University-industry relations in Norway

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Abstract

This paper analyses the relationship between universities and industry in Norway. Funding figures, publication and patent data, surveys and interviews all indicate that there has been a slow and steady increase in university-industry relations the last 20 years. In the 1980s we notice an increase in the share of industry funding of university R&D, and the 1990s saw a strong growth in PhD students finding work in firms. Many of these trends are seen all over the OECD areas, although there are large variations across disciplines, institutions and industries. Some evidence exists to suggest that Norwegian firms may be particularly collaborative when it comes to R&D and innovation. There are, however, also barriers to how close the cross-sector relations may become. For example, data on graduates' transition to work indicate how the shorter-term expectations and needs of firms may be difficult to meet by the universities and colleges.

Version of 23.7.2007

TIK Working paper on Innovation Studies No. 20070613

*This paper is part of the project "Innovation, Path-dependency and Policy" (IPP) carried out at the Centre for Technology, Innovation Culture (TIK), University of Oslo with the support of the Norwegian Research Council (Contract no. 154877). However, the Centre, University and Research Council are not responsible for the content of the paper, which is the sole responsibility of the author(s).

Introduction – increased interest in university-industry relations

In this paper we analyse the *relationship between industry*[1] *and universities* in Norway. Using different empirical sources, we aim to look at the three main tasks of universities, i.e. *research*, *teaching* and the *"third mission"* of knowledge transfer in a wide sense. Studies of innovation in industry and studies of the norms, organisation and results of science have belonged to different disciplines and specialisations. University-industry relations are thus a relatively new subject of investigation.

The expansion of fields of research like ICT, biotechnology and nanotechnology provide arenas for increased, closer and perhaps new forms of university-industry relations. Not least biotechnology is an example of a new industry which owes its existence to university science and where patenting and spin-off companies are central means of collaboration. Still, authors like Stokes (1997) argue against the belief that there ever has been a dichotomy between basic and applied science, even before the arrival of biotechnology and ICT. Stokes argues that science and technology/innovation have "semiautonomous trajectories" but are increasingly intertwined – and that "considerations of use" remains one of several relevant criteria for university research.

In Norway, policy discussions of "improving university-industry relations" are not recent. At the beginning of the 20th century this was a concern among policy-makers, industrialists and university professors alike. Claims that a strong attention to university-industry collaboration and commercialization are of a relatively recent date, are therefore historically short-sighted (Martin 2003; Martin & Etzkowitz 2000). Still, it is obvious that many countries saw important policy changes from the 1980s, what Guston & Kenniston (1994) have called "a new social contract for science". The three decades following WW2 may be seen as an exception to a trend of frequent and/or strong university-industry relations (Martin 2003).

The "old social contract" stated that "government promises to fund the basic science that peer reviewers find most worthy of support, and scientists promise that the research will be performed well and honestly and will provide a steady stream of discoveries that can be translated into new products, medicines, or weapons" (Guston & Kenniston 1994:2). This was based on a linear understanding of innovation as well as experiences with a well-functioning peer review system (Martin & Etzkowitz 2000). With reduced faith in the linear model, pressure on public budgets and increased faith in liberalization and market control, the social contract changed. The new social contract implies expectations that universities, in exchange for public funding, should answer to "needs" of "users" in industry, public sector and elsewhere (Guston & Kenniston 1994). In addition, governments frequently demand accountability for the funds that higher education institutions receive, often in the form of funding systems based on assessments of "results" or "quality" (cf. Nowotny *et al.* 2003).

In many countries, the new contract partly comes in the form of changed legislation, with the U.S. Bayh-Dole Act from 1980 as the prime example (see Mowery *et al.* 2004). Many other countries have emulated this legislative change, giving the higher education institutions formal obligations to commercialize research results whenever possible and often changing intellectual property rights regimes. In 2003, Norway followed the example of many other countries, including Denmark, Germany, Belgium and the Netherlands. The removal of the "teacher exemption clause" about ownership to research results in Norway is part of a broader trend of greater autonomy but also more tasks for the higher education institutions (HEIs). White Papers and other documents emphasise that these changes are not an expression of unhappiness about university-industry relations or commercialisation, but rather are intended to create a simple and coherent support structure for commercialisation of all public R&D. Other trends are largely the same as in other countries, like reduced basic funding, increased accountability, standardisation (Bologna process) and more.

A number of policy mechanisms support university-industry relations. These have grown organically over many years, often spinning out new special programmes and initiatives. One could say that there has been a fair deal of organisational innovation in creating the cross-sector support system. Some of the most important mechanisms presently (late 2007) are:

- *Programmes in the Research Council of Norway*, including “user-controlled projects”, “regional innovation” collaboration support, a programme for commercialisation of R&D results, centres of excellence in basic research (firms are partners in some of the centres) and centres for “research based innovation” (public-private partnerships).
- *Programmes in the innovation agency Innovasjon Norge* including centres of expertise and other “cluster” support mechanisms, innovation project support and various initiatives oriented at small and medium-sized enterprises (SMEs).
- *Infrastructure support in the industrial development agency SIVA*, which supports 18 incubators, 18 regional “knowledge parks”, 9 investment companies, 8 science parks and more. The 8 science parks are all located close to a major university, while most of the knowledge parks have a link to a State College.
- *Industrial and public development contracts*, which involve support for R&D in small and medium sized firms related to procurement from public agencies or large firms.
- *Tax deductions* for private R&D. The deductible amount is doubled if the firm collaborates with an “approved R&D institution” – including all Norwegian and some foreign universities, colleges and research institutes.

There are other support opportunities related to regional support, EU funding and regular research council programmes. However, despite all these programmes, the incentives for

HEIs to engage in industry co-operation may still be fairly weak. Basic funding to HEIs is largely granted based on the number of students, and the tiny “performance indicator”-based part of basic funding favours scientific publishing. A new “third mission” component has recently (autumn 2007) been suggested which will include popular science publications, newspaper articles and patents, but it has not yet been implemented. Scientific publication and other academic credentials are still the only criteria of promotion for staff in most HEIs.

State colleges have little funding from industry and low R&D funding more generally. There is some worry that there is an “academic drift” among the colleges, not least since some of them have concrete aims of getting a university status. Regional industry is very supportive of these processes, however. The oil industry in Stavanger set up a fund to transform the state college in the city into a university, and firms in other regions have taken similar initiatives.

[TABLE 1 ABOUT HERE]

Norway’s higher education system is relatively young. It consists (2007) of 6 universities, 6 scientific colleges, 25 state colleges and 26 private institutions of which most are very small but including a large business school. An overview is found in Table 1. The latest White Papers on research promote a binary system where universities are responsible for basic research and state colleges for regional industrial relations. In practice, however, the state colleges have less contact with industry than the universities. They are practically oriented and were often the results of mergers of e.g. teacher training colleges, nursing schools and engineering schools.

University-industry relations: research

University-industry interaction related to research may have many different forms, from unpaid consultancy to expensive projects lasting many years. In this section we look at funding indicators, output indicators and innovation indicators.

Industrial funding of research in HEIs

Industry funding of university research is probably the most widely used indicator of university-industry interaction. This figure is found for all disciplines, is easily available in statistical time series with opportunities for making international comparisons. Recent studies find that industrial funding may even be a good indicator of activities like patenting and the creation of spin-off companies (van Looy *et al.* 2004; Gulbrandsen & Smeby 2005). In Table 2, we show the development of industrial funding of higher education R&D in a number of countries in the OECD area.

Industrial funding of research in HEIs in Norway is a little below the OECD average, but there are fairly large differences between countries. The overall trend is, however, very similar. In most of the countries, as in the OECD area in total, industry funding more than doubled from the early 1980s to the early/mid 1990s. Since then it has been stable, or in some countries, like the U.S., the UK and partly Norway, it has declined somewhat. Germany is the only clear exception to the trend with a steady increase in industrial funding over the whole period. Varying levels between countries probably reflect many different aspects like size and organisation of the HEI sector, basic funding size and structure.

[TABLE 2 ABOUT HERE]

Two questions may be asked based on the development. First, why was there a sharp increase in the 1980s in the OECD area? Second, why has there been no increase or even a decline in the relative share of industrial funding of HEI research since the mid-1990s, despite the heavy policy attention to university-industry relations the last decade? The increase in the 1980s is probably due to increased industrial interest in university research in some disciplines and to the first policy initiatives to improve cross-sector relations. In Norway, the large technological challenges in the North Sea e.g. related to deep sea and horizontal drilling created the grounds for common projects, as did the development of large firms within computers and electronics. The scientific and technological research council NTNF established "user-controlled" research programmes in the early 1980s – where university-industry collaboration was required based on company needs and specifications – which created a new meeting place with subsidies for joint research activities. Many of the most technologically advanced Norwegian companies took part in this first wave of user-controlled research (cf. Hervik & Waagø 1997). These firms already had collaboration with HEIs and the capability to state technological needs and implement new knowledge.

From the mid-1990s in Norway, new policy mechanisms centred more on SMEs and low-tech industries and at colleges with weak research traditions. Some programmes have sought to build up new relations from scratch, often involving firms with little or no experience in HEI interaction and within "less favoured regions"; others have been mainly oriented at transfer of knowledge through graduates, which does not show in the R&D statistics. A particular explanation for the decline in industrial funding in Norway is that it is not really an absolute decline, but rather increased public funding the last decades, not least due to increasing student numbers (Smeby & Sundnes 2005). This is seen in many other countries. As has been argued elsewhere (see Larsen 2007), the interaction between the sectors, at least given the present organisation and culture in both firms and HEIs, may have reached a level during the 1980s and first half of the 1990s which was “optimal” or at least beneficial to both parties. Further intensification of interaction might lead university researchers away from basic research and teaching and/or lead firms too far away from market-based innovation activities.

Individual-level data on industrial funding/interaction can supplement the statistical data. The share of faculty members at Norwegian universities with industrial funding and/or co-operation has increased from 7 percent in 1982 to 21 percent in 2001 (see Gulbrandsen & Smeby 2005). The increase can be seen in all scientific fields apart from the technological disciplines which are stable at a very high level of funding/interaction and the humanities which are stable at a low level. Co-operation in the technological disciplines has a very long history in Norway (see Gulbrandsen & Nerdrum 2007) and has probably found a form and level which is rewarding to both parties. Industry funding is furthermore strongly related to receiving other external funding, and it is strongly related to “commercial” outputs like new products, patents, spin-off companies and consultancy activities (Gulbrandsen & Smeby 2005). Finally, professors with industrial funding publish significantly more than their peers without such funding. This relationship is found within all academic fields and in all the three national surveys (from 1982, 1992 and 2001), and it confirms similar results from other countries (*ibid.*).

[FIGURE 1 ABOUT HERE]

Figure 1 shows the share of industrial funding of total operating costs in different academic fields.[2] Technology and natural science are the main recipients of industrial funding, both above 100 MNOK in 2005[3]. Also research related to agriculture, fisheries and veterinary medicine has a high share of industrial funding. The low share in medicine might be due to the lack of advanced domestic pharmaceutical companies, but the volume of industrial funding in medicine is still quite substantial (around 75 MNOK in 2005). The overall share of external funding (including research council, non-profit foundations, EU etc.) is much higher in technology, agriculture and natural sciences than in medicine, social sciences and the humanities: roughly 40 percent in the three first areas versus 20 percent in the three last areas. But due to the large increase in total activity within the social sciences in the period, industrial funding has gone from 40 MNOK in 1995 to close to 60 MNOK in 2005. In other words, there industrial funding has increased a lot since the mid-1990s, although there has been an even stronger growth in other sources, slightly reducing industry's share of the total.

[FIGURE 2 ABOUT HERE]

In Figure 2 we show the volume of industrial funding distributed on institutions.[4] The dominance of NTNU can clearly be seen here, although also UMB (formerly the University College of Agriculture) has a high share of industrial funding (over 20 percent in 2005, 17 percent at NTNU this year) albeit much smaller absolute amounts. Only the University of Tromsø receives less industrial funding than all 26 state colleges. The increasing industrial funding at the University of Bergen should also be noted. In 2005 it was 30 million NOK above the University of Oslo which is almost twice as big measured in total budget and number of students. NTNU with 20,000 students had close to 90 MNOK in income from industry for salaries alone in 2005 – most likely for support staff and PhD students. The University of Oslo with 30,000 students, but a more traditional "comprehensive university" profile had less than one-third of this amount. NTNU has a clear national responsibility for technological training – 85 percent of the chartered engineers (Master degree) in Norway are educated here. NTNU is obviously in a special position nationally, and it also seems to try to tailor the social sciences and humanities towards perspectives and specialisations relevant for firms in an effort to become the "private sector university" of Norway (Sotarauta *et al.* 2006).

Small projects dominate the funding figures; projects below 100,000 NOK (about 12500 EUR) constitute around half of the total industry funding of HEI R&D in most years. On the other hand, if we compare with the institute sector (cf. Nerdrum & Gulbrandsen 2007), there are significantly more large projects in the higher education institutions. In the research institutes, only two percent of the projects were above 1 million NOK (in 2000); in the universities and colleges the share is seven percent. In addition, almost one-fourth of the projects in the universities and colleges are found in the 250,000-999,999 NOK category, far more than in the institutes. This indicates that the projects in HEIs and in institutes differ significantly from one another. A Danish investigation found that firms used institutes for problem definition and the explication of technological needs, while universities and colleges were used for problem solving purposes (Valentin & Jensen 2003). This could be a useful hypothesis for a later examination of the Norwegian situation as well.

In sum, funding data show that Norway is not very different from other developed OECD countries. There was a sharp increase in industry's share of HEI research funding in the 1980s but a stabilisation and slight decline after the mid-1990s – although the industry funding has gone up, funding from other sources has increased more. Behind the accumulated figures are large differences between institutions and disciplines. Industrial funding is higher in the technological disciplines and at the university NTNU in Trondheim, although the relative share of such funding is becoming quite high also in the soft sciences and at some other universities. Other countries have large differences as well between disciplines and between institutions. Although the data show increasing industry funding outside of the technological disciplines and technology-oriented universities, the trend is fairly new and probably not strong enough to be called a process of convergence. This may be a central topic for future investigations, however.

Co-publication patterns

Co-publication is an important indicator of collaboration. Its main weakness when applied to university-industry interaction is that such interaction may have special characteristics – more proprietary, more applied, shorter – which do not promote scientific publication. Based on data from ISI which mainly covers renowned English language journals, we have made an analysis of cross-sector co-publishing patterns in Norway. This is a complex issue not least when it comes to standardisation of addresses, and few other countries have comparable data.

In Norway, the university/college share of all ISI publications is a little over 80 percent, which is slightly higher than in the U.S. Norwegian industry's share of publications is around 8 percent, comparable to the level of countries like Canada, the Netherlands and the U.K. (see Calvert & Patel 2003). This share is stable over the period 1991-2004. Co-publication patterns are shown in Figure 3. We see that there is a particularly strong increase in co-publishing between universities and institutes, but also university-industry and institute-industry co-authorships have more than doubled since 1991 – well above the gradual increase in publishing. This could reflect policy initiatives like joint/user-controlled research programmes but also needs of firms to collaborate with public sector research.

[FIGURE 3 ABOUT HERE]

The share of articles from Norwegian industry[5] written in collaboration with authors from a public research organisation fluctuates a bit and increased to over 80 percent in 2004. This year, 45 percent of industry articles in Norway were co-authored with universities/colleges, 28 percent with institutes and 11 percent with both sectors (i.e. 55 percent with HEIs). Data from the late 1990s from the U.K. and Japan show 46 and 45 percent university-industry co-publication, i.e. somewhat lower than in Norway (cf. Calvert & Patel 2003; Pechter & Kakinuma 1999). Conversely, the share of all HEI publications with at least one industry co-author is relatively stable at around 4 percent. This is again quite similar to U.K. data where the share is 4.5 percent in 1996-2000 (Calvert & Patel 2003) and Canadian data where the share was 3.5 percent in 1998 (see Godin 1998). U.S. data do not always separate the private for-profit sector from other sectors, but data from 1999 show that the share of university-industry co-authored papers of all university papers this year was 7.3 percent, up from 4.9 percent a decade earlier. The U.S. thus seems a bit particular in a relatively low share of industrial funding of HEI research but a relatively high degree of co-authorship.

Again, the data shows that Norway probably follows the same trends as other developed countries. University-industry co-authorship patterns are similar to e.g. the U.K. and Canada – a bit surprising since Norwegian industry R&D share of GDP is relatively low. Publishing data thus indicate that industry in Norway may be more advanced than what the R&D statistics suggest.

Innovation survey data

Finally, the university-industry research relation may be seen from the latter's point of view by using the Community Innovation Survey (CIS). Here, firms are asked whether they co-operate on innovation with various actors and whether universities, institutes and other organisations constitute “highly important sources of information for innovation”. Data from the fourth survey (CIS4) have recently become available and are presented in Table 3.

[TABLE 3 ABOUT HERE]

The three highest scores in each column are marked in bold typeface; Finland may be a special case with collaboration scores way higher than any other country. Norwegian firms frequently report innovation co-operation with HEIs and institutes. These data suggest that Norway has a highly collaborative innovation system, and the score of institutes as an important source of information is one of the highest of all the CIS countries. HEIs score among the highest as innovation partner and slightly above average as information source in Norway. A high degree of collaboration could be a small country phenomenon, as most of the larger nations have a comparatively low score on the co-operation indicators.

Numbers for “highly important information source” for innovation are lower but, as expected, related to co-operation. It may be noted that Germany scores relatively low on co-operation – despite having one of highest shares of industry funding of HEI research in the OECD area – but in the top three on HEIs as an information source. One reason could be that there are many large firms in Germany which contribute substantial funds, while the CIS data measure the total share of all innovative firms.

For Norway, it is also interesting to look at the other items in the information source question. Most of the information sources like clients, customers, competitors, consultants etc. receive an average or slightly above average score from Norwegian firms. The most distinct result, apart from the importance of public research organisations, is the low importance granted to “scientific journals and trade/technical publications” where Norway’s score is among the lowest. This could confirm that Norwegian industry consists of many small units with limited absorptive capacity. The collaborative approach of firms in Norway may create personal networks and other knowledge transfer mechanisms that make written sources less needed. In Table 4 we have analysed the same questions distributed on industries (NACE classification).

[TABLE 4 ABOUT HERE]

Innovation co-operation between firms and public sector research is particularly common in high technology industries like chemicals, communication equipment and instruments and in key national industries like oil and gas, basic metals and pulp and paper. There is a tendency for higher education institutions to be more important partners and sources of information than research institutes in high technology industries, and vice versa, but there are also exceptions. Institutes are slightly more important than HEIs in manufacturing industries and slightly less in construction and services. Specialisation patterns, e.g. the lack of research institutes in the medical/pharma field, may account for some of the differences. A general picture is that institutes do not seem to prevent university-industry interaction, perhaps on the contrary as the two sectors’ importance as partner and information source is similar in most industries. Compared to other countries, Norwegian firms give a high score to HEIs and institutes as partners and sources of information, regardless of industry. For example, more Norwegian firms in the chemical industry co-operate with public sector research than firms in this industry elsewhere; this is seen for all the 10 industries we have taken a closer look at.

University-industry relations: teaching

There is not necessarily a clear distinction between research and teaching relations. Earlier investigations have shown that “access to graduates” is an important reason for industrial support of academic R&D (Gulbrandsen & Larsen 2000). Graduation of students is often considered as the single most important output of universities. However, it is difficult to assess the value of higher education to the individual, the labour market and society because the indirect effects are important as education influences the other productive factors.

Few investigations of university-industry relations have looked explicitly on relations related to teaching. Economists have of course been aware of the productive power of knowledge at least since Adam Smith, and various perspectives, in particular human capital theory, have looked at the private and social returns from schooling (e.g. Becker 1964). This body of literature does not seem to have exerted much influence on theories of innovation and technical change, however. It may be a fruitful future lane of research to bridge the two research programmes. Below we concentrate on showing how data from labour market studies may be used to shed light on university-industry relations.

Rosenberg & Nelson (1994) have claimed that a key contribution of U.S. universities to industrial innovation is to create industry-specific training programmes and to change curricula quickly according to employer needs and technological developments. There are no broad investigations of this in Norway, and there are probably variations between HEIs. At NTNU, all departments have had industry/external representatives on their board for decades; this is becoming more frequent at other universities and colleges too. In interviews, industry representatives emphasise the importance of informal contacts for creating changes in curricula and study approaches, e.g. by making data (geological surveys, case material, simulation models etc.) available to students (Gulbrandsen & Larsen 2000). It is also claimed that the quality of students is good from Norwegian universities, and especially the large companies are more worried about shortage on certain candidates than on their quality (*ibid.*).

Transition to work life for students

A key assumption in the innovation systems framework is that private firms are the most important actor when it comes to creating innovations. The share of graduates finding work in the private sector might therefore give us indications of university-industry linkages. In Norway, the "graduate survey" is carried out every second year among all spring graduate students at Master degree level from universities and colleges.[6] The share going to the private sector is shown in Figure 4.

[FIGURE 4 ABOUT HERE]

As expected, the highest share of students going to the private sector is found within business and economics studies, natural science and technology (includes engineers) and primary industry subjects (agriculture, fisheries etc.). There are large fluctuations for many of the graduates; business and labour market cycles seem to be relatively short and influence many categories of graduates. The private sector had problems around the turn of the millennium, but has recently recovered, as in other countries, and unemployment is late 2007 at an unusually low level. The figure shows how a larger share of almost all types of graduates find work in the private sector in 2005 compared to earlier years; we have to go back to the height of the ".com era" in 1997 to find almost as high numbers.

There is a recurrent worry among industry representatives in Norway about the recruitment of engineers and natural science students in particular, partly in light of worries that fewer young people choose such a specialisation in secondary school and partly due to an aging population of engineers. However, the graduate survey shows that engineers and natural science graduates often have problems in the labour market. In Figure 5 we show mismatch to the labour market of Master degree students from natural science (“cand.scient.”) and technology (“sivilingeniør”). Mismatch is defined as unemployment, involuntary part-time work and irrelevant work six months after graduation.

[FIGURE 5 ABOUT HERE]

The figure shows that in 2003, for example, one-third of all Master degree candidates from natural science and technology experienced unemployment or another type of mismatch to the labour market. Even in the heated labour market of 2005 more than 20 percent of them had problems in their transition from academia to work life. A recurrent feature of the survey is that graduates from natural science and technology are much more vulnerable to labour market fluctuations than almost all other graduates. This indicates, perhaps, a particular relation between industry and the HEIs in the “hard sciences”: industry is eager to call out for more graduates in periods of growth and expansion, but these are also often the first persons to be laid off in troubled times. The public sector seems to play a role as a “buffer” in depressed economic cycles, e.g. as the share of engineering graduates going to the public sector is much higher in economic downturns.

Data on Bachelor degree engineers show a similar pattern. These engineers are trained in the state college sector, and most colleges have specialised to fit regional industry, like in

Kongsberg (maritime/electronics), Horten (microelectronics) and Halden (ICT). Some courses at Master and in a very few cases doctoral level are now offered by the colleges, most of the latter organised in collaboration with the university sector and with NTNU in particular. It should also be mentioned that the state colleges often play a more informal role than what shows up in the statistics. For example the South Trøndelag College located in Trondheim has several hundred students working on projects for companies and other users each year (cf. Sotarauta *et al.* 2006). There are no systematic studies of student projects for industry, but explorative investigations indicate that this is a substantial activity (cf. Brandt 2005).

PhDs in industry

Another indication of a "teaching relationship", as well as an indication of R&D competences and absorptive capacity, is the number of PhDs working in different industries. Again this is a rather complex empirical task which involves merging several databases. This has recently been done for Norway, and other countries are working on the same problem (Gunnes *et al.* 2007). Figure 6 shows the number of PhDs working in different industries in Norway – all industries with more than 40 PhDs are shown.[7]

[FIGURE 6 ABOUT HERE]

Many industries have experienced a very significant growth in employed PhDs from the mid-1990s to the mid-2000s. This is easily seen in computer services, chemicals and oil/gas; the latter employed close to 500 people holding PhDs in 2005, which gives an indication of the technological sophistication of the oil and gas industry. Other industries remain at a lower level but some have seen a very large growth, e.g. a quadrupling of PhDs in power/water supply, a tripling in medical and optical instruments and a doubling in metals and foods. All industries taken together the number of employed PhDs has increased by about 80 percent this decade, which indicates, most likely, a remarkable growth in R&D competence. The thick blue line shows total number of new PhDs annually and shows a slow growth in candidates but a leap at the end of the period. The total number of new PhDs has grown a little less (about 70 percent) than number of PhDs in industry, much less (about 55 percent) if we exclude the last two years in the data set. Furthermore, the growth of industrial PhDs occurred before the increase in new PhDs.

PhDs in industry probably imply close linkages to HEIs, as many PhDs keep in touch with their supervisors and may be much more knowledgeable about university research activities and competences than Master degree graduates. The data thus indicate a strengthening of the cross-sector relationship the last decade. It may be mentioned that some of the largest Norwegian companies have supported PhD programmes for many years but organised in a slightly different manner. Norsk Hydro often funds PhDs indirectly through supporting research council programmes, Nycomed (the one large pharmaceutical in Norway, now part of GE Amersham) through grants at the University of Oslo, and Statoil through its own PhD programme called VISTA which is managed by the Norwegian Academy of Science (see Gulbrandsen & Larsen 2000). In general, employer-student relations have long traditions, and large companies tend to view a certain university and/or university department as “their own” recruiting base (cf. Thune 2006). In some specialised technical areas, large industrial firms support R&D not so much for the results as to maintain academic activities within industrially relevant topics and in order to create attractive teaching and learning environment. This, in turn, will attract interesting and valuable students and thereby help promote skilled and specialised graduates to be available in the labour market.

University-industry relations: third mission

There are no clear definitions of the “third mission”, but all Norwegian universities and colleges have strategy documents stating this as equally important to research and teaching. Most often it is defined as direct transfer of knowledge to society, including the role of universities as an informed critique of societal developments. In this section we take a closer look at patenting and the creation of spin-off companies. The third mission, at least as defined by the HEIs themselves, is broader than this.

Patenting and other forms of commercialisation

The number of articles on scientific publishing and academic spin-off companies is rapidly increasing. Patent documents are publicly available, but this does not mean that it is easy to identify university patents. Only in countries where the higher education institutions themselves own the intellectual property rights to their employees’ research results and/or apply consistently for patents in the institution’s name, can this be done with little resources. However, this is only the case in a few countries, most notably the U.S.

Most European countries have – at least until recently – had a so-called “teacher exemption clause” or “professor’s privilege”, granting the individual faculty members the right to commercial exploitation of research results. Academic researchers have applied for patents as private citizens, often using their home address or that of a partner, for example a company. Identifying patents involving academics/universities thus becomes an elaborate task. In Norway, the legislation was changed in 2003 when the teacher exemption clause was removed and the higher education institutions gained the intellectual property rights to inventions from research carried out at the institutions. At the same time, the universities and colleges were given formal obligations to ensure that “practically relevant research results” actually come into use. In addition, they were given funding to establish technology transfer offices (TTOs). Until then, external science parks and incubators had largely functioned as TTOs. To some extent the intellectual property rights (IPR) regulations are now the same in all public research organizations, as there has not been a “professor’s privilege” in the university hospitals or the research institutes. This was a central motivation behind the legislative changes.

But as in other countries, commercialisation is not new. In a survey in 2001, seven percent of all university researchers in Norway stated that their research one time or more had led to patents (Gulbrandsen & Smeby 2005). Patenting, but also consultancy, product development and contributing to spin-off companies, is strongly related to industrial funding and is most commonly found in the technological disciplines (*ibid.*). Also a recent interview study among Norwegian professors indicates that patenting is fairly common in academia, although somewhat “hidden” as the institutions have played a miniscule role in the process and have had no routines for registering commercial outputs (Gulbrandsen 2005).

Quantitative studies show increased academic patenting, especially in the U.S. Henderson *et al.* (1998) showed that academic patents increased 15-fold between 1965 and 1988.[8] This increase in intensity is recognized to involve a set of interlinking changes, including changes in the roles of universities (Gibbons *et al.* 1994; Webster 2003; Etzkowitz 1998; Etzkowitz *et al.* 2000), changes in technology (e.g. Zucker *et al.* 1998), and, related, changes in the patent system (Jaffe & Lerner 2004). Legal, regulatory and not least institutional elements all contribute to a climate for increased interaction between academic knowledge bases and those in the economy. Mowery *et al.* (2004) also argue that enormous federal investments constitute a central explanation for the academic patenting in the U.S.

A survey among TTOs and public research organisations was carried out in 2003 in some OECD countries for the report “Turning Science into Business” to map the extent of patenting and spin-off firms. Key findings are summarised in Table 5. There are obviously methodological differences in comparing figures across countries, e.g. due to varying data collection methods and sector definitions/borders. A simple count of numbers of spin-off companies – generally hard to define – is not a very good indicator either. Mortality rates vary, for example, although some studies do find that academic spin-offs grow more slowly but tend to have a higher chance of surviving compared to spin-offs from private firms (Dahlstrand 1999).

Still, the table does indicate that the orientation towards commercialisation seems relatively high in the Norwegian system. The score is particularly high for spin-off companies, which can have several explanations. First, support initiatives like the research council programme FORNY has for many years focused strongly on this means of commercialisation compared to patenting and licensing. Second, as patenting often happens in areas with little industrial activity in Norway, patents tend to be utilised in spin-off companies, funded by various public support programmes and a growing seed and venture capital sector. Unpublished Norwegian data from a survey among academic inventors show that almost one-third of the academic patents are utilised in start-up companies, a much higher share than in many other countries (cf. Meyer 2006). Many public research organisations, not least research institutes, have long traditions for spin-offs and their own TTO-like support staff. Contributions of public R&D spin-offs are particularly notable in areas like oil/gas and ICT (see Gulbrandsen *et al.* 2006).

[TABLE 5 ABOUT HERE]

In 2005 a fairly good indication of the amount of patenting in Norwegian universities was created (see Iversen *et al.* 2007). This was the result of a complex three-phase approach where the national patent database was merged with the “researcher personnel register” at NIFU STEP followed by a survey and a manual validation of matches. The investigation found that a total of 569 researchers from Norwegian public research organizations (mainly universities and research institutes) were involved in at least one patent application in 1998-2003. There remain a further 154 unresolved cases after these stages. A total of 828 patents – or 10.6 percent of domestic patents – involved at least one public sector researcher inventor. 21 percent of all Norwegian patents in chemicals and pharmaceuticals come from universities and colleges, and a further 8.2 percent from research institutes. The shares are also high in instruments where institutes and universities each contribute to 11 percent of all Norwegian patents. International comparisons are difficult to make, but when conferring with Balconi *et al.* (2004), who followed a very similar approach, we find that university patenting seems twice as frequent in Norway as in Italy.

When the new law to promote academic patenting took effect in 2003, the proportion of academic patents dropped to 10.3 percent from 12.1 percent in 2002. One factor behind the drop may have been that the introduction of the law created a period of uncertainty for some researchers about how the division of labour would change between researcher and institution. For the first time in Norwegian history, the universities themselves should apply for patents and their system for this (TTOs, guidelines etc.) was not established until 2004 (at the earliest). There are also some indications that the TTOs will apply for patents only in the most promising cases to save costs (see Gulbrandsen *et al.* 2006). Still, the overall picture is one of remarkable stability. Patenting levels are similar from one year to another, also indicating that this is not an activity reacting to a relatively recent emphasis on entrepreneurial universities.

Conclusion

There has been much attention to university-industry relations in the recent decades, and support mechanisms have been developed all over the world. Driving forces are found in new perspectives on innovation and knowledge production, political trends as well as organisational and normative developments in industry and academia.

Above we have presented many different data which indicate that increasing university-industry relations seems to be part of long and slow trends that started decades ago – related e.g. to technological upgrading of industry and increased openness to cross-sector collaboration. The data show that the 1980s were a turning point with a strong increase in formal research collaboration between firms and higher education institutions (HEIs), not only in Norway but across the OECD area. This could be due to increasing knowledge needs in industry, but probably also due to changed academic cultures after a decade or two of "radicalisation" all over Europe. Behind increased industrial needs for knowledge are probably several trends: increased global competition and internationalisation, increased pace of technological advance, the student explosion from the 1970s which led to larger numbers of higher degree candidates in firms and thus capacity to utilise new knowledge, and industrial reorganisations leading to higher R&D outsourcing rates. The extent of formal research collaboration has stabilised since the mid-1990s or not grown as much as government funding, student numbers etc. Perhaps the interaction has reached a level where it is mutually beneficial to both parties. Norwegian data still show how the number of PhD graduates working in firms has increased with more than 80 percent from 1995 to 2005, which indicates how the linkages between sectors and the opportunities for co-operation might be better than ever. Not least the oil and gas industry has emerged as very competence-and technology-intensive; its share of private funding of university research is about 10 percent of the total industrial funding (Gulbrandsen & Nerdrum 2007).

This broad trend of slowly increasing interaction seems to affect the largest and most technologically advanced companies and industries in Norway – and they are now supported by policy mechanisms oriented at "centres of excellence" of public-private R&D partnerships. There is a continuing and policy-driven work to include small and medium-sized firms, and firms from not just the large city regions, into this collaboration structure. Public agencies and state colleges are important actors here – and of course the research institutes. Some firms clearly have strong absorptive capacity and keep expanding it. Through intra- and interindustrial spillovers, and by help of special programmes oriented at regions, clusters, SMEs etc., it is hoped that absorptive capacity spreads to other firms as well. Although our analysis has included research, teaching and commercialisation data, we have not discussed other aspects much like consultancy, informal networking and unpaid student work for companies which all may constitute an important part of the university-industry interface. It is natural, however, to assume that these activities are related to indicators of funding, networking and outputs. Industry surveys (CIS) show that the innovation activities in Norwegian firms are often oriented at collaboration, and that universities/colleges and research institutes are more frequent partners and sources of information for the firms than in most other European countries. Data on scientific co-authorships, and to some extent funding, partly confirm this picture – although countries tend to differ a bit depending on the indicators used.

In total this could help explain why Norwegian industrial productivity is extraordinarily high yet industrial R&D expenditures are below average. The collaborative nature of the system ensures quick and efficient knowledge flows, and leading firms obviously have qualified manpower to absorb and utilise new scientific and technological knowledge. R&D costs remain low because they to some extent are shared among many different actors – and maybe research and development in itself is thus organised in an efficient network organisation. In this sense, it is natural to view universities not just as responsive to industrial needs but also an active part of professional communities oriented at transforming and utilising the vast quantities of knowledge that are produced outside of the small country's borders. Innovation collaboration is partly a general small country phenomenon. But as Norway scores comparatively high on many indicators of collaboration, there is probably a cultural, structural and/or historical component here as well.

Furthermore, there is a continuing support for entrepreneurship and commercialisation which has a history of at least three decades in Norway. Patenting happens regularly and it involves Norwegian public research organisations (at least) as frequently as in other countries. There seems to be a particular preference for creating spin-off companies in Norway. Legislative changes in 2003, removing the "teacher exemption clause" and increasing the HEI's responsibility for commercialisation, are too recent to evaluate. Preliminarily, qualitative and quantitative investigations show how there was a slight decline in patenting the first year after the law came into effect. More recently, a support structure of technology transfer offices have been built up. So far these activities are very small compared to teaching and research. There is some worry that increased willingness to take ownership to research results could have consequences for regular university-industry relations, but few data exist to support this.

Finally, it should again be emphasised that the differences are very large between disciplines, industries, institutions, technological areas etc. The technology-heavy university NTNU is dominant in the university-industry relations picture in Norway regardless of what indicators we use. However, also other HEIs receive a significant share of their funding from industry, e.g. the profession-oriented University of Life Sciences (UMB) and increasingly the comprehensive University of Bergen. Patenting and the creation of spin-off companies happen at all institutions. Student projects for companies are common many places, not least among the colleges, but are less visible in the statistics. There is a need to look at the whole of public sector research together – many publications, patents and industry projects are carried out by HEIs in partnership with research institutes. When HEIs are increasingly expected to collaborate with small businesses, to commercialise and transfer knowledge actively, they are more and more moving into activities which traditionally have been the domain of the institutes. This could influence the relations in the whole system.

Notes

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[1] We mainly use "industry" in a broad sense referring to the business for-profit sector – otherwise we specify e.g. "manufacturing industry". In the term "university-industry relations" we also include colleges.

[2] We only include operating costs as industrial funding is very rarely used for investments in buildings. Industrial funding is, however, a significant source of funding for equipment in the technological disciplines and specifically at NTNU.

[3] 1 MNOK equals about 125000 Euro.

[4] The University of Stavanger is included in the state college sector where it belonged until the 2005 statistics.

[5] With at least one author representing a Norwegian firm.

[6] Unfortunately there are no comparable data from other countries. A current EU project named REFLEX aims for a comparative perspective on the transition from higher education to work, but the data are not ready yet (April 2007).

[7] "R&D services" is omitted which includes the research institute sector and has about 2000 PhDs

[8] The explosion of university patents however has accompanied a peaking of this quality-measure during the mid-80s, suggesting, "that the rate of increase of important patents from universities is much less than the overall rate of increase of university patenting in the period" (Henderson *et al.* 1998).

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Table 1. Key characteristics of the Norwegian higher education institutions.

	Total income 2005 (MNOK)	Share external funding 2003	Total Staff 2003 (FTE)	Of which: Professors	PhD Students 2003 (FTE)	Gained doctorates (2005)	Total Students 2005	R&D expenditures 2003 (MNOK)
U. of Oslo	4 534	35 %	5 405	815	1 868	319	30 289	2 149
U. Bergen	2 616	39 %	2 940	478	918	157	15 838	1 255
Tromsø	1 545	34 %	1 828	237	551	60	5 763	717
Stavanger	729	47 %	810	64	102	6	7 066	n.a.
NTNU	3 613	40 %	4 321	602	1 808	218	19 736	1 631
UMB	756	46 %	874	115	293	49	2 784	317
Total unis	13 791	38 %	16 178	2 311	5 540	809	81 476	6 069
State Coll. (25)	7 673	n.a.	8 766	253	85	10	83 410	896
Scientific Coll. (6)	1 015	n.a.	1 177	165	284	39	4 772	n.a.
Private Coll. (26)	n.a.	n.a.	1 542	94	125	17	24 469	n.a.

Sources: DBH (www.dbh.nsd.uio.no/), RCN S&T Indicators, RCN and R&D statistics at NIFU STEP.
Notes: For universities, total staff and PhD students are full time equivalents (FTE). For the others they are head-counts. NTNU's full name is the Norwegian University for Science and Technology, a merger between the technical university NTH and the University of Trondheim from the mid-1990s. UMB is the Norwegian University for the Life Sciences, formerly the University College of Agriculture. UMB and the University of Stavanger received university status in 2005.

Table 2. Industrial funding of higher education R&D (BEHERD), selected OECD countries, 1981-2004. Source: OECD – Main science and technology indicators.

Country	**1981**	**1983**	**1985**	**1987**	**1989**	**1991**	**1993**	**1995**	**1997**	**1999**	**2001**	**2003**	**2004**
Australia	1,4	1,6	2,1	2,3	2,2	2,5	3,5	4,7	5,3	4,9	5,1	..	..
Belgium	..	9,4	8,7	8,7	12,6	15,4	12,1	13,1	11,2	10,5	12,7	11,6	..
Canada	4,1	3,9	4,3	5,0	4,9	7,0	8,6	8,1	9,8	9,1	9,4	8,4	8,4
Denmark	0,7	0,9	1,0	1,3	1,5	1,6	1,8	1,9	3,4	2,1	3,0	2,7	3,0
Finland	2,1	2,6	..	3,8	4,8	3,6	4,6	5,7	5,2	4,7	6,7	5,8	5,8
France	1,3	1,3	1,9	3,6	4,6	4,2	3,3	3,3	3,1	3,4	3,1	2,7	..
Germany	1,8	5,2	5,4	6,4	7,1	7,0	8,4	8,2	9,7	11,3	12,2	12,6	12,8
Ireland	7,1	7,2	6,9	7,1	9,2	8,6	7,1	6,9	6,5	5,9	4,4	3,0	2,6
Iceland	1,2	1,9	0,6	24,3	6,8	5,0	4,3	5,4	9,2	4,0	10,9	9,5	..
Japan	1,5	1,8	2,4	2,8	3,3	3,7	3,8	3,6	2,4	2,3	2,3	2,9	2,8
Netherlands	0,3	0,6	1,0	1,1	1,1	1,2	1,5	4,0	4,3	5,1	7,1	6,8	..
Norway	**2,9**	**3,5**	**5,0**	**4,5**	**3,9**	**4,7**	**5,7**	**5,3**	**5,3**	**5,1**	**5,8**	**5,0**	**..**
Spain	0,0	..	1,1	2,7	9,2	10,0	5,9	8,3	6,5	7,7	8,7	6,4	7,5
Sweden	2,3	3,7	5,5	5,9	7,9	5,2	5,1	4,6	4,8	3,9	5,5	5,5	..
UK	2,8	3,1	5,2	5,7	7,7	7,8	7,6	6,3	7,1	7,3	6,2	5,6	..
US	4,4	5,2	6,1	6,5	6,8	6,8	6,8	6,8	7,3	7,4	6,5	5,3	5,0
Total OECD	*2,9*	*3,5*	*4,2*	*4,8*	*5,7*	*6,0*	*6,1*	*6,2*	*6,4*	*6,5*	*6,4*	*6,1*	*..*
EU 15	*2,0*	*3,0*	*3,7*	*4,3*	*5,9*	*5,8*	*5,8*	*5,9*	*6,1*	*6,5*	*6,8*	*6,6*	*..*
EU 25	*..*	*..*	*..*	*..*	*..*	*..*	*..*	*6,0*	*6,1*	*6,6*	*6,7*	*6,5*	*..*

Table 3. Share of firms with innovation activities which report innovation co-operation with public sector research 2002-04, and share of firms with innovation activities which report public sector research as “highly important source of information for innovation” 2002-04. All industries incl. services.

	Innovation co-operation		*Highly important information source*	
Country	*HEIs*	*Institutes*	*HEIs*	*Institutes*
Belgium	13.2 %	9.2 %	**3.8 %**	**2.3 %**
Denmark	13.7 %	6.9 %	3.3 %	0.5 %
Germany	8.5 %	4.1 %	**3.4 %**	1.4 %
France	10.1 %	7.3 %	2.3 %	2.0 %
Italy	4.7 %	1.5 %	2.0 %	1.0 %
Netherlands	12.4 %	**9.4 %**	2.6 %	2.0 %
Austria	10.0 %	5.2 %	n.a.	n.a.
Finland	**33.2 %**	**26.4 %**	**4.9 %**	**2.4 %**
Sweden	**17.4 %**	6.4 %	n.a.	n.a.
United Kingdom	10.0 %	7.6 %	n.a.	n.a.
Norway	**14.8 %**	**16.3 %**	3.1 %	**3.2 %**

Source: Eurostat (CIS4).

Table 4. Innovation collaboration/information source distributed on industries. Total figures for each main category of industries (bold) and selected sub-categories. Data for Norway.

	Co-operation		***Information source***	
Industry	***HEIs***	***Institutes***	***HEIs***	***Institutes***
Mining and quarrying (all)	**26.3 %**	**26.3 %**	**12.3 %**	**10.5 %**
Extraction of oil and natural gas	32.5 %	30.0 %	12.5 %	15.0 %
Manufacturing (all)	**17.2 %**	**19.6 %**	**2.8 %**	**4.6 %**
Food and beverages	17.2 %	25.8 %	1.6 %	3.7 %
Textiles	9.3 %	9.3 %	0 %	0 %
Wearing apparel, dressing, fur	23.1 %	30.8 %	0 %	n.a.*
Wood and wood products	10.4 %	14.1 %	n.a.*	4.4 %
Pulp, paper and paper products	23.8 %	38.1 %	9.5 %	9.5 %
Publishing, printing, media	2.5 %	5.9 %	3.4 %	2.5 %
Chemicals/chemical products	37.7 %	27.9 %	11.5 %	6.6 %
Non-metallic mineral products	27.6 %	32.8 %	1.7 %	5.2 %
Basic metals	30.8 %	33.3 %	5.1 %	5.1 %
Machinery and equipment	18.6 %	20.6 %	2.5 %	6.4 %
Radio, television, com. equipm.	39.5 %	34.2 %	5.3 %	2.6 %
Medical, precision and optical instrum.	27.1 %	23.7 %	8.5 %	5.1 %
Furniture	8.6 %	9.4 %	0.9 %	1.7 %
Electricity, gas and water supply (all)	**22.0 %**	**22.0 %**	**3.3 %**	**1.1 %**
Construction (all)	**6.3 %**	**6.6 %**	**5.0 %**	**2.6 %**
Services (all)	**11.8 %**	**12.9 %**	**3.2 %**	**2.0 %**
Wholesale and retail trade	6.7 %	11.5 %	0.9 %	0.7 %
Hotels and restaurants	0 %	0 %	0 %	0 %
Transport, storage and communication	5.4 %	6.3 %	2.5 %	2.9 %
Financial intermediation	7.3 %	4.9 %	1.2 %	2.4 %
Real estate, renting and business activities (includes R&D consultancy)	20.0 %	18.0 %	6.1 %	2.8 %
All industries	**14.8 %**	**16.3 %**	**3.1 %**	**3.2 %**

Source: Eurostat (CIS4).

Note: * means confidential information (not made publicly available)

Table 5. Patent grants (one year) and patent applications (same year) and spin-offs (same year) from HEIs and research institutes in various OECD countries

Country	***Institution***	***Patent grants***	***Pat. applications***	***Spin-offs***
Australia (2000)	Universities	219	586	32
	Institutes	279	248	15
	Total	**498**	**834**	**47**
Belgium (Flanders) (2001)	**Total (universities and institutes)**	**57**	**121**	**15**
Germany (2001)	Institutes only	747	1058	37
Italy (2000)	Universities	34	102	27
	Institutes	30	88	9
	Total	**64**	**190**	**36**
Japan (2000)	**Total (universities and institutes)**	**163**	**567**	**6**
Korea (2000)	Universities	186	244	19
	Institutes	832	1448	37
	Total	**1018**	**1692**	**56**
Netherlands (2000)	Universities	64	111	27
	Institutes	103	101	10
	Total	**167**	**212**	**37**
Norway (2001)	Universities	20	40	16
	Institutes	28	43	51
	Total	**48**	**83**	**67**
Spain (2001)	**Total (universities and institutes)**	**64**	**133**	**11**
Switzerland (2001)	Universities	59	132	56
	Institutes	53	43	12
	Total	**112**	**175**	**68**
U.S. (2000)	Universities	3617	6135	390
	Institutes	1486	2159	n.a.
	Total	**5103**	**8294**	**n.a.**

Source: OECD (2003).

Note: Universities includes all higher education institutions in most cases. Institutes includes all “public research organisations” in most cases. Numbers for patents for universities in Norway are estimates based on Iversen *et al.* (2007) of patents involving university scientists and applied for through the commercialisation structure.

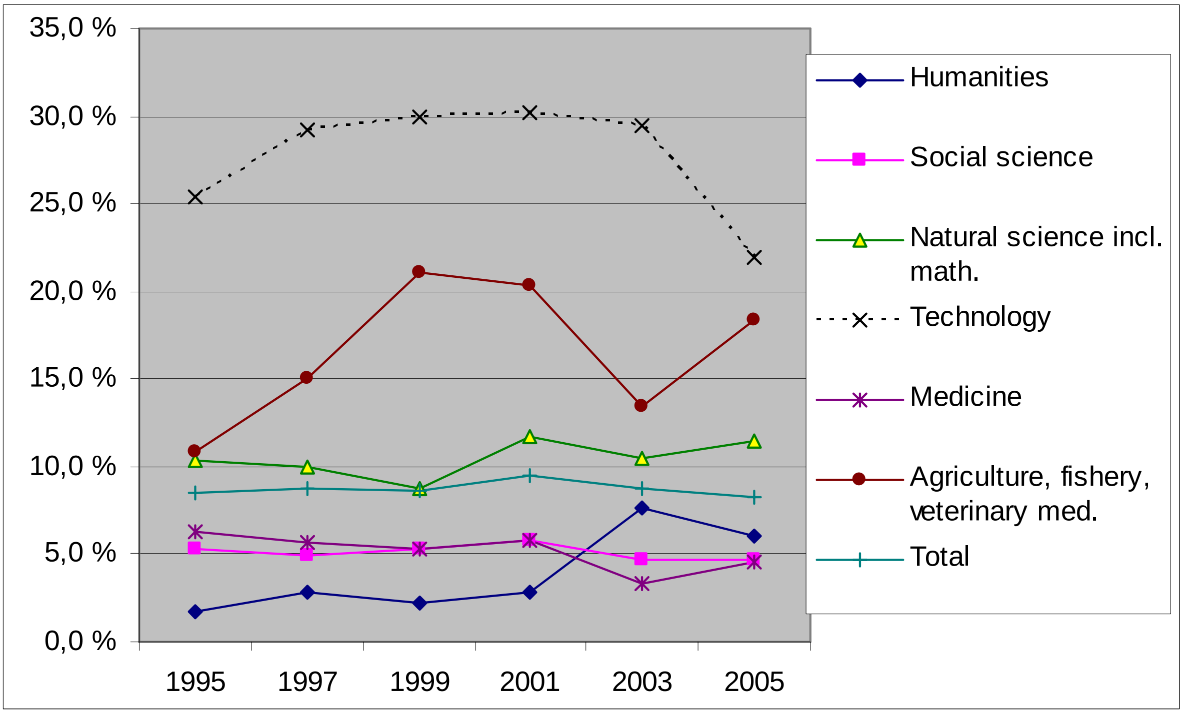

Figure 1. Academic fields: share of industrial funding of total operating costs of R&D in the HEI sector in Norway. Source: R&D statistics, NIFU STEP.

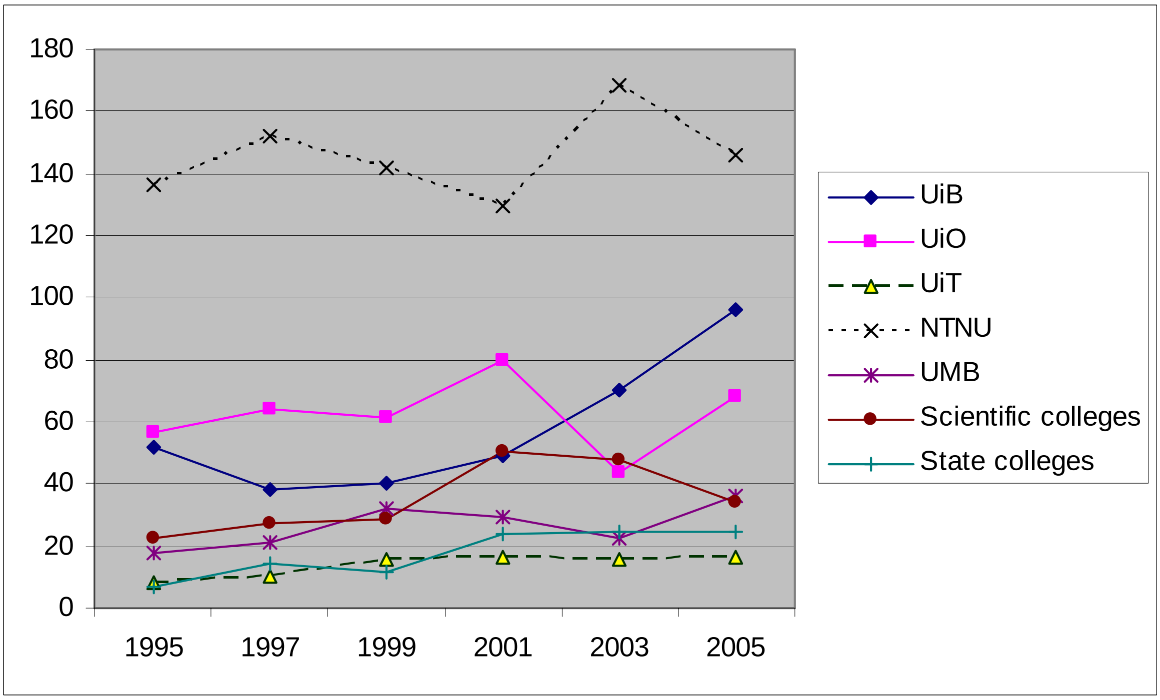

Figure 2. Level of industrial funding in the HEI sector in Norway, 1995-2005. Million NOK, fixed (2005) prices. Source: R&D statistics, NIFU STEP.

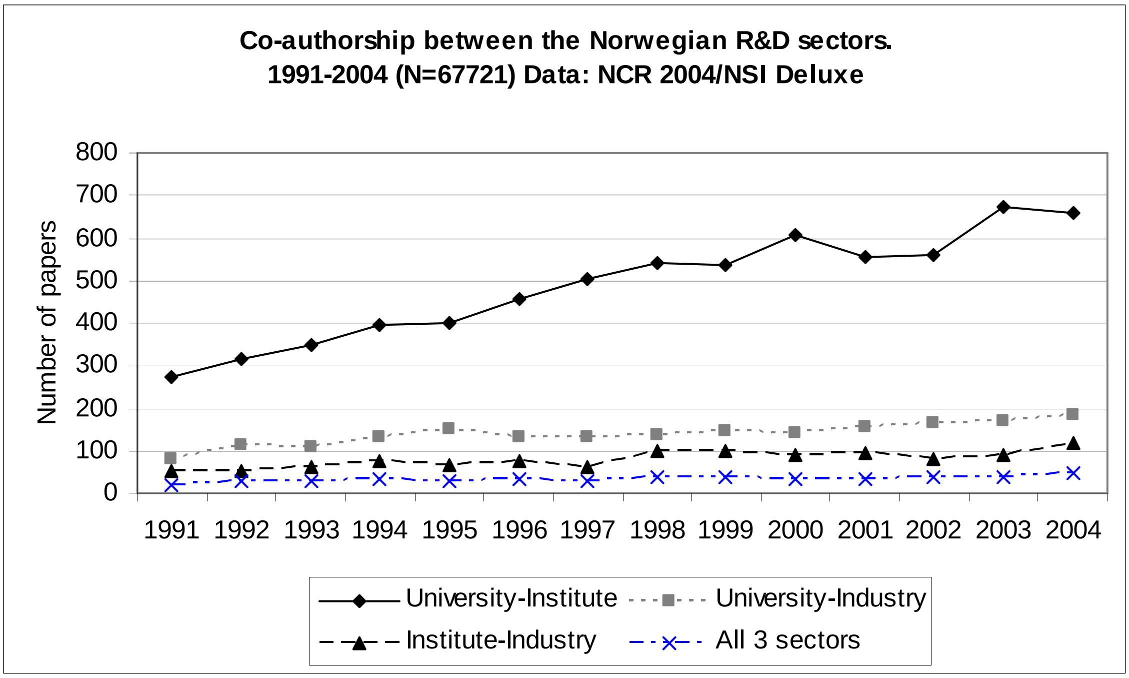

Figure 3. Co-publication patterns between sectors in the Norwegian research system. Based on data from Frölich & Klitkou (2006).

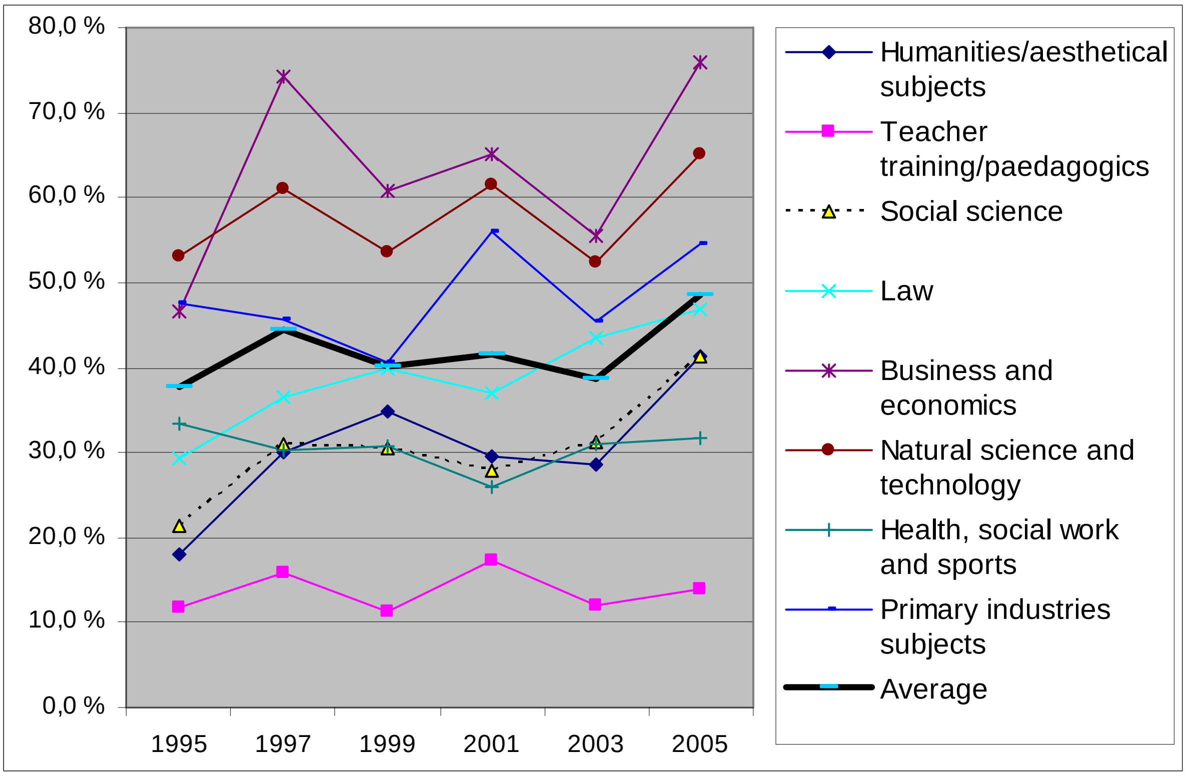

Figure 4. Share of graduates of different subjects leaving HEIs to work for the private sector, 1995-2005. Source: NIFU STEP Graduate Survey.

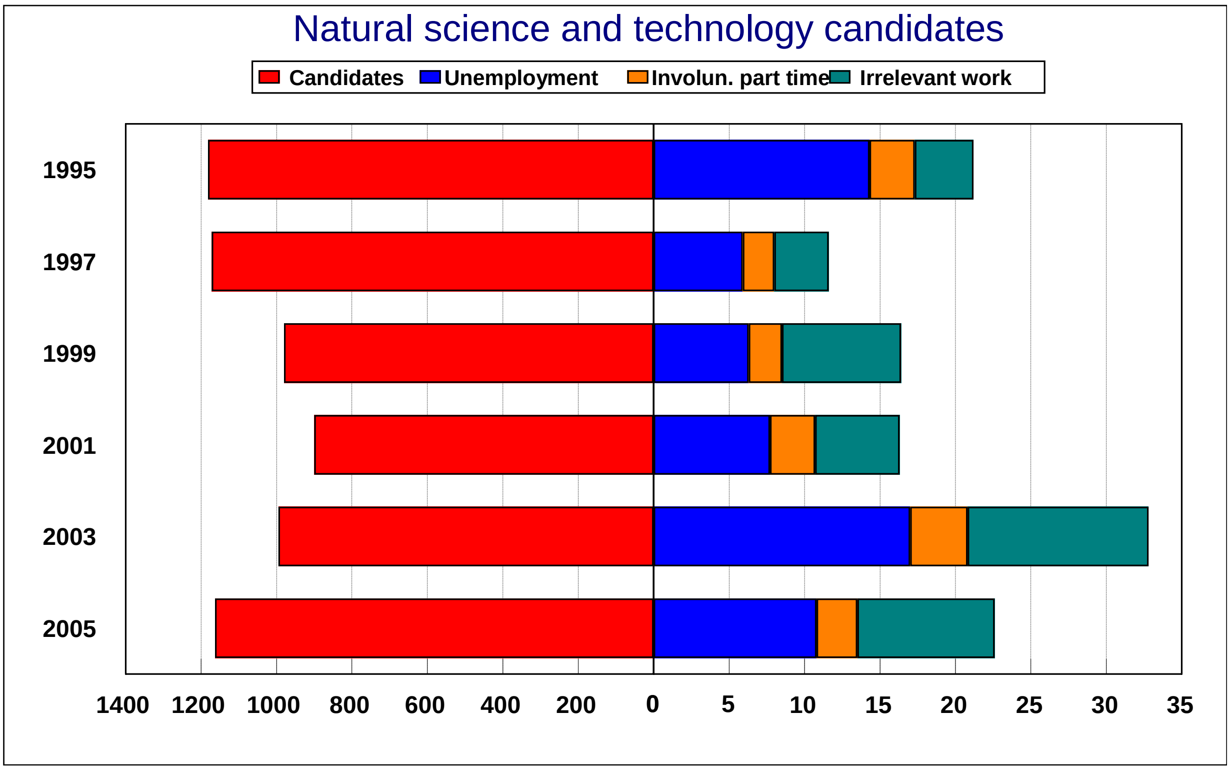

Figure 5. Labour market mismatch six months after graduation for Master degree graduates. Source: NIFU STEP Graduate Survey. Number of graduates left, percentages right.

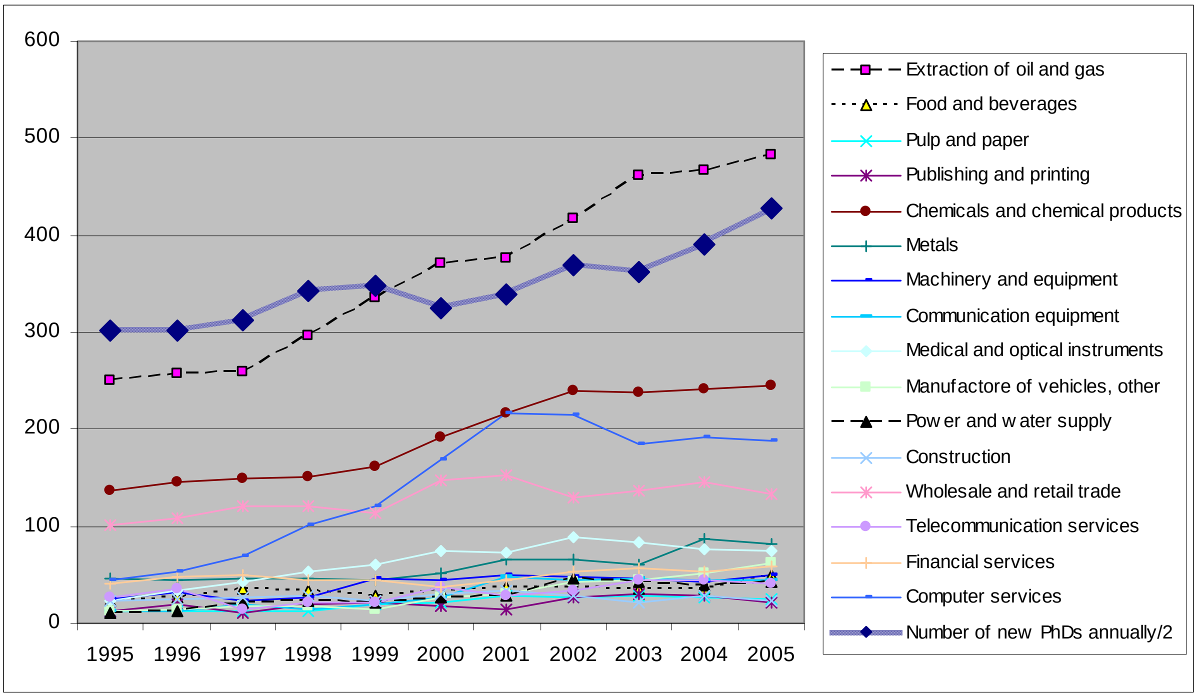

Figure 6. Number of PhDs in selected Norwegian industries. Source: Gunnes et al. (2007).