processes of engineering and technological development. Organisational changes are not regarded as innovations, and the influence of non-R&D inputs to innovation, such as management, learning, market research, are also neglected (Smith, 1994b). This is very compatible with the neo-classical understanding of technology as codified and context-independent knowledge.

The "linear" approach and neo-classical economic theory have indeed been much intertwined. The neo-classical market-failure argument combined with the linear understanding of basic science as the source of technological innovation has very powerful implications for economic policy. If basic research is a vital source of innovation and thereby crucial for economic growth, and there is a lack of market incentives for undertaking basic research, then government funding of such research is a logic response. Without such support of basic research, the result will be a lower level of research than what is optimal for society. This market-failure argument has indeed been a powerful rationale for public support of basic research and an important legitimisation of universities.

However, government funding of institutions performing R&D is not the only policy implication of the linear model. Although the linear approach view technology as applied science, the transformation of basic scientific principles into applied research and further into technological development is not assumed automatic. The linear model of innovation thus has been a rationale for supporting policies aimed at technology diffusion and technology transfer, as well as for creating investment incentives (Smith, 1994a).

2.3 "Modern" Innovation Theory

During the 1980s and 1990s, the linear model of innovation has been attacked from a number of sources. Modern innovation theory, with its emphasis on incremental innovations and learning, has some of its roots in this critique of the linear model. Critics have argued that the linear model of innovation does not capture the incremental and practical kind of innovation that takes place particularly in small- and medium-sized companies and companies in low-technology industries (Isaksen, 1997). Because of this critique, modern innovation approaches are based on broader definitions of innovation than the linear approach, including service- and organisational innovations. The focus is on incremental innovations rather than on radical innovations based on scientific discovery. While traditional innovation theory tends to focus on inventions and on the role of individual entrepreneurs, modern innovation theory views innovation in a wider perspective, stressing the importance of the social and cultural context of innovation processes.

Modern innovation theory has some of its roots in evolutionary economics, but this is only one of many sources of a new understanding of the innovation process. The relationship between science, technology and innovation has attracted increased interest from scholars belonging to other disciplines than pure economics. Studies of science and technology by academics from a wide range of academic disciplines have provided new perspectives on technological innovation. Modern innovation theory breaks with central assumptions in the linear model of innovation, and this seems to be an outcome of a more complex understanding of the characteristics of technology itself.

2.3.1 Innovation as interactive learning

While traditional innovation theory views innovation as a sequential process starting with scientific discovery, modern innovation theory stresses that most innovations are *non-linear* processes involving other activities than R&D. According to this view, innovation is about doing something new, but this does not necessarily involve the discovery of new scientific principles. Rather than scientific discovery, *problem-solving* is seen as the core activity of innovation processes. Hence, innovation can stem from a wide range of sources, including design, marketing, pilot plants, customer feedback etc. (Isaksen, 1997). Companies possess a certain knowledge base, consisting of their core competencies, and they try to produce new products, processes or services by utilising this knowledge base. In order to do something new, companies try to utilise or combine existing knowledge in a new way. Innovation thus involves interaction and feedback between different activities and departments and persons performing different functions in companies (Smith, 1998b).

Rosenberg & Kline's (1986) well-known "chain-linked model of innovation" illustrates how innovation can be seen as a non-linear, problem-solving activity within a company, as illustrated in Figure 2 (p. 29). This model originated from a study of innovation processes within one single organisation, but it has been recognised as a model illustrating innovation processes in at least small- and medium-sized companies in general. The model captures some of the richness and diversity of interactions between various actors within the company. The main idea is that companies try to innovate by modifying or changing their already existing activities, and that they will only conduct or consult research when they run into a problem they can not solve based on their existing competencies (Smith, 1998b). In this perspective, only research of a problem-solving character is seen as relevant for innovation, and basic research become marginalized (Hauknes, 1998).
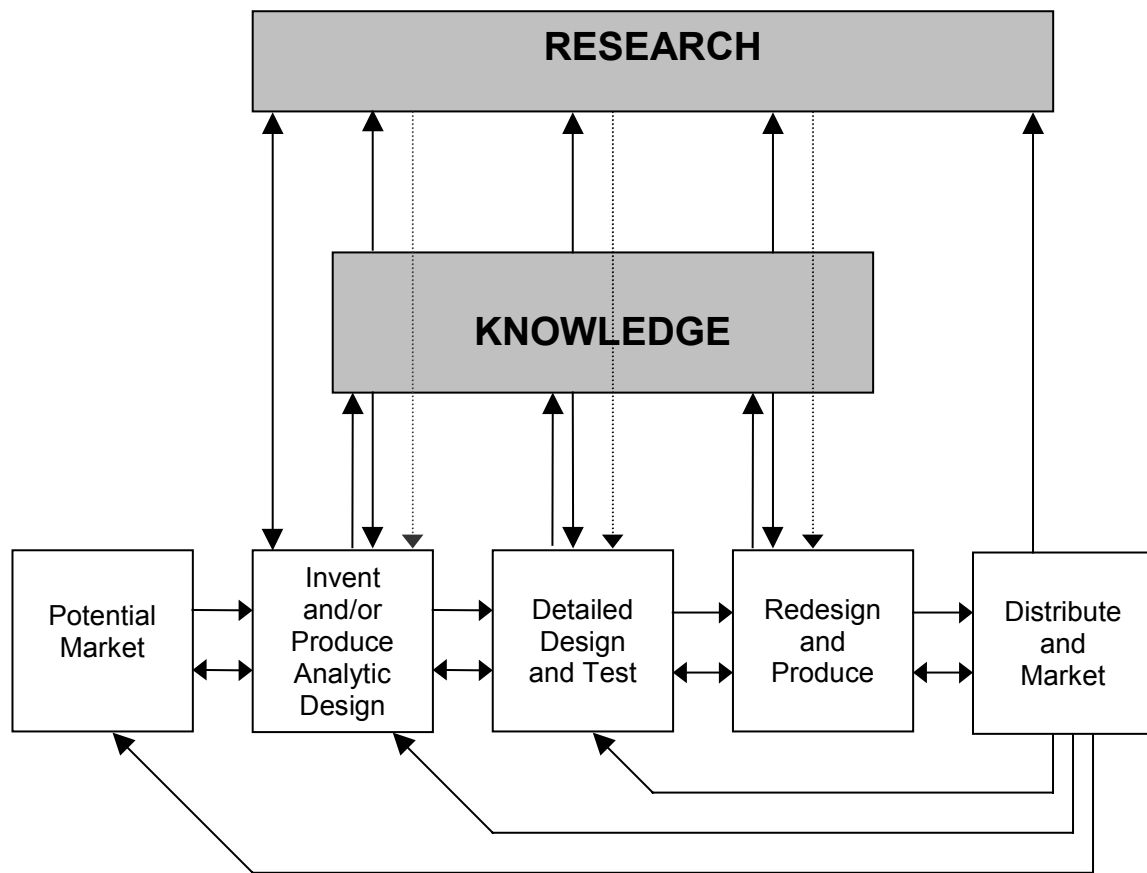
Figure 2: The interactive innovation model. Adapted from Rosenberg & Kline (1986).

The emphasis on interactions between different actors is closely connected to the concept of *interactive learning*. Innovation is about doing something new, or at least something that is new for the organisation, and it thus necessarily involves learning. One of the key ideas in modern innovation theory is that innovation is based on learning through processes of interaction and feedback (Smith, 1998b). Interactive learning does not only take place within companies, however. Companies also learn from interactions with other companies and institutions. These interactions involve an exchange of knowledge and mutual processes of learning. According to the interactive learning-perspective, innovation cannot be seen as an isolated phenomenon. All innovations involve some degree of interaction between the

innovating company and its surroundings, and innovation cannot be treated as a context-independent phenomenon. Innovation is rather seen as a process involving continuous interaction and feedback between different actors and institution both within the company and outside the company (OECD, 1997; Lundvall, 1992; von Hippel, 1988).

2.3.2 Innovation as a systemic phenomenon

The interactive learning-perspective on innovation stresses that innovation involves complex relations and interactions within the firm and between the firm and its surroundings. External sources of knowledge, such as other companies and research institutions, often play an important role in innovation processes. Research has revealed that companies with an external orientation and the ability to utilise external knowledge are recognised as more successful innovators than those relying on internal competence only (Nås, 1994).

One of the most important and common forms of interaction takes place between users, producers and suppliers in related industries. Users play an important role as sources of incremental innovation through their feedback on new and existing products (Lundvall, 1992). The system of innovation-approach emerged from investigations of such relations between suppliers, users and customers (see e.g. Lundvall, 1992), and from studies of the importance of the social, cultural and political context for innovation (Smith, 2000). The innovation system-approach is based on the idea that companies' innovativeness depend on the ability of companies to absorb and utilise knowledge from other actors in their innovation process, and that the institutional framework plays an important role for companies ability to innovate. Through interactive learning, companies combine their own resources and

competencies with those of a number of other actors' in order to build a unique, company specific knowledge base that can be a competitive advantage (Isaksen, 1997).

Producers, suppliers and users are seen as parts of a larger system of actors and relations between these. Which actors and institutions are considered important, varies between different regions, industrial sectors and countries and between broad and narrow definitions of the concept "innovation system". However, most definitions include the following institutions: companies involved in innovation processes (users, producers and suppliers), the educational sector, public and private R&D institutions, technological centres, financial institutions and government agencies shaping policy, legislation and incentive structures for innovation (Isaksen, 1997). Broad definitions of innovation systems also include cultural factors such as language, tradition, norms, and values as important factors shaping innovation. The innovation system-approach emphasises how companies' ability to innovate is strongly influenced by the institutional and organisational setting.

The innovation system-approach is based on the interactive learning model of innovation, but it takes this model one step further by emphasising the institutional framework as a factor influencing innovation. Public and private research institutions, including the higher education sector, are thought of as "the knowledge infrastructure" in national systems of innovation (OECD,1997). The nature and intensity of the interactions between this knowledge infrastructure and the industry is seen as one of the factors influencing industry's ability to innovate. Such interactions involve both formal and informal forms of collaboration as well as student- and researcher-mobility and other types of contact. But even though the national system of innovation-approach includes the knowledge infrastructure as an important element in the innovation system, research institutions are not assumed to play the same key role in innovation as in the linear model.

2.3.3 Scientific and technological knowledge in modern innovation theory

The linear model of innovation provides us with a very simple understanding of the relation between science and technology: The output of science is codified knowledge that can be transformed into technological products or processes through applied research. Within this framework, technology is simply applied research, and the knowledge flow is unidirectional - from science to technology. In other words, technology cannot provide inputs to science. This view has been challenged from modern innovation theory. Innovation system theories and studies of the social shaping of science and technology have shown that the relationship between science and technology is more complex than predicted by the linear model. Empirical studies have shown that only a few industries, such as i.e. chemicals and pharmaceutics, use basic research as a direct source of innovation (Schibany et al., 1999).

Studies of links between science and technology have suggested that most industries benefit from academic research in a more indirect way. This understanding rests on a new understanding of science and technology. Modern innovation theory acknowledges that skills and other forms of experience-based, tacit knowledge play an important role in technological innovation. Technology is viewed as something different from applied science - it can rather be seen as the integration of knowledge, technique and organisation (Smith, 1994). Technological knowledge is closely related to the ability to solve problems, and important aspects of technological knowledge are therefore person-embodied. The importance of person-embodied, tacit knowledge, as well as instrument-embodied knowledge, has to an increasing extent also been considered relevant aspects of scientific knowledge (Senker & Faulkner, 1994). In other words, scientific articles are not the only output of university research.

2.3.4 Contributions of academic research to technological innovation

Modern innovation theory has complicated the relationship between science and technology by introducing a more complex understanding of the nature of technological knowledge. Technology is seen as something more or different from the application of basic research. But this does not imply that science and technology are not regarded as related. On the contrary, scientific and technological developments are seen as intertwined processes. University research, or basic science, is thought of as contributing to technological innovation in more indirect ways, through e.g. instrumentation, methodologies and skilled scientists. Moreover, the relationship between science and technology is not seen as a process of one-way knowledge transfer, but rather as a two-way exchange of knowledge with potential for mutual learning.

In an influential study of 30 industrial innovations in Britain, Gibbons and Johnston (1974) managed to identify a range of outputs of academic science that were considered important to innovation by companies. This study revealed that codified information is only one output of basic research that might be relevant for industrial innovation. The study suggested that there are several channels and interactions between science and technological innovation, and that these relations are often indirect and diffuse. The Gibbons-Johnston typology has been elaborated through further studies of the impact of academic research on industrial innovation (Senker & Faulkner, 1995; Pavitt, 1998). The list of economic relevant outputs from academic research include:

- New, useful information.
- New instrumentation and methodologies.
- Skills.

- Access to networks of experts and information.

- People good at solving complex technological problems.

- Spin-off companies.

(Source: Schibany et al., 1999.)

These economic benefits are pretty much the same as the ones recognised by Gibbons and Johnston (1974) in their study of economic benefits of science to industry. As we can see, these inputs to technological innovation include more than just formal konwledge. Skills and people able to solve complex technical problems are examples of person-embodied or "tacit" knowledge, while access to networks of scientists is an example of "know-who". These kinds of knowledge are not considered relevant outputs of academic research in traditional or "linear" approaches to innovation. In modern approaches to innovation, on the other hand, all these kinds of knowledge are seen as important aspects of technological innovation.

2.3.5 A new mode of knowledge production?

Studies of economic outputs of academic research have revealed that basic science and technology are linked in complex and often indirect ways. The main bulk of these studies emphasise how science influences technology, however, and not the other way around. But examples of how technology influences science also exist. Technological development can raise questions that might puzzle scientist and even lead to scientific breakthroughs (Hauknes, 1998). This aspect of the links between science and technology seems to be quite under-emphasised, though.

In *The New Production of Knowledge* (1994), Gibbons and his colleagues argue that knowledge production is undergoing major changes and splitting in two different modes. Mode 1 refers to the traditional, disciplinary production of basic science (mainly in academic institutions such as universities). In this mode, the boundaries between basic and applied research are clear. Mode 2, on the other hand, refers to interdisciplinary knowledge production. The generation of knowledge stems from a broader range of sources and includes applied science in universities and research institutions as well as knowledge generated in other spheres of society. Mode 2 is characterised by interactions and feedback between basic and applied research, and the result is that the boundaries between these types of research are vanishing. According to Gibbons and his colleagues, Mode 2 does not only apply results from research activities in Mode 1, but distinct types of knowledge are created within Mode 2 (Gibbons et al., 1994).

The Mode 2 production of knowledge can be seen as a version of the interactive learning-perspective on innovation. Knowledge is produced not only in the academic sphere, but also in the industrial sphere. The boundaries between science and technology, basic and applied research are getting more and more blurred as they are getting more and more intertwined.

2.4 University-industry collaboration and innovation

2.4.1 Technological collaboration

Modern innovation theories stress the importance of networks and interactions for technological innovation. Several studies have revealed that much of the knowledge exchange is taking place on an informal basis, i.e. between engineers in different companies (Von Hippel, 1988; Lundvall, 1994). The systems of innovation-literature emphasises geographical proximity, cultural background, friendship, common educational background etc., because these factors are favouring mutual trust and understanding and thereby collaboration (Lundvall, 1992; Von Hippel, 1988). However, network- and innovation system-studies have tended to focus on inter-firm collaboration more than on collaboration between companies and the "knowledge-infrastructure" or the science-base of the innovation systems.

There are several theoretical approaches to technological collaboration. Some are based on a neo-classical understanding of companies and institutions as entities making profit-maximising choices between different options. These tend to see collaboration mainly as a cost-reducing action. Other approaches focus more on technological uncertainty and companies' bounded rationality and see collaboration as a learning-mechanism for companies. These approaches view collaboration more as a risk reducing and a strategic behaviour, where collaboration is an answer to companies' search for an expanded knowledge base. Dodgson (1993) defines three main categories of collaboration:

- Infrastructural collaboration: collaboration with institutions that are part of the national science system (such as research institutes and the higher education sector).

- Contractual collaboration: collaboration between companies or between companies and public users or suppliers.

- Informal collaboration: collaboration taking place through personal contacts and networks without any commercial transactions.

University-industry collaboration is an example of infrastructural collaboration. However, contact between university and industry is often of an informal character. The term "university-industry collaboration" in this thesis encompasses informal interactions between universities and industry as well as formal relations. University-industry collaboration is different from inter-firm collaboration, both concerning modes and motivations. Transaction cost theories and other theoretical perspectives on technological collaboration try to explain the phenomenon by pointing out motivations such as cost and risk reduction, economies of scale, market-shares and access to complementary skills and knowledge. However, most of these rationales for collaboration seem quite irrelevant for university-industry collaboration.

The extent of university-industry collaboration varies between different nations, reflecting differences amongst others in the structures of university research funding. While such collaboration is quite common in the USA, it has been more rare in European countries. However, the share of university research financed by industry has increased since the 1980s. Senker (OECD, 2000) argues that this is due to:

i)   universities' need to look for non-governmental sources of funds;

ii)   the need for industry to access a broader science base (because of increased competition and shorter time horizons for R&D);

iii)   the push for greater returns from government support for R&D.

Although these factors might explain the increase in university-industry collaboration, they do not give a very detailed picture of the characteristics of and motivations for collaboration. The literature on university-industry collaboration seems to a large extent to focus on types of interactions, motivations for and benefits from collaboration, as well as obstacles and barriers related to such collaboration (e.g. Bowie, 1994; Geisler & Rubenstein, 1989; Bonaccorsi & Piccaluga; ESTA, 1997). The literature reveals that there is a rich diversity of university-industry interactions, and that companies' motivations for entering collaborations are many. What seems to be more or less taken for granted, is that universities' main motivation is access to external sources of funds. Types of interactions, motivations for collaboration and obstacles and barriers to collaboration are discussed in the next chapter, and the empirical findings are related to the literature on university-industry collaboration.

2.4.2 Models of innovation and implications for collaboration

As we have seen, the different models of innovation view the contribution of scientific research differently. The linear model views technology as applied science, and hence science as the major source of technological innovation. The contribution from the science system to companies is essentially seen as codified knowledge, or "know-why". From this point of view, the main reason for companies to enter research collaboration with universities would be to gain access to basic research results for which the incentive to invest internally is too low (Bonaccorsi & Piccaluga, 1994). If the linear model of innovation gives an appropriate picture of innovation processes in science-based and high technology companies, getting access to basic research results at an early stage in order to gain lead-time should be the main rationale for collaboration. Collaboration might then be expected to be undertaken mainly in order for companies to get access to basic research. If science is clearly separable from

technology, as the linear model of innovation suggests, university-industry collaboration must be seen as a process of one-way knowledge transfer. If this is true, universities would be expected to collaborate with industry mainly for financial reasons, and not for the sake of acquiring external knowledge.

While the linear model of innovation indicates that access to the scientific frontier in order to get new ideas for products and processes is the main motivation for industry to collaborate with universities, "modern" approaches to innovation imply more diverse and complex types of and motivations for such collaboration. According to the interactive innovation model, innovation is mainly a problem-solving activity. Seen from this perspective, one would expect industry to turn to university research in order to solve specific problems, rather than to use university research as a source of new ideas. Since also scientific knowledge is thought to have tacit components, access to university researchers' specific skills and problem-solving capacities should be more important than access to more general knowledge. Modern innovation theory, and particularly the radical "Mode 2"-theory of Gibbons et al. (1974), implies that university-industry collaboration should also involve considerable possibilities for universities to learn from companies. If there is a two-way flow of knowledge between academic research and technological development, then financial motivations should not be the only reason for universities to link with industry. Rather, modern innovation theory implies that there are fields of overlapping interest between universities and industry, and that universities might link with industry in order to acquire new knowledge.

CHAPTER 3:

UNIVERSITY-INDUSTRY COLLABORATION:

KNOWLEDGE TRANSFER OR MUTUAL LEARNING?

- A DISCUSSION OF EMPIRICAL FINDINGS

3.0 Introduction

As discussed in Chapter 2, the perception of basic research as the main source of innovation has been modified and contradicted by modern approaches to innovation. Rather than focusing solely on formal outputs of university research, such as written articles, there has been a growing realisation that academic knowledge also flows through channels such as instruments, methodologies and particularly through well-trained scientists and engineers. Hence, modern approaches to innovation suggest a variety of motivations for and modes of university-industry collaboration, as compared to the "old" paradigm in innovation theory. Focus on the transition into a "knowledge-based economy", with an increasingly science-based industry, has also raised questions about whether university-industry links are mutual learning processes rather than one-way knowledge transfers. These questions are investigated in the following sections, through a discussion of different types of, motivations for and obstacles to university-industry collaboration.

The analysis is based on empirical data collected through fourteen semi-structured interviews, as mentioned in section 1.2. The industry interviewees are industrial R&D managers in companies mainly selected from biotechnology, pharmaceutics and computing and

information technology companies. In addition to two employees in the university administration, the university interviewees include professors and other scientific personnel from the departments of physics, informatics and pharmaceutics, as well as from the Centre of Materials Science at the University of Oslo. A list of interviewees can be found in Appendix 1. The interviewees were asked questions related to the following main dimensions of collaboration:

A. Types of university-industry collaboration the interviewee had been involved in.

  i) Characteristics of the collaboration partner.

  ii) How the collaboration was initiated.

  iii) Modes of collaboration (contract research, assistance with experimentation and testing, student theses, collaborative research, consortium, joint ventures etc.).

  iv) Financial arrangements, intellectual property rights etc.

B. Motivations for and benefits from collaboration, including the perception of the other parts' motivations.

  i) Financial motives.

  ii) Access to external knowledge (what kinds of knowledge?).

  iii) Access to instrumentation, equipment and facilities.

  iv) Other motivations and benefits.

C. Positive and negative experiences concerning university-industry collaboration, and obstacles to initiation and performance of collaborative relations.

As mentioned in section 1.2, the interviewees were guarantied a certain degree of discretion. The source of any specific quotation is therefore not revealed in the text. The empirical

findings are presented in rather general terms, only specifying if the source is a university or an industry interviewee, and in some cases which sector the interviewee represents[6]. The interviewees' responses to the above questions concerning types, motivations and obstacles to university-industry collaboration are discussed and contrasted with the theoretical approaches to innovation and the implications of these.

3.1 Types of collaboration and channels of communication

3.1.1 Modes of interaction - a classification and empirical findings

According to Wu (2000), there is no universally accepted classification of university-industry interactions. Interactions can be formal or informal; they can range from a single phone-call, a student-thesis or assistance with experiments, to co-publications, co-patents and long-lasting collaborative research contracts. Some interactions involve practical collaboration with researchers from both parties participating, while others are more or less ordinary consulting relations. Interactions can take place between individual researchers at the university and in the company, or between the company and a research group, or even between several companies and universities through multilateral arrangements such as joint ventures or consortiums. Collaborative research can be financed by industry alone, partly by industry and partly by university and/or by public sources such as e.g. the Research Council or the EU. A rather comprehensive classification of university-industry interactions is included in order to exemplify the complexity and diversity of interactions (Table 1):

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[6] The interviewees are grouped in two main categories, namely the 'computing and information technology sector' and the 'biotechnology' sector. The biotechology sector in this case also includes interviewees from the field of pharmaceutics. This rough grouping of companies is necessary in order to make comparisons between different branches of industry, while still preserving a certain degree of discretion for the interviewees.

Table 1: A classification of university-industry interactions.

Type of arrangement	Modes of interaction and some mechanisms
1. Industrial Extension Services	1.1 Information transfer and consulting. 1.2 Workshops, classes. 1.3 Undirected corporate gifts to university funds. 1.4 Capital contributions to university departments. 1.5 Industrial fellowships.
2. Procurement of Services	2.1 By university from industry. Prototype development, fabrication, testing, on-the-job training for students, theses topics and advisors, specialised training. 2.2 By industry from university. Education and training of employees (degree programs, continuing education); contract research, consulting services.
3. Co-operative Research	3.1 Joint research planning and execution. 3.2 Faculty and student participation. 3.3 Co-operative research projects: direct co-operation between university and industry scientists on projects of mutual interest; usually basic, non-proprietary research. No money changes hand: Each sector pays salaries of own scientists. May involve temporary transfers of personnel for conduct of research. 3.4 Co-operative research programs: industry support of portion of university research project (balance paid by university, private foundation, government): results of special interest to company; variable amount of actual interaction. 3.5 Research consortia: single university, multiple companies, basic and applied research on generic problem of special interest to entire industry; industry receives special reports, briefings and access to facilities.
4. Research Parks	4.1 Research co-operation on frontiers of science and technology. 4.2 Informal interactions. 4.3 Increased sharing of research facilities and participation in consulting, seminars, and continuing education. 4.4 Contractual arrangement – specific and detailed: both parties contribute substantially to the enterprise.

Source: Geisler & Rubenstein (1989).

Empirical findings regarding modes of collaboration

The material gathered in the course of this study suggests that companies are engaged in a wide range of linkage activities with universities, covering nearly all the modes of interactions exemplified in table 1. Consulting, contract research, student theses, assistance with testing and experimentation, industrial scientists lecturing at the university, university researchers as members of companies' scientific boards, joint research projects, consortiums, exchange of personnel, continuing education for industrial scientists, gifts and grants to university departments were only some of the interactions mentioned. It is also important to note that nearly all the interviewees were collaborating with one or more partners abroad. Although it is difficult to draw any general conclusions about the frequency or importance of each type of contact from this study, the material suggests that the majority of interactions are related to procurement of services and to co-operative research (group 2 and 3 in Table 1). Collaboration involving students, as well as consulting relations and assistance with experiments and tests seem to be particularly popular forms of co-operation.

3.1.2 Channels of communication – informal contacts and networks

Informal collaboration

The most striking finding is the perceived importance of informal interactions as compared to formal arrangements. All the interviewees strongly emphasised that university-industry collaborations are almost entirely based on informal interactions with personal contacts, and that informal contact is not only restricted to certain modes of collaboration, as suggested by Table 1. The importance of informal interaction based on personal contacts has in fact been

highlighted by several studies (ESTA, 1997; Meyer-Krahmer & Schmoch, 2000; Schibany et al., 1999; Faulkner & Senker, 1994; Gibbons & Johnson, 1974). Informal interaction between individual researchers in the university and industry sector takes place both during and in the wake of formal collaboration, and it also takes place apart from any formal arrangement. Indeed, informal contact often seems to be a necessary precondition for more formal, large-scale collaboration, and it might be an important outcome of formal collaborations starting without such previous informal knowledge of each other. According to the interviewees, third parties, such as technology transfer offices, the faculty or other departments at the university, only very rarely mediate contact between university and industry.

The interviewees suggested that informal contact is particularly important for "small-scale" collaboration related to specific problem-solving activities. Once contact is established, university researchers are turned to for student theses, consulting, testing, feedback on prototypes, assistance with experimentation and more. However, personal contacts are also important for open discussions and exchange of opinion. According to the interviewees, the most common form for collaboration may be informal agreements where university researchers or departments get paid in terms of free or discounted instruments and equipment. Informal collaboration seems to be preferred both for short-term and long-term relations, and formal agreements are avoided as far as possible. Some interviewees argued that informal collaboration is preferred in order to avoid complex and time-consuming contractual procedures. The exceptions seem to be when the parties do not know each other, when a formal agreement is a necessary condition for external funding, or when there are difficult questions regarding intellectual property rights involved.

Personal contacts and networks

The interviewees emphasised that all types of collaboration, formal as well as informal, are usually based on personal contacts. Several of the interviewees argued that personal contacts are so important that collaboration actually follows individuals rather than companies or institutions. This indicates that networks consisting of individual scientists and engineers working within the same scientific or technological field play a very important role in university-industry relations. Most of the interviewees said that domestic scientific and technological milieus are usually so small that keeping an eye on each other is quite easy. The following statements by two university interviewees and one industry interviewee illustrate the importance of personal contacts and networks:

"I started co-operating with some people about 10 years ago. And we are still in touch, even though these people are working for different companies now. (...) It's all on a personal level. So when they start working for a different company, the collaboration sort of follows them. And it's very rarely formal."[7]

"Personal contacts are very important, and much of the contact with industry is based on this. They make a phone-call if they have a problem."

"Collaboration is almost entirely based on contacts. Except from student theses, almost everything is informal and based on previous contact. The domestic milieu is quite small, so we know where we can get help. We meet people at conferences, know them from university studies or search for them."

All interviewees agreed that they prefer to work with people they already know, in order to prevent misunderstandings and conflicts regarding for instance research goals, time-schedules, modes of collaboration or intellectual property rights. The interviewees suggested that previous knowledge of each other is particularly important for the initiation of collaboration. This is partly due to practical matters such as lack of resources and time to keep updated on all relevant collaboration partners. However, mutual trust and understanding were perceived as more important factors affecting the chance of successful collaboration. Quite a few of the industry interviewees stressed that trust was important not only because of the threat of leakage, but also in order to assure that they are working with somebody who understands that companies have to work on a tight time-schedule. Some of the university interviewees argued that successful collaboration is unlikely if the parties do not know each other's academic capabilities. Previous knowledge of the other part thus seems to influence the parties' confidence in collaboration and each other.

Personal contacts are to some degree established through channels such as conferences, meetings and research programs. Some interviewees argued that participation in large research programs may be motivated mainly by the possibility of establishing new contacts, since the output in terms of new knowledge in many cases is considered minimal. Quite a few interviewees particularly mentioned large EU-projects as typical examples of collaborations where the main goal might be new contacts. According to the interviewees, chance meetings at conferences can be very valuable, and quite a few collaborations are initiated rather incidentally through such meetings. However, all interviewees emphasised that the main bulk of personal contacts are former colleagues and students. Students establish contact with future industry and university researchers during their university studies, and some of these contacts persist over time. Networks of university and industry scientists and engineers seem to be

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[7] The quotations are translated from Norwegian to English by myself.

based mainly on common academic background. The industry interviewees admitted that they are most likely to collaborate with scientists and institutions they or their colleagues know through education. Two of them exemplified this, arguing that:

"Much is initiated on the basis of old friendship and knowledge of each other. (…) Often you know the milieus through education, because you have studied at the university yourself - and more formal types of contact are often based on these relations."

"Collaboration is almost always established through our network. Personal contacts play a significant role. You have studied at the university, and you have friends who still work there. You travel together and go out for a couple of beers after conferences and - well, you end up discussing technical and scientific problems in your leisure time, too."

The university interviewees agreed that most of their industry contacts are former colleagues, students or friends from their studies. Former students were considered particularly important industry contacts by the university interviewees, and much collaboration seems to be based on such prior student-professor relations. This illustrates how students can be important channels of communication between the two sectors. The following statements by an industry and a university interviewee exemplify how students might play an important role as contacts:

"Students taking their main subject[8] and doctorate degree are important to us. We establish a lot of contacts through them. There are quite a few spin-offs from these

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[8] 'Main subject' denotes the Norwegian 'hovedfag'.

activities: we started supervising some students from a university in Sweden, and soon we invited professors over here to give lectures etc."

"I guess about 10-20 % of our students do their master thesis in a company, but it depends on us knowing somebody.... Most often, former students are working in these companies, and we ask them to fix something."

These statements exemplify that students might be important for the maintenance of scientific and technological networks. Student theses, supervising and internships provide possibilities for university and industry researchers to stay in touch and keep updated on each other's competencies and fields of interest. Nearly all the interviewees stressed that student-related collaboration sometimes is an effective way of establishing new contacts and thus expand existing networks. Interviewees from the industry as well as from the university sector acknowledged this benefit from collaboration. Most interviewees considered "side-effects" of student-related collaboration, such as new contacts, more important than the direct outputs in terms of new knowledge.

3.1.3 Some conclusions regarding modes of collaboration

What we realise is that university-industry relations are rich and diverse, and that they encompass long-term collaborative research as well as specific problem-solving based on ad-hoc arrangements. The motivations for engaging in this multitude of linkages will be explored and discussed further in the following sections. However, a certain collaborative pattern might be discerned: university-industry collaboration seems to rest almost entirely on personal contacts between individual scientists and engineers in the university and industry sectors.

These relations seem to be long-lasting and based on common academic interests. University-industry collaboration therefore appears as a highly networked process of informal interactions based on personal contacts and mutual trust.

3.2 Why do private companies collaborate with universities?

Traditional economic analyses of technological innovation have stressed the gap between private and social rates of return to investments in knowledge production, as discussed in section 2.1.2. Bonaccorsi & Piccaluga (1994) argue that according to these analyses, the only motivation for private companies to collaborate with universities is in order to get access to basic research, for which there is a low private incentive to invest internally. However, investigations of university-industry collaborations have revealed that companies' motivations for entering such collaborations are much more complex. This is more in line with modern approaches to innovation, which suggest that the impact of academic research on industrial innovation is largely indirect. According to this view, universities serve as a "knowledge infrastructure", leveraging well-educated scientists and engineers, rather than as a direct source of innovation. This implies more diverse motivations for companies to collaborate with universities than the "old" paradigm does. Different motivations for companies to collaborate with universities will be discussed in the following sections.

3.2.1 Access to scientific frontiers

The "old" paradigm in innovation theory (see section 2.2) suggests that academic research may be utilised rather directly for new products and processes. According to this view, companies might be expected to collaborate with universities mainly to get access to research results at a very early stage, in order to develop new products and processes faster than the competitors. But how important is early access to research results for companies' innovativeness? Access to scientific frontiers is commonly considered one of the main motivations for companies to collaborate with universities (see e.g. Bowie 1994; Geisler & Rubenstein, 1989). However, access to scientific frontiers might be important for several reasons, and not only in order to get new ideas for products and processes. Other advantages from access to the scientific frontier might encompass state-of-the-art information, access to scientific networks and joint competence building in new fields of interest. The industry interviewees in this study generally confirmed that access to the scientific frontier is an important rationale for collaboration, and some argued that this is the most important motivation. Although academic research in rather exceptional circumstances might be utilised rather directly for industrial innovation, the interviewees considered competence building, access to state-of-the-art information and scientific networks even more important benefits from staying close to the scientific frontier.

New, useful ideas for products and processes

Although most innovations are incremental "bottom-up" processes, clear examples of science-based, linear innovations exist. Several of the industry interviewees in this study reported that they had been involved in university collaboration resulting in patents or new products.

Nearly all of them had also experienced being contacted by university researchers, sometimes from abroad, with ideas for patents or products. The interviewees stressed that such approaches usually are based on prior contact, although there are exceptions. The frequency of such approaches seem to vary considerably between different sectors, and interviewees in the biotechnology and pharmaceutics companies reported about more such incidents than the other interviewees. One of the industry interviewees in this sector even reported that this happened several times a year. The university interviewees were somewhat more hesitant to this, although two of them said they sometimes did approach industry with specific ideas for innovations. As one of them explained:

"When university researchers are young and "new in the game", they are almost always contacted by industry, and not the other way around. But when university researchers get some experience with industry collaboration, they are usually the ones initiating collaboration. In my case, this is almost always the case. You understand that something might be interesting for industry, and then you get in touch with companies in your network. I have a handful of companies in my network that I usually go to."

Even though these examples demonstrate how university research can be used as a direct source of new ideas for innovations, it is important to note that most of the interviewees stressed that this is the exception rather than the rule. They did not consider new ideas for innovations a very important motivation for collaboration, and they put more emphasis on obtaining state-of-the-art information as one of the major benefits from collaboration.

Obtaining state-of-the-art information

State-of-the-art information does not contribute directly to companies' innovation efforts, but keeping an eye on the latest developments on the scientific and technological frontiers might effect the innovative capabilities of companies in a long-term perspective. Access to state-of-the-art information is commonly regarded as one of the main motivations for companies to collaborate with universities (see e.g. Bonaccorsi & Piccaluga, 1994; Geisler & Rubenstein, 1989). "Modern" approaches to technological innovation, and particularly evolutionary economic theory, stress the risk and uncertainty of technological development. Still, technological and scientific advance is seen as strongly cumulative processes. Competition forces companies to follow short-term strategies. Narrow specialisation might increase companies' risk of getting "locked in" into one technological trajectory and miss other opportunities. According to this view, staying abreast of scientific and technological frontiers can be an important tool for companies trying to predict directions of research and to decrease the threats of lagging behind technological developments.

The industry interviewees argued that state-of-the-art information might be obtained from a wide range of sources. These include literature, conferences, personal contacts and regular meetings with research groups at the universities. Two of the industry managers interviewed said that they obtain state-of-the-art-information through regular "updating"-meetings with university researchers. Nearly all the industry interviewees considered university contacts important for open exchange of opinions about trends and possible future directions of research. Such discussions seem to take place both on a formal basis and on a more irregular and informal basis through personal contacts. Interestingly, four of the companies involved in this study have university professors as members of their "scientific board". The following statements by three industry interviewees from the computing and information technology

and the biotechnology sectors demonstrate how some companies use industry in order to obtain state-of-the-art information:

"We have a scientific board in which some university professors are members. They play an important role by keeping us informed about what is going to happen in the future. The biotechnology industry has a very high turnover on new technology, and it is decisive to stay in touch with the scientific institutions in order to stay abreast of the development."

"We have university professors in our scientific board. They keep us updated on trends at the scientific frontier, thereby giving us information about possible new areas of interest."

"For five years we had a sort of "boy's club" with members from industry, research institutes and universities who were all working within the same field. We met once in a while and explained what we were doing and had a good time. The main motivation was to discuss future trends and developments - what kinds of competencies were likely to be the most important in the future, and stuff like that…".

All the industry interviewees agreed that they contact university researchers once in a while in order to get a point of view on the direction of research. However, much state-of-the-art information is exchanged through channels of a very informal character, as illustrated by the last statement. Open discussions about the future direction of research were considered positive "side-effects" of other types of collaboration by several interviewees. The possibility of an open exchange of opinion was also appreciated by some of the university interviewees,

who mentioned informal discussions with industry researchers as an additional source of knowledge and learning.

Joint competence building in new fields of interest

Staying abreast of scientific frontiers and keeping a "window on technology" was not only seen as important for identification of future directions of research or as a source of new ideas, though. Some of the interviewees also regarded closeness to the research frontier relevant for more general competence building. As a part of their strategies for expanding their knowledge base, some companies regularly invite academics to give lectures, let their employees take courses or degrees at the university, have workshops etc. Expansion of their own and of the available knowledge base in directions that might possibly be important for future innovation seems to be a long-term strategy for some companies. It is interesting to note that industry interviewees from different sectors acknowledged this motivation. As two of the industry interviewees, from the computing and information technology and the biotechnology sectors, argued:

> "I think people easily draw too negative conclusions because their ambitions
> are too high, and maybe they don't see the values created. (...) One example is
> that we built a milieu around a technological field, X, in Norway. Now there are
> five people in this company and five in the institute sector and five at the
> university who knows this technology. That's the fruit of collaboration."

"We do not expect university-collaboration to help us develop new products any faster. We use university collaboration as a way of building competence in certain academic fields we believe will be important in the future."

Such joint efforts to build new areas of expertise and specialisation were mentioned as fruitful modes of collaboration for both universities and companies. There is interesting research involved for the academics, and the companies get a chance to build up a new specialisation without having to acquire all the competence internally. In a few cases, influence on the direction of research was seen as a potential benefit from rather "basic research" collaborations. One industry interviewee argued that his company actively tried to "…canalise the existing university competence towards the fields and problems that are most relevant to us." However, all those who saw this as a potential motivation for collaboration, stressed that financial support from public sources is a necessity, since building up new areas of competence is costly.

Access to scientific networks

Since linkages between universities and industry commonly seem to be informal and based on personal contacts, access to scientific networks might be a possible motivation for companies to enter collaboration. University researchers are members of international networks of expertise and have a "knowledge of knowledge" that enable them to utilise the knowledge of other scientists and engineers (Pavitt, 1998). Access to scientific networks has been identified as a rather important motivation for collaboration by some studies (see e.g. Bonaccorsi & Piccaluga, 1994). Through contacts in the academia, industry gets access to a wider network

of knowledge. This was too some extent acknowledged as a motivation by the interviewees in this study as well. As one of the university interviewees argued:

"The most important benefit for companies collaborating with universities is that they get access to a network of expertise, and then they know where to go next time. (…) I do a lot of consulting for industry. This is particularly due to my experience, which gives me a very wide network. Through me, industry gets access to a wide spectre of public and semi-public research institutions. Thus, they get access to a lot of research in a more cost-effective manner than if they had to gather this information themselves. I know where to find the information they want."

Although only a few industry interviewees agreed that they deliberately seek university-collaboration in order to get access to such networks, most of them acknowledged that this is a valuable side effect of collaboration. By being included in scientific networks, companies know where to go when they need assistance, and they increase the possibility of being contacted by university researchers with ideas for commercialisation. Some interviewees also acknowledged the benefits of having university as a "back up"-institution for industry researchers, both as an assurance and in order to keep some of the most academically interested industry researchers happy. One of the industry interviewees explained this:

"Competence is the main thing at universities, right, and that's what we go there for. It's not because we want to buy small things like analyses or tests. We don't bother them with that. It's because we want a scientific milieu that our researchers can lean to and get support from. It's two-way, but from our point of

view - well, our researchers like to have and get enriched by having a scientific milieu backing them. It's part of our quality assurance."

Broadly speaking, staying abreast of scientific and technological development seems to be an important motivation for companies' to engage in university-industry collaboration. But staying close to the scientific frontier is not only a question of early access to research results for new products or processes, although this can be an outcome of collaboration in quite exceptional circumstances. More commonly, companies seem to use university contacts as "gatekeepers" for advise on future directions of research and in order to identify new fields of interest for commercial exploitation.

3.2.2 Access to expertise, skills and problem-solving capacities

Both industry and university interviewees seemed to share the view that although companies might benefit from access to the scientific frontier, university researchers are usually approached for more specific purposes. Access to university researchers' specific skills or problem-solving capacities has been highlighted as one of the most important motivations for collaboration by several studies lately (Pavitt, 1998; Senker & Faulkner, 1994; Meyer-Krahmer & Schmoch, 2000). The interviewees in this study generally confirmed that access to university researchers' specific skills and problem-solving capacities is often in the main motivation for collaboration. As two of the industry interviewees, from the computing and information technology and from the bio-technology sectors respectively, explained:

"Specific knowledge and projects are our main targets. We approach universities mainly if we need expert knowledge in areas where we do not have the necessary competence ourselves. They complement us in the areas where we ourselves are weak."

"Specific expertise for problem-solving is important. University competence is utilised both for predicting general trends and for specific problem-solving."

All the interviewees agreed that companies do not use universities primarily as a source of new ideas for products and processes. Rather, companies tend to approach universities for help and assistance when they run into a very specific problem that they are not able to solve themselves. Hence, university-industry collaboration often seems to involve specific problem-solving rather than long-term collaborative research. Collaboration of a "problem-solving" kind usually involves ad hoc-arrangements, and universities thus seem to be included rather late in the innovation process. This was indeed confirmed by all the interviewees, who argued that industry very seldom turns to universities without having specific projects or problems on their minds. According to the interviewees, universities are rarely the first place for companies to look for assistance when they lack internal resources and competence to solve a specific problem. Research institutes and technological consulting companies are more common partners, and these are more adjusted to industrial problems as well as to companies' time-schedules. If university researchers are turned to for help with specific problem-solving, this is almost entirely based on personal contacts. All the interviewees strongly emphasised that personal contacts are particularly important for the delegation of specific problems and tasks.

According to the interviewees, companies very rarely engage in research just out of "curiosity". Research of a very basic kind is an expensive and risky investment, and the interviewees argued that very few Norwegian companies are large enough and close enough to the scientific frontier to conduct such research. If research of a rather explorative character is conducted, this seems to be related to competence building in new academic fields or areas of expertise. Even though research collaboration can be a way of accessing basic research in a more cost-effective manner, the interviewees still argued that "basic" research collaboration is quite rare and heavily dependent on public support. University researchers thus seem to be approached mainly for their problem-solving skills, and rarely for collaborative "basic" research.

However, several of the interviewees emphasised that the development of what they described as *generic technologies* or *product concepts,* is another important area of university-industry collaboration. Such generic technologies or product concepts have a wide range of potential applications. Quite a few of the interviewees argued that development of generic technologies represents a typical area of overlapping interests between universities and industry. The research activities involved are not of a very "basic" character, but they are neither as specific as most of the development activities companies usually undertake. The complementary knowledge of university and industry scientists and engineers was seen as particularly valuable for the development of such technologies (see section 3.3.3). The interviewees in the biotechnology sector emphasised that they quite often have a "product concept" rather than a specific product on their mind when approaching universities, as exemplified by the first of the following statements. The other statements further exemplify the importance of collaborative development of generic technologies, as perceived by industry interviewees from the biotechnology and the computing and information technology sectors, respectively:

"We sporadically contact universities when the company needs a solution to a particular problem. This is one form of collaboration, but more general research collaboration is more common. (…) Small tasks are delegated to the university because they have the equipment, but other collaborations are started in order to get a product concept rather than a concrete product."

"We usually collaborate with universities through larger projects that may result in general technologies. Such general technologies can be a basis for the development of several products."

"The research we do in collaboration with industry is not directed towards specific projects, it's more about developing general technologies."

As we understand from these examples, companies do not approach universities for general state-of-the-art information or for new ideas for products and processes only. Companies also seem to acknowledge academic researchers' capacity of solving complex technological problems. This capacity is utilised both for the development of "generic technologies" and for the solving of very specific problems that companies run into during an innovation process. The perceived importance of university researchers' skills and problem-solving capacities suggests that scientific and technological knowledge have important tacit, or person-embodied, aspects. This is more in accordance with modern than with traditional approaches to technological innovation, and several studies have pointed to problem-solving capacity as the most important contribution of academic research to industrial innovation (see e.g. Pavitt, 1998, Senker & Faulkner, 1994, Gibbons & Johnson, 1974).

3.2.3 Testing, feedback and access to university facilities

Closely related to the importance of person-embodied skills, companies might turn to universities for tests, assistance with experimentation and feedback on new products and processes. Access to university equipment is commonly mentioned as a motivation for collaboration (see e.g. Geisler & Rubenstein, 1989; Bowie, 1994), but this was not seen a very important factor by the interviewees in this study. On the contrary, the interviewees argued that industry often has more advanced equipment than the universities, and that university researchers today are just as keen on getting access to industry's equipment as the other way around. Still, access to university facilities was not considered completely irrelevant as a motivating factor. Universities may have some instruments that take up a lot of space and are too expensive to buy for any singly company. However, the interviewees argued that Norwegian universities are suffering from deteriorating equipment. Some of the interviewees, mostly within the biotechnology sector, pointed to a specific reason for collaborating with universities: At the universities, there are people capable of utilising scientific instruments and of interpreting results of analyses and tests. The following statement illustrates this aspect of access to university facilities:

> "When sponsoring PhDs, we try to build a good relation to the institute, since they often have good instruments for analyses etc. We can do some analyses and get something back from the collaboration this way. In some cases, we have better laboratories than the universities, but they often have large instruments and people who can operate them. We cannot afford having people just operating instruments. It's nice to go to universities in these cases, because they have competent people to operate these instruments."

According to most of the interviewees, feedback and testing is an important part of the informal contact between universities and companies. The interviewees in the computing and information technology sector particularly emphasised the importance of feedback and testing of components and prototypes as an important mode of collaboration. University researchers receive components, new machines and software, and in return they provide feedback and advice on possible improvements. Both industry and university interviewees in this sector agreed that university researchers and students play a role as particularly competent users. The following statements by an industry and a university interviewee in the computing and information technology sector illustrate the role of university researchers as competent users:

"Having universities as users is excellent. It provides you with the possibility of feedback. An example is scientific personnel, PhDs or students working with our products and giving us continuous feedback."

"My impression is that industry approaches us when they almost have a finished product. They have a prototype or an idea, and they ask us: 'Do you think this is a good idea?' or 'Could you test this for us? Can you help us improve this one?' We often add some software or components, and I believe we are used as a sort of competent users or 'beta-users'".

The last statement demonstrates very well that universities are sometimes approached for feedback on prototypes and new products. Several of the university interviewees argued that the most frequent contact was indeed of this kind; industry approaches their contacts at the university to get feedback on prototypes and products that are almost ready for production. This kind of feedback is one of the clearest examples of how university researchers can contribute directly to companies' innovation processes, and some of the industry interviewees

emphasised that such feedback can be a very valuable contribution to product development and contribution.

3.2.4 Recruitment

Access to university researchers' skills has already been mentioned as one of the main motivations for companies to collaborate with universities. However, access to skilled graduates for recruitment purposes is also commonly regarded as an important motivation for companies to collaborate with universities (see e.g. Wu, 2000; Geisler & Rubenstein, 1989). Nearly all interviewees acknowledged this motivation. Both industry and university interviewees confirmed that most companies look at universities as an important source of highly skilled employees. Particularly the computing and information technology sector has a lack of qualified employees, and the competition for new recruits is fierce. Interviewees in other sectors also agreed that recruitment is an important motivating factor for collaboration, however. Several benefits from student-related collaboration were acknowledged. Firstly, having a diploma-, master- or PhD-student working on something interesting for the company does not only provide the company with rather "cheap" labour and access to research results. Maybe more importantly, the graduate can be a valuable recruit when finishing the project. The company has the opportunity to "test" possible future employees, as well as to educate and train people in fields of interest at low cost. This benefit was emphasised by nearly all interviewees, as exemplified by the statements by a university and an industry interviewee:

> "PhDs and other graduates are usually financed by university, and they provide
>
> a valuable opportunity for companies to test recruits and train them for free."

"Recruitment is an essential part of collaborating with universities. We have many examples in this company of people who have done their projects in our company and continued working for us afterwards. People who have been working with us for a year or three have an enormous competence compared to other graduates."

As mentioned above, modern approaches to innovation suggest that person-embodied skills are an important output of academic research. The importance of students as carriers of academic knowledge into the industrial sphere has been highlighted by quite a few studies, suggesting that skilled graduates might very well be the most important contribution of academic research to industrial innovation (see e.g. Gibbons & Johnson, 1974; Florida, 1999; OECD, 1997). The empirical findings in this study seem to support the view that students provide a key link between universities and industry, and that skilled graduates might enhance the innovative capabilities of companies.

3.2.5 Conclusions regarding companies' motivations for collaboration

As one understands from the above discussions, companies' motivations for university collaboration are not restricted solely to achieving early access to research results in order to develop new products and processes faster. Rather, the rationales for companies to get involved in collaboration seem to be many and diverse. Academics might be contacted for prediction of future directions of research, for identification of new areas of commercial interest, for specific problem-solving and for recruitment purposes. Rather than regarding universities as the source of new technology, companies seem to utilise them for the

delegation of specific tasks during an innovation process, as well as for more general competence building.

3.3 Academics' motivations for collaboration

While quite a few studies have focused upon industry's motivations for collaboration with universities, university's motivations for entering collaborations have caught less attention. Declining government support, increased costs and a growing demand for economic relevance of university research are seen as some of the driving forces behind the increase in university-industry collaboration (OECD, 1999; Bowie, 1994). Motivations such as access to industry facilities, exposure of students to future employees, adjusting of curricula and access to companies' engineering competence are often mentioned as factors that might have some impact on university's interest in collaboration. However, access to external sources of funds seems to be widely acknowledged as academics' single most important motivation for collaboration (Hall et al., 2000; Bowie, 1994; ESTA, 1997, OECD, 1999). The following analysis will investigate whether or not this is a satisfactory explanation of university-industry collaboration in Norway for the examples observed in the course of this study.

3.3.1 Access to external sources of funds

The last decade or so some have argued that the situation for academic research in Norway is worsening. This has been considered a consequence of such factors as insufficient government funds, a large increase in number of students, deteriorating equipment and

recruitment problems. Several of the interviewees in this study, from both parties, perceived that there is some kind of crisis going on at the Norwegian universities nowadays. Most argued that this is due to decreasing funds, although a few regarded this more as a crisis of identity, where the universities struggle to define their role in a new and knowledge based economy. Statistics do not support the view that Norwegian universities are undergoing a crisis, at least not in terms of funds. The government support of universities has not been declining, although external funds have increased their share of the total budgets in the higher education sector from 21 % in 1981 to 31 % in 1997 (Research Council of Norway, 1999). This might indicate that the university sector has become quite dependent on external sources of funds. However, industry is only a minor source of external funds. In 1997, the level of industry funding of research in the higher education sector was about 6 % (Norwegian Research Council, 1999). Universities might have become more dependent on external funds, but about 90 % of the total budgets are still covered by public sources. There is no dramatic drop in government funding suggesting that universities have become dependent on industrial funds.

The opinions on funds as a motivating factor varied greatly between the interviewees in this study. One of the university interviewees stated that money was totally irrelevant to him, as he was in the start of his career and more concerned with publications and competence building. However, all the other interviewees considered access to external sources of funds a relevant motivation for academics to collaborate with industry. Still, the emphasis they put on this factor varied considerably. Neither university nor industry interviewees considered personal gain a relevant motivation for academics to enter collaborations, although university researchers may benefit from their research results through patents and licences[9]. Several of

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[9] According to Norwegian legislation, university researchers have the intellectual property rights to results of their own research (Source: Norges lover: "Arbeidstakeroppfinnelsesloven", paragraf 1).

the interviewees emphasised that scientist will not stay at the university if they are motivated mainly by money. As one of the university interviewees explained:

"University professors in this country are not well paid, and we could all have made a lot more money working in the industry. So personal gain is definitely not a motivation for collaboration. Those who choose to become university professors, despite the low salaries, do it out of academic interest. However, external funds can be important because you get the opportunity to finance other interesting research."

Most of the interviewees agreed that external sources of funds might be important, but rather as a means of financing other research projects at the institute than as a source of personal gain. The interviewees from the university administration shared this view, arguing that about 90 % of university departments' budgets are allocated to salaries and other fixed expenses. Hence, there is not much room for university departments, institutes and research groups to make own priorities. Additional sources of funds seem to be welcomed mainly because they increase the economic freedom of university departments and institutes, thereby enhancing their ability to make their own research priorities.

One of the most central questions regarding university-industry collaboration, is whether or not academics tend to accept research tasks that are not academically challenging in order to get hold of external funds. A rather striking finding is that although the industry interviewees regarded access to funds as one of the main motivations behind academics' interest in collaboration, none of them believed that university researchers would engage in research collaboration that is not academically challenging. The university interviewees, on the other hand, were more divided on this question. Some argued that access to funds is one of the main

motivations for collaboration, and that they might accept collaboration involving research without much academic interest in order to get access to external funds, as exemplified by the following statements:

> "Contract research is a necessary evil. But it's OK, since it's a way of funding other research projects. I usually say that we must accept a level of 20% "prostitution" in order to do what we would like to do the last 80% of the time. Industry pays very well, so this is not a problem, really."

> "Collaboration is fine because you get money to do interesting projects. The projects are academically interesting, although I believe we would accept also more routine-projects if they were well paid. University collaborates with industry mainly because there is an increasing pressure to get hold of external resources, I believe".

Although some university interviewees agreed that access to external funds was so important that they might engage in collaboration not offering very academically interesting problems, they still regarded this a quite unlikely situation. Those who admitted that they might do some "routine" work for industry mainly motivated by the payment, argued that they would hardly accept collaboration with absolutely no academic value. If they accept such tasks, the collaboration is usually undertaken on a private basis, the university interviewees emphasised. However, the majority of the university interviewees argued that they would simply not accept collaboration involving research that is not academically interesting and challenging. Some argued that there is a lot of administrative work connected to external funds, and that industry in fact does not pay very well. Collaborations most often involve a great deal of resources also from the university, and industry rarely pays more than a maximum share of 40

% of the total expenses[10]. Some of the university interviewees stressed this, and they did not consider access to external sources of funds the main motivation for collaboration. As one university researchers argued:

"We feel a certain pressure[11] from the administration, but often there is so much administrative work connected to external funds, and the net gain is very low or none. The industry does not pay that well – actually we tend to underprice what we do. So we don't accept collaboration if there is no interesting research involved".

As mentioned above, industry is not the only source of external funds. The Research Council, the state ministries and the EU are examples of other important sources of external funds for research projects both in the university and in the industry sector. External funds from these sources are sometimes earmarked for public-private research collaborations, and access to these funds therefore might be a motivation for universities and industry to seek collaboration. Both the industry and the university interviewees agreed that access to such funds can be a motivation for collaboration sometimes, and that this sometimes leads to formalisation of collaborative relations. Several industry interviewees reported about incidents of university researchers or research groups approaching them with projects involving such external funds. The university interviewees also partly acknowledged this motivation, and some of them argued that they had been approached by industry interested in access to such funds. Most of the interviewees argued that they did not actively try to initiate collaboration in order to get hold of external funds, but they all regarded this as a factor helping collaborative agreements get started.

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[10] According to my sources in the university administration, industry finances 15% if a project is classified as a basic research project, and 40 % if it is classified as a more application-oriented industry project.
[11] The interviewee was pointing to pressure to get hold of external funds.

3.3.2 Exchange of knowledge

While funding is commonly acknowledged as one of the main motivations for academics to collaborate with industry, access to industry's competence seems to be more or less ignored as a possible motivating factor. Competence is seen as the most important rationale for industry to get in touch with universities, but not so much the other way around. However, the view of university-industry collaborations as "asymmetrical" learning relations, involving learning only for industry, has been challenged by some recent studies. These suggest that university-industry collaborations in some cases might be "symmetrical" relations involving mutual learning (Meyer-Krahmer & Schmoch, 2000).

Possibilities for two-way learning are often related to the complementary knowledge of universities and industry. Universities can benefit from the more know-how-related knowledge in industry, and from their engineering expertise. The interviewees in this investigation generally confirmed this view. Both industry and university interviewees, particularly within the computing and information technology sector, claimed that some of the synergies from collaboration stemmed exactly from combining the knowledge of university researchers with the more practically oriented "know-how" of industry researchers. By joining the general competencies and the broad orientation of university researchers with the problem-solving capacities of industry researchers and engineers, interesting results could emerge, several of the interviewees argued. The following statement by one of the university interviewees exemplifies this:

> "I guess I also learn from them. Definitely. They have more competence of the
>
> "how to make it work" kind, or more engineering competence, you might say.
>
> When we co-operate with industry, we get access to this competence, and that's

very useful for us. If you only have the broad picture, your ideas might not be possible to realise."

The combination of university and industry scientists' complementary knowledge was seen as particularly fruitful for the development of generic technologies, as discussed in section 3.2.2. Much academic research seems to be closely related to instrumentation, particularly in the computing and information technology sector. New instruments, machines or equipment might serve as "building blocks" for new research, some interviewees argued. According to some interviewees, particularly within the computer and information technology sector, industry sometimes generates interesting and puzzling problems for research. This view was generally confirmed by the university interviewees, who all agreed that industry sometimes come up with intriguing problems catching their interest. The following statements by industry interviewees in this sector illustrate how joint university researchers might benefit from collaboration through the development of "platform technologies" as well as industrially generated research problems:

"Although our equipment is important to them, I do not think that is their main motivation for collaborating with us. The most important factor is the technology we represent, and the research aspects related to this technology. We have made it possible for the university to start new research projects and try out new possibilities based on results of our joint projects. You can look at our products as some sorts of "building blocks" that open up possibilities for new areas of research."

"It must be very satisfactory for academics to increase the number of industrially generated problems that we present and work at. I am sure we

provide university researchers with very challenging problems. Absolutely. Otherwise, there wouldn't be this kind of collaboration."

Universities do not only benefit from industry's "engineering" knowledge, however. Both industry and university interviewees agreed that in some "high technology" and "science based" sectors, such as biotechnology and computer science, industry might have as much, or even more, competence than universities. It is interesting to not that all the university interviewees acknowledged the high competencies of their industrial counterparts, thus breaking with the myth of the university as an "ivory tower". The industry interviewees seemed confident that their companies contribute to their university partners' learning processes. They argued that university researchers learn from the expertise industrial scientists and engineers have in some very specific areas, where their knowledge might complement and supplement that of the university researchers. The following statements by university interviewees from three different fields illustrate that the university interviewees acknowledged their industrial counterparts' competencies:

> "The point is that particularly within the IT-industry, but also in biotechnology and all these new branches, there is so much competence in industry that very often competence flows from the industry sector to the university through its employees. (…) If there is any one-way flow of knowledge, I would say that it is from the outside and into the university"

> "We learn a lot from industry. Several companies in this sector have expertise on areas that are complementary to ours. The researchers in industry are very knowledgeable and up-to-date."

"Some of the largest companies have very competent researchers that are very up-to-date within their field. We learn a lot from them, I guess. (…) It's very true that industry has a very high competence within certain fields, such as material sciences, biotechnology, electronics, computing and such…"

The potential benefits from combining university and industry researchers' complementary knowledge were recognised by nearly all interviewees. However, nearly all interviewees emphasised that in certain new fields of science and technology, such as biotechnology, computer science and materials science, the research conducted by industry is not very different from university research. Most interviewees argued that industry is undertaking more science-based activities nowadays, and that this opens up new possibilities for university-industry collaboration in certain fields of science and technology. The high competence of many companies in some high technology and science-based sectors was indeed acknowledged by both university and industry interviewees, as exemplified by a university interviewee from the computing and information technology sector and an industry interviewee from the biotechnology sector:

"In the "brain-industry" today – well, of course you work within an economic reality, but the way you organise your work… it has become very similar to the situation at the universities (…) The opportunities for collaboration have increased because some parts of the industry are working at more scientific problems. The research conducted in the industry and at the universities has become more similar".

"There is no sharp division between university and industry research anymore. Universities should not resent collaboration, because much of the interesting

research today is conducted in the industry sector. There is a lot of competence here, and the universities have a lot to learn from us. Our company started as an effort to import and build a new technology in this country. This competence did not exist here before, and now there are people at the universities engaged in what we are doing, too. That's a very clear example that universities can learn from companies. We built the competence together, and it was definitely a case of two-way learning and communication."

All interviewees acknowledged that the possibilities for collaboration were highest in the more "science-based" parts of industry, where industry often has a higher competence than universities. Four of the industry interviewees reported that their company had collaborated closely with industry as a means of building domestic competence in a new academic field, and this was seen as a typical case of two-way learning with benefits in terms of new knowledge for both parties. Some of the university interviewees agreed that industry actually provides an important forum for open discussions of scientific problems, as the boundaries between industrial and academic research are quite blurred in certain fields of science and technology. This supports the view that certain parts of the industry today is indeed so scientifically and technologically competent that academics have trouble keeping up with their industrial counterparts.

3.3.3 Access to industry's facilities and equipment

As discussed in section 3.2.3, industry today tends to have more advanced instruments, facilities and equipment than universities. This particularly seems to be the case within the computing and information technology sector. Since research and development activities

within this sector are often very closely related to the machines or to the software as such, university interviewees agreed that they increase their competence by getting access to the most advanced equipment available. A an industry and a university interviewee within this sector said:

> "It's more like we have more than them, right, and it's often very interesting for students and PhD's to come here and try out our equipment when they are doing their research".

> "We often receive free equipment from companies we collaborate with. And this equipment tends to be so advanced and interesting that we do some testing almost for free."

The interviewees in this sector acknowledged that instrumentation represents a channel of knowledge flow, and that academics appreciate access to industry's equipment. Academics benefit from industry's advanced equipment, and companies benefit from feedback on this equipment. In other words, this is another example of how knowledge might flow from the industry sector and into the university sector.

3.3.4 Other benefits and motivations

According to the interviewees, knowledge exchange and access to external sources of funds definitely are the most important rationales for collaboration, although access to industry's instrumentation and equipment might play a role in some cases. Factors commonly mentioned as motivations for universities to collaborate with industry, such as industrial career

opportunities and employment for students, adjustment of curricula and exposure of students to industrial problems (see e.g. Bowie, 1994; Geisler & Rubenstein, 1989) were not considered important motivations for collaboration by hardly any of the interviewees. However, a few of the university researchers argued that industry collaboration indicated whether or not their own research was on track. As one of them said:

"The most important reason for collaborating with industry is to make sure that my research is on the right track, so to say - that I don't start working on a side-track that nobody's interested in. Within the field of X, it is important that you do something that somebody takes interest in. If you don't - well, then you'll end up working all by yourself, and nobody will be interested in what you're doing…"

Nearly all interviewees emphasised that some university researchers actually find it stimulating to see their ideas turn into innovation projects, or to help pulling projects through. The university interviewees in this study might be the exception rather than the rule, but at least this study reveals that some university researchers actually find it valuable to stay in touch with "the rest of the world". As a university and an industry interviewee argued:

"Doing something else for a while is not unimportant. Collaboration with industry helps us stay in touch with the rest of society. It is interesting and motivating to see that some of what we are doing can actually contribute to new products and innovations. You see some real and substantial output of your own research, and I really enjoy that."

"I believe that industrial use of their research is an important motivation for many researchers, particularly for those working within technological fields. It's nice for them to see their students doing a career in industry, and they are a bit proud that they took part in their education and training… That's pretty obvious."

3.3.5 Conclusions regarding academics' motivations for collaboration

As we understand from the above discussion, the view of university-industry collaborations as one-way knowledge transfers does not seem very appropriate for the collaborations described by the interviewees in this study. The discussion of academics' motivations for collaboration reveals that academics to not perceive industry only as a source of external funds, but that some academics also view industry as a source of high competence and potential learning. The findings suggest that in some fields of science and technology, access to industry's competence might be more important than access to external funds as a motivating factor for academics. In other words, university-industry collaboration in some cases seem to be processes of knowledge exchange and mutual learning.

3.4 Obstacles to collaboration

Although there might be several rationales for entering university-industry collaborations, there are also quite a few obstacles to such collaboration. One should bear in mind that collaboration always involves costs in terms of time and resources. The most obvious obstacle to university-industry collaboration is the differences in research mission - universities mainly perform research of a rather "basic" character, while industry is more into product development. However, we have seen that there are areas of overlapping interests. Still, there might be obstacles to collaboration even in these areas of overlapping interest. Other factors than the strategic ones might affect the initiation and success of collaboration. Conflicting interests and values, conflicts regarding intellectual property rights and publication, different time horizons and hostile attitudes are problems commonly related to university-industry collaboration (Wu, 2000; Bowie, 1994; Geisler & Rubenstein, 1989). The relevance of these obstacles to collaboration will be discussed in the following sections.

3.4.1 Intellectual property rights

Questions related to intellectual property rights are commonly identified as one of the most problematic areas of university-industry collaboration (see e.g. Geisler & Rubenstein, 1989; Bowie, 1994). The interviewees in this study generally confirmed that intellectual property rights indeed can be very problematic. As mentioned before, teachers and scientific personnel at the universities have the intellectual property rights to their own ideas, if nothing else is specifically stated in the research contract. However, deciding who is the source of an idea in a collaborative project is often an impossible task, and companies are rarely interested in financing research without getting property rights to the results. According to the

interviewees, companies usually get the property rights to research results when financing a research project. Nearly all the university interviewees seemed to accept this practice, arguing that it is a necessary condition for companies to invest in university research at all. This is exemplified by one of the university interviewees, arguing that:

"Companies won't invest in university research if they can not get any exclusive rights to the results. The university and faculty are not interested in patenting, so it's ok that industry applies for patents".

At large, both industrial managers and university researchers agreed that companies were better than the universities at applying for patents, and that patenting should be industry's rather than university's task. Several of the industry interviewees warned that they would retreat from collaboration if universities get too interested in patenting and commercialising results, as this would lead to an unfortunate mix-up of roles. Hardly any of the university researchers were severely bothered by industry patenting research results. However, there were a few exceptions. The university administration expressed some concern that university researchers give away their intellectual rights to easily, and this was also a point of concern for a few of the researchers interviewed. One of them expressed doubts, arguing that:

"At this institute we share the feeling that what we do is funded by public sources, and therefore should be publicly available. We are not into patenting at all. But of course companies are interested in patenting. So how do we arrange it if companies want to use one of our ideas in a new project? (…). We have experienced some of this, because some of our students have come up with results that companies have wanted exclusive rights to, and there has been some problems concerning intellectual property (…). I have seen examples of

contracts stating that the result of a student's work is the property of the company, since the company sponsors the student or maybe only the equipment. I think that's giving away too much too easily, really."

Intellectual property rights is particularly problematic in university-industry collaborations, since university researchers benefit from their general competence when they enter university-industry collaborations, even if these are on a private basis. Furthermore, companies rarely finance all the costs in collaborative research projects. On the contrary, some of the university interviewees argued that most collaborative research projects are actually deficit projects for the university. Several of the university interviewees believed that they and their colleagues are a bit commercially "naive" and tend to underprice their services. The university is always the contractual partner in formal agreements. This leads to quite complex contractual arrangements, since the rights of at least the company, the university researchers and the university should be taken care of. Some interviewees considered this an obstacle, as exemplified by one of the industry interviewees arguing that:

> "Collaborating with other companies is usually easier, because we are more similar, and this simplifies the juridical part. But collaborating with universities usually works out fine, as long as the division of labour is clear. The university is interested in research and publications, while industry is interested in products and patents."

Several of the interviewees complained that administration of contracts can be very time-consuming, and some of them considered contractual procedures a barrier to collaboration. Although most of the interviewees agreed that these problems were usually possible to sort out, they emphasised that problems related to contracts and intellectual property rights

sometimes hamper the initiation of collaboration. Both university researchers and industry agreed that getting started is often the most problematic part of collaboration, although the industry managers were the ones who were most bothered by this. The difficulties of settling contractual arrangements might to some extent explain why informal arrangements seem to be so common.

3.4.2 Confidentiality and delayed publications

Questions about intellectual rights also may result in conflicts regarding confidentiality versus publications. Although only a few of the interviewees regarded this as a very big problem, almost all of them identified this as a potential conflict-area. University researchers are usually eager to publish research results, since academic reputation largely depends on publications. Companies, on the other hand, usually depend on a certain degree of confidentiality, at least if they are not patenting research results (this varies considerably between different branches and companies, though). The university interviewees' view on confidentiality varied considerably. While some argued that confidentiality is not really a problem as long as the industry pays part of the research, others felt that university research should be publicly available (as illustrated by the second statement in the past section).

The clash between these interests seems to be an obstacle to collaboration in some cases, although most of the interviewees argued that these problems are usually possible to sort out. Sometimes researchers can write their report, excluding vulnerable information, but this is not always a solution. In some cases, the university researchers have to exclude so much information due to confidentiality agreements that there is no point in publishing at all. Patenting can also cause considerable delay in publishing of articles, and by the time the

researcher is allowed to publish the results, it might be outdated. Delayed publications seemed to be the most commonly reported difficulties related to collaboration.

3.4.3 Lack of information and communication

Lack of information is another potential obstacle to university-industry collaboration (Schibany et al., 1999; ESTA, 1997). The interviewees in this study gave very diverse answers to the question about whether or not there is an information-gap between universities and industry. Some interviewees confirmed that there is indeed a lack of communication between universities and industry, while others contradicted this. Most of the industry interviewees were sure that they are well informed about what is going on in the academic milieus that are relevant for them. Interviewees from both parties explained that the number of persons or institutes involved in the research they are interested in, is so low that it is almost impossible not to know what everybody else are doing. Still, quite a few of the interviewees thought that communication could be improved, and agreed that there is some lack of communication between the two sectors.

An interesting point is that half of the industry interviewees suggested that communication would improve a lot if university researchers spent some time in industry during their careers, instead of staying at the university faculty all their time. Increased mobility of researchers between the academic and the industry sector would increase communication and help keeping both sides informed on who does what, they argued. Both industry and university interviewees agreed that an obstacle to collaboration is that only a very small share of Norwegian industry is science-based, and that there is a very low willingness to take risks.

Some interviewees explained the information gap by arguing that universities lag behind industry in several fields. One of the industry interviewees complained that:

"It would be nice if university researchers were more in touch with industry. They can easily lag behind and miss what is going on in the world outside if they only stick to themselves. I wish there was more mobility and flexibility, and that researchers more often spent a few years in industry before they carried on with their university careers."

Communication seems to be based mainly on personal and informal contacts, and there is evidently a lack of information when such contacts are absent. Universities and industry seem to stay updated on each other's activities and fields of interest once contact is established. However, there is evidently a lack of meeting-places for more systematic and general "updating" where new contacts can be established. The industry interviewees expressed that they would like to stay more in touch with the university sector, but that lack of time prevented them from searching for suitable partners and contacts.

3.4.4 Cultural differences and conflicts of interest and values

University researchers are often perceived as difficult and unwilling collaboration partners who take no interest in industrial research and who are not adjusted to practical considerations such as limited time horizons. Universities are often accused of having too much of an "ivory-tower"-attitude to the rest of the world, and this has been identified as an obstacle to collaboration. Cultural differences are seen as factors that might hamper collaboration.

Both industry and university interviewees identified different attitudes to practical matters, such as deadlines and schedules, as one of the typical challenges to university-industry collaboration. A few of the industry interviewees argued that getting projects finished on time was more difficult when they were collaborating with universities. However, most of the interviewees considered these practical problems minor obstacles only. This was seen as a challenge rather than as something that actually thwarted collaboration. Most of the industry interviewees said that they simply did not expect university collaboration to result in fast product development, and that most of their university partners adjust to their time-schedules. Both parties showed a surprisingly high understanding of the situation of the other part, and the university researchers had an almost humble attitude to this problem. As an industry and a university interviewee, both in the computing and information technology sector, argued:

"Academics want the ideal technical solution, while we want the realistic one. That's a problem. Another problem is that the university researchers are so busy coming up with new problems all the time. They are not able to limit their work and solve one problem at a time – everything tends to just slip away".

"Companies live in a different world than we do, with other time horizons. This is the area where university researchers have most to learn and most trouble adjusting. But these things go smoother as one get more experienced."

Different research agendas were recognised by both sides as the most important factor limiting collaboration between universities and industry. Still, nearly all the interviewees agreed that there are several areas of overlapping interests, where collaboration can result in valuable synergies. However, the interviewees complained that university researchers in general do not acknowledge these potential synergies. According to the interviewees, the

ivory tower-attitude still persists in many academic milieus, and some academics are very hostile to collaboration. The term "ivory tower" is commonly used as a metaphor to describe how universities tend to see themselves as the only sources of "true" knowledge and as isolated from the rest of the world (Etzkowitz, 2000). Three of the industry interviewees and two of the university interviewees actually used the term "ivory tower" to describe how they sometimes perceived the Norwegian universities. As a university interviewee said:

> "The administration encourages us to get external funds, but they don't really give you any credit for it once you've got something. Rather, you're left alone with "the wolves" – your own institute."

Nearly all the industry interviewees had experienced university researchers or departments not interested in any communication with industry at all, although they stressed that they had mainly positive experiences from university-industry collaboration. The interviewees also said that they sensed an increased openness to collaboration from university researchers in general. Still, some industry interviewees also complained that university researchers should be a bit more flexible and willing to try out new fields of science and new technologies, instead of just doing what they have been doing all their lives. As one of them argued:

> "In some departments of our company there is some frustration that the university is not more interested in new fields of science and technology – fields we know will be important in the future. Instead they tend to continue on that safe, old path, doing what they have been doing always. We can provide them with interesting problems that they just don't bother to give any priority (…) So they could be a little more flexible sometimes, and more willing to try out new things."

All interviewees further emphasised that the attitude towards collaboration varies greatly from person to person and from institution to institution. Several industry interviewees considered The Norwegian University of Science and Technology in Trondheim more open towards industry collaboration than the other universities. Some institutes at the other universities were also perceived as quite positive to collaboration, while others were known to resist any kind of industry collaboration at all. The "attitude"-problem seems to be prevailing, but to a varying degree from institution to institution and person to person.

CHAPTER 4: CONCLUSIONS AND PERSPECTIVES

4.1 Some tentative conclusions

The main objective of this thesis has been to investigate how and why industry and academics collaborate, in order to find out whether or not collaborative relations in some science-based and high technology fields might be understood as mutual learning processes rather than linear knowledge transfers. As discussed in Chapter 2, traditional approaches to innovation views technology as applied science, and hence scienctific discovery as a direct source of technological innovation. The empirical findings in this study suggest that this linear understanding of innovation processes does not capture to a full extent how academic research is related to technological innovation in the high technology and science based sectors investigated.

The empirical analysis suggests that the companies interviewed only rarely utilise academic research directly for new products and processes. Although some interviewees argued that such linear innovations take place every once in a while, new ideas for products and processes were not considered the most important benefits from collaboration with universities. In other words, the companies interviewed do not seem to have the same main rationales for collaborating with universities as implied by the linear view of innovation.

Rather than utilising university research as a direct source of technological innovation, the companies in this study seem to approach academics mainly for the sake of more general competence building as well as for help with specific problems. The perceived importance of access to academics' problem-solving capabilities as a motivation for collaboration suggests

that one of the main contributions of academic research might be person-embodied and tacit skills, rather than codified knowledge in the form of scientific publications. Accordingly, the empirical findings suggest that innovation processes in science-based and high technology sectors such as the biotechnology and the computing and information technology sectors might be characterised as problem-solving activities. This is very much in accordance with modern innovation theory, in which innovation is seen as a problem-solving activity and technological knowledge is assumed to have certain tacit aspects.

The analysis of the empirical findings has revealed that academics' do not collaborate with industry only in order to get access to external funds. Rather, access to industry's competence was perceived as one of the main motivations for academics to collaborate with industry, and the university interviewees acknowledged that there is a lot of scientific and technological competence in industry. This suggest that university-industry collaboration in some cases are two-way learning processes, involving learning for academics as well as for their industrial counterparts. Technological problems generate interesting research questions for academic researchers, and new technologies and instrumentation sometimes provide "building blocks" or platforms for the academic researchers. In other words, the empirical findings illustrate that scienctific and technological development in some fields can be seen as closely intertwined and interdependent processes, as suggested by modern approches to innovation.

The investigation also revealed that university-industry collaboration seems to be a highly networked process, with networks of scientists and engineers playing a major role for collaboration. Such networks have been highlighted by modern innovation theory, and particularly by system theories of innovation as an important factor for inter-firm collaboration and innovation. It is interesting to note that networks also seem to play an important role for collaborations between universities and industry. This illustrates that

scientific and technological collaboration takes place in a social context, where mutual trust and recognition of each other's competencies seem to be relevant factors for success.

From the analysis of the empirical findings, one might conclude that university-industry collaboration in the scientific and technological fields investigated in some cases can be seen as examples of innovation and collaboration involving systemic interaction and mutual learning. Industry have very high competence in certain fields, and university-industry collaboration in the fields investigated therefore seem to offer possibilities of two-way knowledge exchange.

4.2 Suggestions for further research

Although the findings in this study suggest that there are areas of overlapping interest where universities and industry might benefit from collaboration, it is important to bear in mind that the companies and researchers investigated only represent a small fraction of the university and industry sectors. Hence, the empirical material in this study does not allow for any conclusions about university-industry collaboration in general. However, the study might serve as an illuminating example of how university-industry collaboration in the sectors studied in some cases might be seen as processes involving systemic interaction and mutual learning.

An interesting topic for further research might be to make a more large-scale investigation, in order to allow for statistical generalised conclusions. Another relevant topic for research is the

investigation of university-industry collaborations in different industrial sectors and fields of science and technology, in order to find out if the mutual learning perspective might be relevant also in other fields of science and technology than those investigated. Further, research might be conducted to investigate how factors such as i.e. size of the company and size of the R&D department influence collaboration and companies' ability to utilise university research. This study did not include enough companies to make any conclusions about such factors.

4.3 Some perspectives regarding universities' future challenges

The investigation revealed that there are several obstacles to university-industry collaboration. Although only a few of these were regarded difficult to overcome, questions concerning intellectual property rights and confidentiality cannot be ignored. These questions were identified as factors that can seriously hamper collaboration by the interviewees. Problems related to confidentiality, patenting of research results and delayed publications seem to be overcome in most collaborations, but some university interviewees felt that there is a clash between this and the academic value of public available research results.

Closely related to this, a main question regarding university-industry collaboration is whether closer interactions might affect the direction of university research. Traditional approaches to science and technology are based on a rather clear distinction between "basic" and "applied" research[12]. Basic research is regarded as universities' main mission, while applied research is seen as industrial companies' starting point for innovation (Malecki, 1991). Modern

approaches to science and technology suggest that the distinction between basic and applied research is not so clear, since scientific and technological development in many cases are interdependent processes. In practice, the boarders between basic and applied research might be impossible to draw (Malecki, 1991).

Although the term "basic" research in the traditional sense might not be very adequate, academic research is assumed to have a distinct character. This is often related to a more long-term perspective than the research undertaken in industry. Somehow, the boarders between academic and industrial research might be blurred, as suggested by the findings in this study. Nevertheless, research of a rather basic character is regarded as one of the university's main tasks (see e.g. NOU, 2000/14). Although the interviewees in this study generally welcomed collaboration, both industry and university interviewees emphasised that universities should not forget their primary mission, which is to conduct research that is too long-term and uncertain for companies to invest in.

The empirical findings in this study seem to suggest that academics turn to industry mainly because they can learn from them, and because industry offers interesting research problems. Whether or not closer collaboration with industry makes academics turn away from long-term, "basic" research is hard to tell. Universities thus seem to face a difficult challenge, namely to be open towards industry in order to benefit from the fruits of collaboration, while at the same time maintaining their curiosity and willingness to engage in research of a "basic" character.

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[12] For a discussion about the concepts of "basic" and "applied" research and the boarders between these, see e.g. Hauknes, J. (1998).

BIBLIOGRAPHY

Bonaccorsi, A. and Piccaluga, A. (1994) "A theoretical framework for the evaluation of university-industry relationships", *R&D Management,* 24(3), p. 229-247.

Bowie, N. E. (1994) *University-Business Partnerships: an Assessment*, Lanham, Md: Rowman & Littlefield.

Dodgson, M (1993) *Technological Collaboration in Industry: Strategy, Policy and Internationalization in Innovation.* London, Routledge.

Edquist, C. (1997) "Ch. 1: Systems of Innovation Approaches - Their Emergence and Characteristics", in Edquist C. (ed.) *Systems of Innovation: Technologies, Institutions and Organizations.* London, Pinter Publishers, p. 1-35.

European Science and Technology Assembly (1997): *Academic and Industrial Research Cooperation in Europe,* ESTA Report 97/207.

Etzkowitz, H. (1998): "The norms of entrepreneurial science: cognitive effects of the new university-industry linkages", *Research Policy*, 27(8), p. 823-833.

Fagerberg, J. (1994): "Technology and International Differences in Growth Rates" in *Journal of Economic Litterature*, 32, 1147-75.

Fagerberg, J. and Verspagen, B. (1996): "Heading for divergence – regional growth in Europe reconsidered", *Journal of Common Market Studies*, 34, p.431-448.

Faulkner, W. and Senker, J. (1994) "Making sense of diversity: public research linkage in three technologies", *Research Policy,* 23, p.673-695.

Florida, R. (1999): "The role of the university: Leveraging talent, not technology", *Issues in Science and Technology Online,* http://www.nap.edu/issues/15.4/florida.htm (16.11.2000).

Geisler, E. and Rubenstein, A. (1989) "University-industry relations: a review of Major issues" in Link, A. N. and Tassey, G. (eds.) *Cooperative Research and Development: the Industry-University-Government Relationship.* Boston: Kluwer Academic Publishers.

Gibbons, M. and Johnston, R. (1974) "The role of science in technological innovation", *Research Policy*, 3, p.220-242.

Gibbons, M. et al. (1994), *The New Production of Knowledge. The Dynamics of Science and Research in Contemporary Societies.* London: Sage Publications Ltd.

Hall, B., Link, A. and Scott, J. (2000) Universities as Research Partners, Working Paper 7643, National Bureau of Economic Research, Cambridge MA.

Hauknes, J. (1998) "Grunnforskning og øknonomisk vekst: ikke-instrumentell kunnskap" in Kallerud (ed.) *Grunnforskning i innovasjons- og forskningspolitikk. Rapport fra NIFU og STEP-gruppen,* NIFU, 2/98.

Isaksen (red.) (1997) *Innovasjoner, næringsutvikling og regionalpolitikk.* Kristiansand: Høyskoleforlaget AS/Norwegian Academic Press.

Kallerud, E. (1998) "Forskningens kulturdimensjon" in Kallerud (ed.) *Grunnforskning i innovasjons- og forskningspolitikk. Rapport fra NIFU og STEP-gruppen,* NIFU, 2/98.

Kline, S. and Rosenberg, N. (1986) "An overview of innovation" in Landau, R. and Rosenberg, N. *The Positive Sum Strategy*, Washington D.C.: National Academy Press, p. 275-306.

Lundvall, B.-Å. (1992) "User-Producer Relationships, National Systems of Innovation and Internationalisation" in Lundvall, B.-Å. (ed.) *National Systems of Innovation. Towards a Theory of Innovation and Interactive Learning.* London: Pinter Publishers; p. 45-67.

Lundvall, B.-Å. and Johnson, B. (1994) "The learning economy", *Journal of Industry Studies*, Associated Business Press, 1(2), p.23-42.

Malecki, E. J. (1991): *Technology and Economic Development: the Dynamics of Local, Regional and National Change*. Harlow: Longman.

Maurseth, P. B. "Convergence, Geography and Technology", available at http://meritbbs.unimaas.nl/tser/tser.html (20.07.00).

Meyer-Krahmer, F. and Schmoch, U. (2000) "Science-based technologies: university-industry interactions in four fields", *Research Policy*, 27(8), p. 835-851.

Nelson, R. and Rosenberg, N. (1994), "American universities and technical advance in industry", *Research Policy*, 23, p. 323-348.

Norges offentlige utredninger (2000) "Frihet under ansvar",

http://odin.dep.no/kuf/norsk/publ/utredninger/NOU/014001-020004/index-dok000-b-n-a.html

Nås, S. O. (1994) "Forsknings- og teknologisamarbeid i norsk industri", STEP Group Report 7/94, Oslo.

OECD (1996), *The Knowledge-Based Economy*. OECD, Paris.

OECD (1997) *National Innovation Systems,* OECD, Paris.

OECD/STI (1998) *University Research in Transition*, OECD, Paris.

OECD (2000) "Special Issue on Public/Private Partnerships in Science and Technology", STI Review No. 23, http://www.oecd.org/dsti/sti/index.htm (20.08.2000).

Pavitt, K. (1998) "The social shaping of the national science base", *Research Policy,* 27(8), p. 793-805.

Research Council of Norway (1999) *Det norske forsknings- og innovasjonssystemet - statistikk og indikatorer 1999.* Oslo: Norwegian Research Council.

Rosenberg, N. and Nelson, R.R. (1994) "American universities and advance in industry", *Research Policy*, 23, p.323-348.

Schibany, A., Leonhared, J. and Polt, W. (1999) *Towards Realistic Expectations. The Science System as a Contributor to Industrial Innovation,* Österreichisches Institut für Wirtschaftsforschung, Seibersdorf.

Smith, K. (1994a) "New directions in research and technology policy: identifying the key issues", STEP Group Report, 1/94, Oslo.

Smith , K. (1994b) "Interactions in knowledge systems : Foundations, policy implications and empirical methods", STEP Group Report 10/94, Oslo

Smith, K. (1998a) "Hva er grunnforskning?" in Kallerud (ed.) *Grunnforskning i innovasjons- og forskningspolitikk. Rapport fra NIFU og STEP-gruppen.* NIFU, 2/98.

Smith, K. (1998b)"Bruk av grunnforskningsbasert kunnskap i norsk industri: begreper og tilnærminger" in Kallerud, E. (red.) Kallerud (ed.) *Grunnforskning i innovasjons- og forskningspolitikk. Rapport fra NIFU og STEP-gruppen.* NIFU, 2/98.

Smith, K. (2000) "Innovation as a Systemic Phenomenon: Rethinking the role of Policy", *Enterprise & Innovation Management Studies,* 1(1), p. 73-102.

Stiglitz, J (1996) *Economics.* New York and London: W. W. Norton.

Tidd, J., Bessant, J. and Pavitt, K. (1997) *Managing Innovation. Integrating Technological, Market and Organizational Change.* John Wiley & Sons Ltd, Chichester.

Von Hippel, E. (1988) *The Sources of Innovation.* Oxford University Press.

Wu, V. F.-S. (2000) "An Empirical Study of University-Industry Research Cooperation - The case of Taiwan". Unpublished paper prepared for the workshop of the OECD-NIS Focus Group on Innovation Firm and Networks, Rome, 2-3. October, 2000.

Ørstavik, F. and Nås, S. O. (1998): "The Norwegian Innovation-Collaboration Survey", *STEP Group Working Paper,* 10/98, Oslo.

Appendix 1

LIST OF INTERVIEWEES

<u>Industry interviewees:</u>

Lars Korsnes, R&D Manager, Dynal AS, Oslo.

Hans Kristian Guren, Product Development Manager, NERA Satcom, Asker.

Ivar Christian Miljeteig, Product Development Director Technology, Tandberg Data, Oslo.

Hugo Kohmann, Director Software Engineering, Dolphin Interconnect Solutions, Oslo.

Ole Jørgen Marvik, Managing Director, Affitech (Affinity Technology Laboratories), Oslo.

Kjell Einar Bregge, Product Development Manager, Hydro Gas & Chemicals AS, Oslo.

Erik Aulie, Director Research & Development, Alpharma, Fine Chemicals Division, Oslo.

<u>University interviewees:</u>

Yngve Joseph Sjøgreen Foss, Head of section, Department of Academic Affairs and Research Administration, University of Oslo).

Kristine All Simonsen Knudsen, Senior consultant, Department of Academic Affairs and Research Administration, University of Oslo.

Stein Gjessing, Professor, Informatics and communication systems, Department of Informatics, University of Oslo.

Tom Henning Johansen, Professor, Condensed Matter Physics/Superconductivity, Department of Physics, University of Oslo.

Jan Karlsen, Professor, Galenic Pharmacy, School of Pharmacy, University of Oslo.

Truls Norby, Professor, Centre for Material Sciences, Chemical division, University of Oslo/Oslo Research Park.

Sverre Arne Sande, Associate professor, Galenic pharmacy, School of Pharmacy, University of Oslo.

Bernhard Skaali, Professor, Electronic engineering/Experimental nuclear physics, Department of Physics, University of Oslo.

Appendix 2

R&D FUNDING IN THE HIGHER EDUCATION SECTOR IN NORWAY

The total R&D expenditure in Norway was 18,2 billion NOK in 1997, which equals1,7 % of the GDP (The Research Council of Norway, 1999)[1]. There are two main sources of R&D funding: the public sector and industry. Figure A1 illustrates how R&D resources flow from source of funding to sector of performance. As shown in the figure, industry finances nearly all of its own R&D, while the higher education sector (HES) and the research institute sector are primarily public funded. However, there are departures from this general picture. The institute sector receives about 25 % and the HES about 6% of their funds from industry. The figure also illustrates that industry spends about half of the R&D expenditure, while the HES and the institute sector both spend about 25 % each of the total R&D expenditure.
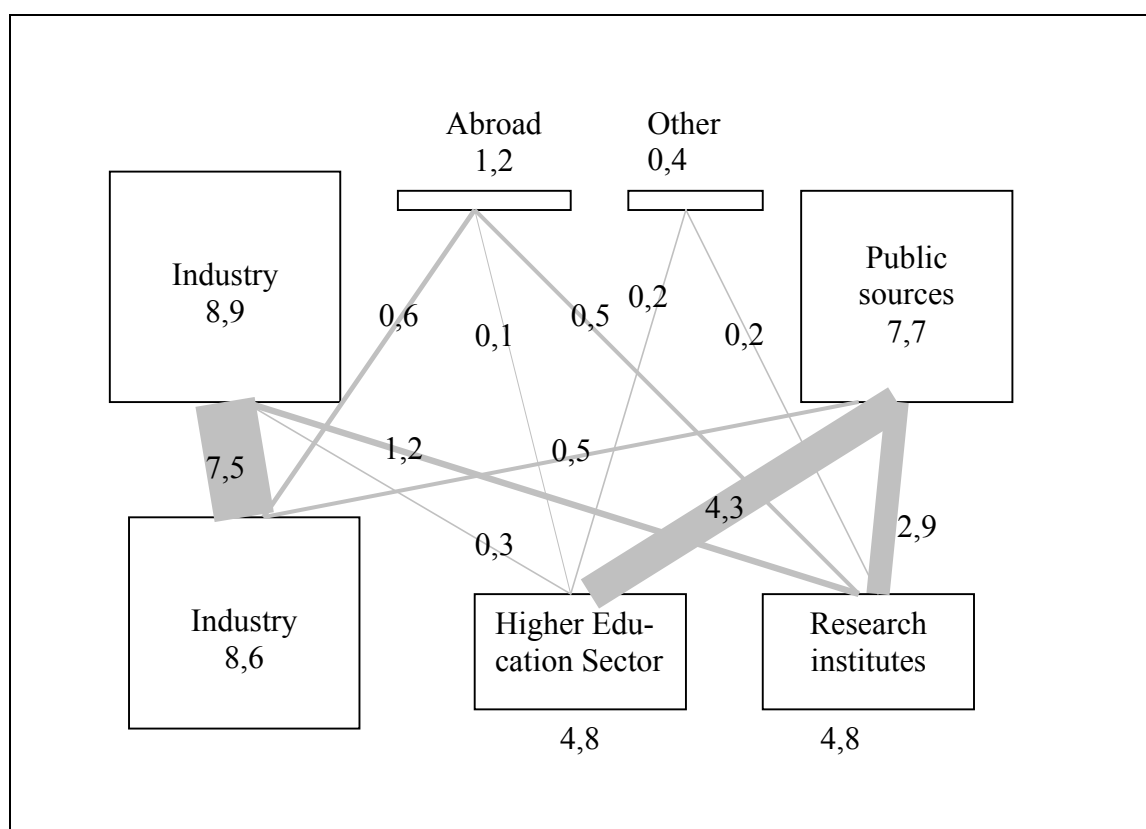

Figure A.1: R&D expenditure in Norway from source of funds to sector of performance in 1997. Billion NOK. Source: Research Council of Norway.

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[1] All the statistical material in this chapter is sourced from the Research Council of Norway (1999): *Det norske innovasjonssystemet – statistikk og indicatorer 1999.*

External funding in the HES

The higher education sector (HES) in Norway consists of four universities: the University of Oslo (UiO), the University of Bergen (UiB), the University of Tromsø (UiTø) and the Norwegian University of Science and Technology, Trondheim (Norges teknisk-naturvitenskapelige universitet, NTNU), as well as some university-level colleges and numerous state-colleges. The universities and university-level colleges perform the main bulk (80 %) of the R&D in the HES.

The most important source of funding for the HES is the Department of Church, Education and Research, which is the main contributor to the institutions' *general budgets*. All funding that is not included in the general budget is labeled *external funding*. Sources of external funds thus include industry, the Research Council of Norway, other public sources (public funding except from the general budget and the contributions from the Research Council), sources from abroad (both public and private) and "other sources" such as gifts, etc. Figure A2 reveals that there has been a tendency towards increasing external funding of the HES the last decade or so. The amount of external funding of R&D expenditure within the Norwegian HES has increased from 21 % in 1981 to 31 % in 1997. However, the major bulk of the external funds come from public sources. The Research Council is the single most important source of external funds and contributes with 45 % of all external funding to the HES. The Research Council is followed by the industry, which in 1997 contributed with 17 % of the total share of external funding. Figure A2 gives an overview of R&D expenditure in the HES by institution and source of funds in 1997.

The average level of industry funding is about 6 % for the HES, but there are huge variations between the different institutions. NTNU has traditionally had a much closer co-operation with industry than the other universities, and the share of industry funding is markedly higher here than at the other universities and university colleges. However, there are also variations between different academic fields of science, as shown in Table A1. R&D expenditure in the humanities and social sciences being funded almost entirely from public sources (93 %), while the natural sciences and technological fields have a somewhat larger share of non-public funding.
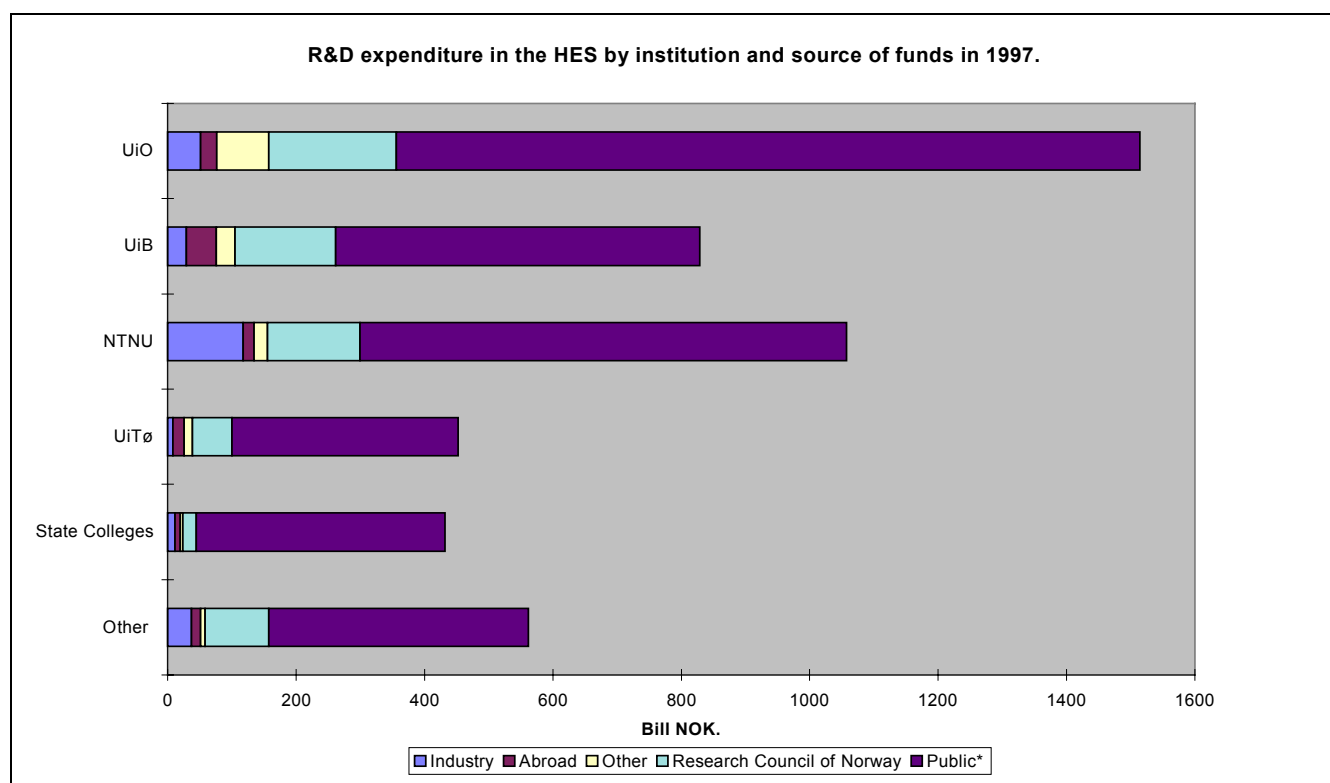
R&D expenditure in the HES by institution and source of funds in 1997.

Figure A.2: R&D expenditure in the HES by institution and source of founds.
Billion NOK. Source: Research Council of Norway.

Table A1: R&D expenditure and percentage of public resources in the Norwegian Higher Education Sector in 1997. Source: Research Council of Norway (1999).

Field of science	Public funding (%)
Humanities	93
Social sciences	93
Natural sciences	87
Technology	80
Medical sciences	84
Agriculture-, fishery and veterinary medicine	88
Total	**87**