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Research Policy 34 (2005) 932–950
research policy
www.elsevier.com/locate/econbase

Industry funding and university professors' research performance

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Received 19 September 2003; received in revised form 3 May 2005; accepted 12 May 2005

Abstract

University research is to an increasing extent funded by industry, and the share of basic funding is decreasing. In the literature, there are optimistic and pessimistic views on the implication of this development. Based on data from a questionnaire study among all tenured university professors in Norway ($N = 1967$) we find that there is a significant relationship between industry funding and research performance: professors with industrial funding describe their research as applied to a greater extent, they collaborate more with other researchers both in academia and in industry, and they report more scientific publications as well as more frequent entrepreneurial results. There is neither a positive nor negative relationship between academic publishing and entrepreneurial outputs.
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Keywords: University research; Research funding; Research performance; University–industry relations; Academic entrepreneurship

1. Introduction

The trend across the whole OECD area is that university research is increasingly funded by private companies and that the share of basic funding for universities is decreasing. In Norway, industrial funding of university research has more than doubled since the start of the 1980s, just like the OECD average. This article investigates the relationship between commercialisation of research and university professors' research performance.

Universities and colleges are seen as key actors or organisations in national innovation systems, not least because these organisations constitute a vital infrastructure for the private research laboratories where many of the innovative activities are carried out (Freeman, 1987; Lundvall, 1992; Nelson, 1993). The frequently indirect nature of the relationship between universities and industry is emphasised—universities train industry personnel, create a pool of fundamental knowledge and, varying with discipline, engage in more direct contract work for private companies

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doi:10.1016/j.respol.2005.05.004

(Rosenberg and Nelson, 1994). Increased direct interactions between universities and industry is often taken as an indication of a new mode of knowledge production or a changed social contract for science (Gibbons et al., 1994; Guston and Kenniston, 1994; Martin and Etzkowitz, 2000; Martin, 2003). Policy-makers have pushed for such a development, including an increased focus on the direct commercialisation of academic research results (Godin and Gingras, 2000; Van Looy et al., 2004). Through changed funding regimes and changed legislation regarding ownership of research results in many countries, policy-makers aim for a close "triple helix" relationship between universities, governments and industry (Etzkowitz and Leydesdorff, 2000). While the social contract based on the linear "science push" model of innovation provided basic researchers with considerable autonomy, the new social contract, followed by or preceded by changing funding patterns, implies that scientists in return for public funds should explicitly address research problems of industrial and social relevance.

In general, there are optimistic and pessimistic views on this development and on the future of universities as central social and economic institutions (see Rosenberg and Nelson, 1994; Martin and Etzkowitz, 2000 and Martin, 2003 for overviews). Some are worried, others not, about the consequences of universities' external orientation and changed funding base for academic roles and performance. The "pessimistic view" is based on a possible decrease in long-term research or changed research agendas, tensions between the culture of open science and increased commodification and commercialisation, and increased pressures on the researchers and the traditional teaching and basic research tasks they carry out (cf. Slaughter and Rhoades, 1996; Vavakova, 1998; Geuna, 2001; Nelson, 2001; Geuna and Nesta, 2003). Over time, this might be detrimental to the "academic commons" (Hellström, 2003) or "academic heartland" (Clark, 1998). Even when major contributions to industrial growth and restructuring are desired, it is claimed that university researchers should concentrate on teaching and on basic research (Rosenberg and Nelson, 1994).

On the other hand, it has been argued that the convergence between academic and corporate research can imply increased flexibility and autonomy for researchers (Kleinman and Vallas, 2001; also Benner and Sandström, 2000). Universities may strengthen their traditional norms and their research and teaching activities as a "second academic revolution" leads them into becoming "entrepreneurial institutions" with closer and more productive relationships with industry and the public sector (cf. Clark, 1998; Etzkowitz, 1998, 2003; Etzkowitz and Leydesdorff, 2000). Instead of being a question of either-or, successful universities and university researchers manage to combine academic excellence with industrial contacts and/or entrepreneurial contributions (Godin and Gingras, 2000; Van Looy et al., 2004). In between these optimistic and pessimistic views, it is relevant to place those who claim that there is tension between the "newer" application-oriented and transdisciplinary knowledge production – often called "Mode 2" – and the "older" disciplinary academic research referred to as "Mode 1" (cf. Gibbons et al., 1994; Nowotny et al., 2001). Mode 2 knowledge production might be more suited to the needs of many modern societies, but implies a reduced importance for universities in knowledge production.

In a follow-up of the "Mode 2" debate, Nowotny et al. (2003) view commercialisation as one of three central contemporary trends for research, next to increased thematic priorities and accountability. The authors prefer the term "engaged research" to commercialisation, referring to two developments. The first is the hunt for industrial and other types of funding as basic funding for the universities is decreased. Included here are many traditional forms of university–industry relations in the form of collaborative projects. This may be termed the traditional type of commercialisation of university research. The second development of "engaged research" is the increased focus on the value of intellectual property rights, including support for patenting, licensing and the creation of spin-off companies. This can be called the new type (although there are many historical examples) of commercialisation. Many authors are more worried about the new types of commercialisation (cf. Nowotny et al., 2003; Rosenberg and Nelson, 1994).

The aim with this article is to examine the optimistic and pessimistic claims regarding commercialisation of university research, based on data on individual university professors. Our main focus is on industrial funding, although we deal with both types of commercialisation and their relationship to each other. We examine the extent to which there is a relationship between industrial funding and: (a) whether professors characterise their research as primarily basic, applied or development work, (b) extent and profile of their research collaboration, (c) scientific publishing and (d) entrepreneurial outputs in terms of patents, commercial products, establishment of firms and consulting contracts. Finally, we examine the relationship between commercialisation in terms of entrepreneurial outputs and academic performance in terms of scientific publishing. A micro-level approach is a useful addition to the more system-level approaches in the literature, and it is also justified since several investigations of university–industry relations have found that some of the most important linkages between the sectors may be found informally at the individual level (see Rosenberg and Nelson, 1994; Gulbrandsen, 1997; Godin, 1998). Our data furthermore add an importance nuance to earlier investigations that have used "industrial funding" as an indicator of other commercial outputs (e.g. Van Looy et al., 2004).

2. Main propositions

The fundamental hypothesis of this article is that there are significant differences between university professors with industrial funding and professors with other types of funding or no external research funding at all with respect to their research activities, and that there is a negative relationship between entrepreneurial activities and academic publishing on an individual level.

In Norway, as in many other countries, the professors' salaries – still the largest part of the research cost in most disciplines – are covered completely by the core funding/basic grant. This core funding also contributes to maintaining a certain infrastructure, including administrative and technical personnel, some equipment and Ph.D. scholarships. External sources provide additional funding for positions (Ph.D. students, postdocs, assistants, etc.), equipment and other research expenses. Professors may also use external funds to reduce their teaching load. Research councils, industry, foundations, public agencies and international sources like the EU are central external funding sources in many countries. Doing research is an individual legislative right in Norway tied to a permanent professor position, but lack of success in securing external funding may severely limit the research opportunities, although many professors may focus on smaller-scale "cheaper" activities rather than give up research altogether.

With resource dependency theory it may be argued that money "at the margins" alters faculty behaviour (Slaughter and Leslie, 1997). Even though the relative magnitude of industrial funding is not extensive, it may constitute a *critical* resource to the recipient (Pfeffer and Salancik, 1978). Funding sources influence the behaviour and outputs of researchers through different selection and evaluation criteria and by changing network configurations. Over time, the criteria and processes of selection and evaluation become institutionalised. Using neo-institutional theory, Benner and Sandström (2000) argue that research funding and research funding organisations create "organisational fields" through coercive, normative and mimetic processes. One example is an increasing standardisation of contracts for university–industry relations and increasing experience with cross-sector collaboration. Over time, these "organisational fields" affect the fundamental routines, norms and organisational structures of the researchers and their institutions. External funding is thus not "neutral", it carries with it expectations of certain outcomes and processes that may or may not be similar to what would have happened if the research funding came from an "internal" source. It has also been argued that entrepreneurial activities like patenting could ideally create funding with no strings attached, but in practice, patenting is costly and is often followed by disclosure agreements or behaviour that may violate norms of openness and communalism in science (have even more important impacts on university faculty research performance (Geuna, 2001; Nelson, 2001). Based on these assumptions we have developed five hypotheses.

2.1. Classification of research activities

As mentioned, there is worry that increased industrial funding will force universities into taking on ever more applied research and development work (Geuna, 2001; Geuna and Nesta, 2003; Nelson, 2001), thus leading them to neglect their responsibilities for long-term knowledge development. This has been called "drift of epistemic criteria" (Elzinga, 1983) or the "skewing problem" (Florida and Cohen, 1999). Also the Mode 1/Mode 2 distinction perceives traditional disciplinary university research and research in the context of applications more or less as alternative and incommensurable modes of research (Gibbons et al., 1994). Other authors have claimed that Mode 2 does not necessarily always conflict with Mode 1 (Jacob, 2000) and that Pasteur's use-inspired basic research demonstrates that applied and basic are independent and not incommensurable dimensions (Stokes, 1997). It has also been emphasised that the terms basic and applied research are open to several definitions and that the researchers use the concept strategically depending on the situation and audience (Calvert, 2000, 2004).

Although data from leading U.S. research universities reveal that their share of basic research has not been reduced under changing funding regimes and increased weight on commercialisation (Nelson, 2001), there is also evidence that this is not the case in all institutions (Geuna, 1997). Geuna finds that a handful of the British universities receive the lion's share of the industrial funding that is long-term and/or has "no strings attached", while a larger number of technology-oriented institutions get the shorter-term and less basic contracts. This increases the specialisation of the institutions and creates a "hybrid" higher education sector. A Belgian case study comparing research groups within a university, finds no evidence of a skewing problem, however (Van Looy et al., 2004). At least measured by publication patterns, industry-oriented groups do not differ markedly from groups with no industrial orientations. Moreover, the direction of a possible relationship is also not certain—does industrial collaboration lead to applied research, or are researchers with applied interests drawn to co-operation with firms (cf. Van Looy et al., 2004)?

Nevertheless, we know that many university professors are indeed motivated by a desire to contribute to national competitiveness, job and wealth creation, etc. (e.g. Rosenberg and Nelson, 1994; Etzkowitz, 1998; Gulbrandsen, 2004). Not least the technological disciplines in Norway are often seen as "less basic" than similar disciplines in other countries (Van Brussel et al., 2004). In sum, we therefore expect that *professors with industrial funding depict their own activities as applied research or development work, more often than professors without industrial funding do* (**Hypothesis 1**).

2.2. Collaboration patterns

In general, it is reasonable to assume that professors with external funding collaborate more with colleagues in other sectors than professors with no external funding. This is a clear expectation following many funding arrangements (e.g. the large "user-controlled" research programmes in the Research Council of Norway) and may also be tied to broader developments towards "triple helix" networks of knowledge production where university research becomes more relevant and accessible to society (Etzkowitz and Leydesdorff, 2000). Furthermore, in the R&D management field it has long been established that the more applied the research, the more the researchers need to communicate with different groups inside and outside of the scientific/technological communities (e.g. Katz and Allen, 1982; also Ernø-Kjølhede et al., 2001).

The emergence of biotechnology, ICT and other generic technologies/disciplines the last decades has probably also made collaboration with groups external to academic science more relevant to a larger number of researchers (cf. Zucker et al., 1998; Nelson, 2001). Not least in these disciplines, the sharp increase in the number of "academic entrepreneurs" signifies strengthened linkages across sectors (e.g. Etzkowitz, 1998). In sum, we therefore propose that *professors with external funding generally collaborate more than their colleagues with no external funding do, but professors with industrial funding have a somewhat diverging collaboration profile and co-operate more frequently with groups outside of the higher education sector* (**Hypothesis 2**).

2.3. Academic output

Research is often expensive regarding materials, equipment and assistance. It seems therefore almost self-evident that professors with external funding are more productive than colleagues with no such funding. Eminent scientists may get a disproportionate amount of credit and resources, a process that can be termed a "credibility cycle" (see Latour and Woolgar, 1979). It has been argued that increased industrial contacts contribute to the same non-meritocratic processes as traditional academic science (Geuna, 2001).

This is supported by two earlier investigations, one among U.S. life science faculty (Blumenthal et al.,

1996) and another using a broad selection of Canadian university personnel (Godin, 1998). Both found that university researchers with funding from and/or collaboration with industry produce more scientific publications than their colleagues without such funding/collaboration. It is claimed that there is no tension between many types of contract work and good academic science, and/or that high scientific quality is a prerequisite to being able to take on many external contracts (cf. also Salter and Martin, 2001).

On the other hand, some empirical studies indicate that the correlation between external funding and number of publications is relatively weak (Kyvik, 1991). Moreover, U.S. life sciences may be special as the country has the world's most advanced biomedical industry, and Canada is a particular case with one of the highest shares of industry funding of university research in the OECD area. There is also some counter-evidence. British universities hit hard by budget cuts are to some extent pushed to do routine contract research for industry and that this has been accompanied by a lowering of the average scientific publication rate (Geuna, 1999, pp. 102–103). A study among genetics researchers found that almost half of them had been turned down when approaching colleagues with requests for information (Campbell et al., 2002). All these investigations may point to the "secrecy problem"—patenting, confidentiality issues or simply academic research strategies could lead to less openness in science (Florida and Cohen, 1999; Nelson, 2001). One possible outcome is that professors with industrial funding could publish more reports and less journal articles than colleagues with other types of external funding, a publication profile more typical of applied researchers.

Hypothesis 3 becomes: *Professors with external funding publish more than colleagues with no external funding, but there are differences in publishing profile between professors with industrial and other types of funding*.

2.4. Commercial outputs

No earlier investigations have focused explicitly on the relationship between funding and commercial outputs. There is some evidence that increased contract research often follows from patents and academic entrepreneurship (cf. Geuna and Nesta, 2003). The relationship between industrial funding and entrepreneurial outputs may, however, be vague since the extent of entrepreneurial activities is rather limited. The recent surge of interest in academic patenting does, for example, not mean that this is an extremely widespread phenomenon (despite a notable growth) especially if we look further than leading research universities. In a survey of more than 500 higher education institutions in the U.S., Coupé (2003) found that 372 of them were not listed with any patents at all. For most academics, publications are still the favoured and valued output (e.g. Owen-Smith and Powell, 2001).

Moreover, Van Looy et al. (2004) argue that the relationship between industrial funding and commercial outputs may not be significant if we look further than the industrial contacts themselves. There may be a tension between doing regular contract work for established companies and starting new companies and/or creating academic patents. Over time such types of commercialism may nevertheless be correlated. In sum, we therefore suggest that *professors with industrial funding can point to more patents, spin-off companies and other commercial results than other professors* (**Hypothesis 4**).

2.5. Commercial and academic outputs

Irrespective of whether there is a positive relationship between industrial funding and academic as well as commercial outputs, there may be a tension between the two types of outputs. Blumenthal et al. (1997) found that 19.8 percent of a sample of U.S. academic life scientists had withheld research results for more than 6 months due to intellectual property rights discussions, patent applications, etc. Geuna and Nesta (2003) refer to a study by the European Commission where it was found that a small share of industrially oriented university researchers experience large delays in their publications. This finding is mainly explained by lack of practice with patenting rather than any inherent tension between academic and commercial outputs. The authors nevertheless suggest that there may be a substitution effect between publications and patents, where only the most experienced researchers will be able to be academically *and* commercially productive.

The investigation of Campbell et al. (2002) could not explain the lack of openness among genetics researchers with increased commercialisation or industrial contacts. They point instead to scarce resources and professional priorities. Professors have limited time even if they work twice the normal working hours in a country. Patenting and other entrepreneurial activities do not lead to conflicts of interest or commitment, but there is a "time squeeze" problem since such involvement most likely will leave less time for other academic pursuits (e.g. Etzkowitz, 1998; Vavakova, 1998). In sum, we therefore assume that *there is a negative relationship between scientific publishing and commercial outputs* (**Hypothesis 5**).

3. Data source

The data are drawn from a 2001 questionnaire study among all faculty members of the rank of assistant professor or higher at Norway's four universities. The response rate in 2001 was 60 percent ($N = 1967$). The response was somewhat higher in the natural sciences (66 percent) than in the humanities and technology (54 percent). The response rate in medicine and the social science was 64 and 58 percent, respectively. Moreover, the response rate was higher among full professors (64 percent) than among associate (57 percent) and assistant professors (47 percent). There are no significant differences in response rates between men and women, age groups and between the four universities (Smeby, 2001).

Analyses from a similar study in 1981 showed that those who did not respond published on average 30–35 fewer publications than those who responded (Kyvik, 1991). Data have not been available to conduct similar analyses in the present study. Nevertheless, since professors publish more than associate and assistant professors this may be a reason why the response rate is higher in the former group in both studies. However, analyses show that full professors also have more funding and collaboration with industry, and more often report various types of commercial outputs from their research than assistant and associate professors. Our sample tends to have a bias in direction of elite performers academically as well as commercially. Even though it may be argued that this selection bias have limited impacts on our analyses of the relationship between commercialisation and academic performance, the problem of focusing on academic elites will be discussed at the end or the article. The relatively low response rate in technology as well as in the humanities implies a bias with respect to fields with the highest and lowest proportion of professors involved in commercial activities. These biases seem to have contrary implications, but separate analyses have been conducted for each field of learning.

The central background variable in this paper is research funding. Respondents were asked if they during the last 5 years had received research funding from the Research Council of Norway, industry/business, public agencies, private foundations/organisations, EU programmes and other foreign sources. In the analyses, we distinguish between three groups:

(1) professors (assistant, associate, full) with no external research funding;
(2) professors with research funding from industry;
(3) professors with other types of external funding.

The second group may have other types of external funds in addition to industry funding, while the third group is composed of respondents with external research funding but no money from industry. This third group is rather heterogeneous, but statistical analyses confirm that there are no relevant differences in characteristics of respondents based on the "other types" of external funding.

To examine the relationship between funding and research orientation/performance the following indicators are considered:

- Respondents' characterisation of their research as primarily basic, applied or experimental development according to the definitions given in the guidelines for the international R&D statistics (OECD, 1994).
- Respondents' assessment of statements on the impacts of contracts: (a) contracts introduces new and interesting research topics? (b) Contracts are prerequisite to accomplish expensive and interesting research projects? (c) Contracts are problematic with regards to autonomy and independence of research?
- Whether respondents have had collaboration with researchers in their (a) own department, (b) other university departments, (c) colleges, (d) research institutes, (e) industry/business and (f) foreign research institutions during the last 5 years.
- Respondents' scientific publications the latter 3 years in terms of (a) articles in scientific and scholarly

journals, (b) articles in research books, text books and conference proceedings, (c) research books and textbooks, reports if part of a publications series, (d) and articles that they would characterise as popular science.

- Whether respondents reported that their research and development work ever had resulted in commercial outputs in terms of (a) patents, (b) commercial products, (c) establishment of firms and (d) consulting contracts.

In order to develop a simpler indicator on scientific publishing that takes account to the different publication patterns across academic fields and to adjust for the effect of multiple authorship, a productivity index was constructed according to the procedure used by Kyvik (1991). All publications have been recoded into *article equivalents*. An article in a journal or book is given the value of 1, a book the value of 4 while a report receives 1 point. In cases of co-authorship, the number of points is divided by 2, irrespective of number of co-authors.

In the presentation of the results, bivariate relationships between research funding and the indicators listed above are presented in figures and tables. All results reported in the text are statistically significant at least on a 0.05 level. Patterns of research funding differ significantly between academic fields (Fig. 1). The field classification follows the guidelines for research statistics suggested by UNESCO (1978). In general, results are reported for the whole population, but separate analyses for each academic field (natural sciences, social sciences, technological disciplines, the humanities and medicine) have been conducted to examine whether differences between respondents with different types of research funding is an indirect effect of characteristics of the respective fields of learning or whether the patterns holds for all fields. The results from these analyses are reported in the text. Analyses show that there are only minor differences between the four universities which are not indirect effects of the disciplinary composition of the respective institutions (one of them is particularly technology-intensive). Differences between universities are therefore not discussed any further in the present article.

In the last section logistic regression analyses of the probability to report different types of commercial output are presented. Demographic variables, external funding, research collaboration, publications and academic field are included as independent variables. An assumption in these analyses is that the patterns are relatively stable. Scientific publishing are, for example, based on publications the latter 3 years, while commercial outputs are not limited to a specified period of time. Descriptive statistics of the variables included in the analyses are presented in Table 1. While the interpretation of coefficients in a multiple linear regression is rather straightforward, the beta coefficients in a logistic regression, which are showing the independent variables' proportional influence, cannot be interpreted directly. Based on the beta coefficients

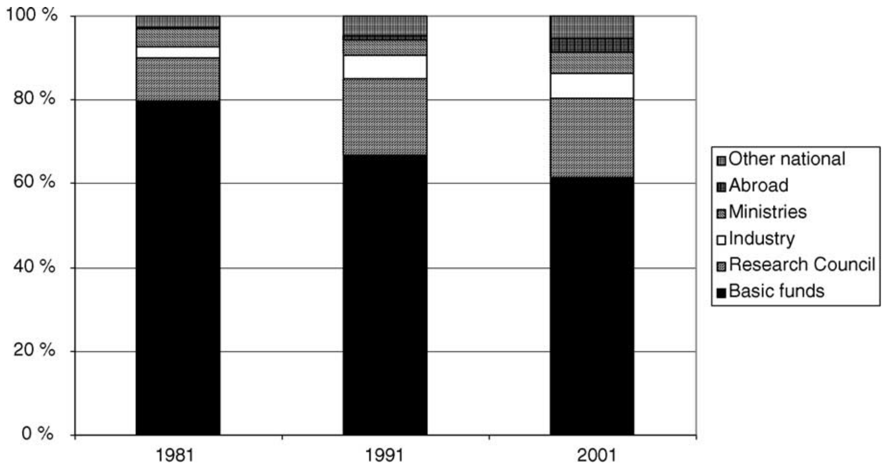

Fig. 1. R&D operating costs and equipment costs in universities by source of funds.

Table 1
Descriptive statistics of the variables used in the logistic regression analyses

	Mean	S.D.	Minimum	Maximum
Demographics				
Full professor	0.58	0.49	0	1
Age	52.06	8.86	25	70
Female	0.20	0.40	0	1
External funding				
Funding from industry	0.21	0.41	0	1
Only other external funds	0.55	0.50	0	1
Research collaboration				
Universities	0.80	0.40	0	1
Research institutes	0.31	0.46	0	1
Industry	0.21	0.41	0	1
Foreign institutions	0.66	0.48	0	1
Publications				
Article equivalents	7.23	7.62	0	69
Journal articles	5.17	6.72	0	90
Books	0.49	1.16	0	12
Book articles	2.54	4.29	0	45
Reports	0.81	2.46	0	48
Popular publishing	1.99	5.64	0	99
Commercial outputs				
Patents	0.07	0.26	0	1
Commercial products	0.10	0.30	0	1
Establishment of firms	0.07	0.25	0	1
Consulting contracts	0.31	0.46	0	1
Academic field				
Humanities	0.21	0.41	0	1
Social Sciences	0.22	0.42	0	1
Natural science	0.29	0.45	0	1
Medicine	0.20	0.40	0	1
Technology	0.08	0.26	0	1

$N = 1967$.

the odds of an event occurring may, however, be calculated.

Our hypotheses are all to some extent based on the assumption that commercialisation has important impacts on research performance. However, bivariate and multivariate analyses do not give any evidence about causal relationships. Industrial funding may course promote more applied research and increased scientific publishing, but applied and high performing researchers may also attract industrial funding to a greater extent. In this article we therefore avoid taking about "impacts" and "effects", but rather use concepts like "relationships".

4. Results and discussion

It is an international trend that external funding has become increasingly important, albeit slowly, during the last two decades (cf. Geuna, 1999, 2001). While external funding constituted 20.5 percent of R&D expenditure (operating costs and equipment, i.e. excluding investments in buildings, etc.) in Norwegian universities in 1981, the corresponding proportion was 38.4 in 1999. The decrease in basic funding has partly been compensated by increased research council funding. Funding from industry increased from 2.8 to 6.0 percent in the same period (Fig. 1), and Norway has been very close to the OECD average on this indicator the last two decades. Even though the proportion of basic funding continued to decrease during the 1990s, the most significant changes in the funding patterns occurred during the 1980s. The exception is the international funding (mainly the EU), which has tripled its share since the early 1990s (Fig. 1).

Data from our survey shows that the majority (76 percent) of respondents received external research funding in the period between 1995 and 2000 (Fig. 2). Even though funding from industry only composes 6 percent of the total research funding, 21 percent of the professors received such funding during this 5-year period. As expected, the funding patterns differ significantly between fields of learning. Fig. 2 shows that over 80 percent of professors in the natural sciences medicine and technology received external research funding between 1995 and 2000, while the proportion is 74 percent in the social sciences and 54 percent in the humanities. The proportion that received funding from industry varies even more. This is most common in technology (66 percent) and least common in the humanities (3 percent).

Comparisons with data from earlier similar surveys (from 1992 to 1982) confirm that the major shift in funding from industry and other external sources took place during the 1980s. In 1991, 20 percent of the respondents reported that they had received research funding from industry (not much less than the 21 percent in 2001). The number was 7 percent in 1981. In the 1981 survey, however, the National Institute of Technology (now part of the Norwegian University of Science and Technology in Trondheim) was not part of the study. The large increase in the 1980s and small increase in the 1990s can nevertheless be seen in all the

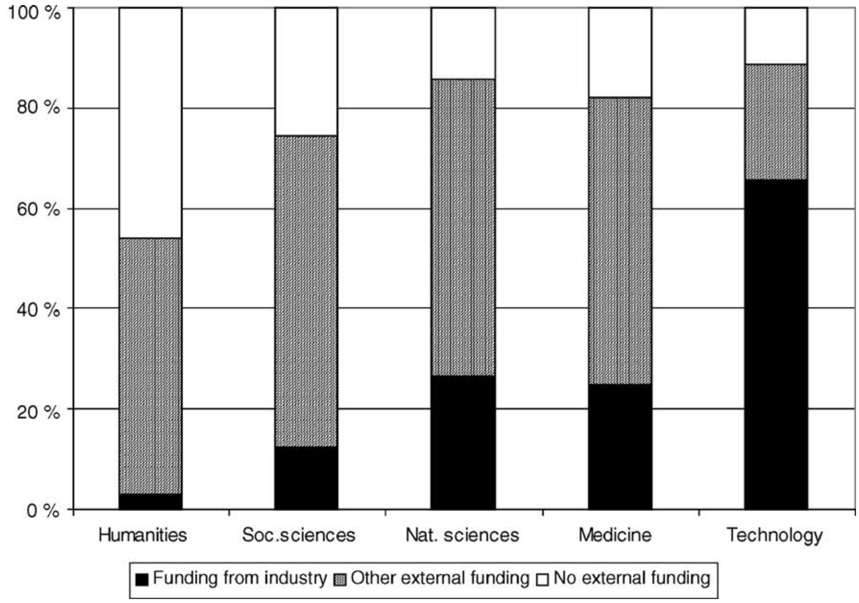

Fig. 2. Percentage of faculty members who received research funding from industry, from other external sources and who had no external research funding in 1995–2000 by field of learning.

other fields of learning—with the social sciences as the exception. In these disciplines, we see a doubling in the share of professors with industrial funding from 1991 to 2001 up to 15 percent. This could indicate recent changes in the social sciences at the universities and/or increased industrial interest in these disciplines.

It is interesting to compare the national R&D statistics – business enterprise funding share of higher education R&D – with our individual-level data, even though the data sets are not directly comparable (Table 2). The individual data are based on whether professors have received funding during a 5-year period, while R&D statistics are based on expenditures for 1 year. Nevertheless, a comparison shows that the proportion of professors involved in project funded by industry is much higher than indicated by the proportion of industrial funding in the R&D statistics. We see that in the natural sciences, social sciences and technological disciplines, the share of professors that have received funding from industry in a 5-year period, is about two times the share of industry funding of university R&D in the national statistics. The deviant case is medicine, where one out of four respondents have had industry funding, yet the national statistics only report that 3 percent of medical science is funded by industry. This could indicate that there are relatively many small projects which are distributed among many professors in this field. Our crude comparison of individual-level data and macro statistics may thus support some of the worries of Geuna (2001) and others. Industrial funding of university R&D, which seems such a small share of the total, involves a relatively large proportion of the professors.

Table 2
Industry/business funding as percentage of R&D expenditure in higher education sector (National R&D statistics 2001) and as percentage of university faculty members with the industrial funding during the last 5 years (University census 2001), by academic field

	Percentage of R&D expenditure in higher education sector	Percentage of university faculty members with industry funding
Humanities	3	3
Social science	7	15
Natural science	14	26
Medicine	3	25
Technology	38	66
Mean	6	21

4.1. Nature of research

Respondents were asked to characterise their research as primarily basic research, applied research or experimental development. Fig. 3 confirms that there is a relationship between research funding and these kinds of characterisations of the research output. Nearly half of the respondents who had received research funding from industry the last 5 years, characterised their research as primarily applied research, while only one out of four of those with no research funding or with research funding from other sources did. It should, however, be recognised that nearly 40 percent of those that had received industrial funding stated that their research is primarily basic research. It is also interesting to note that the "basic research" group is even larger among those who had received other types of external funds than those who had not received external funds at all. How respondents typify their research differs somewhat between fields, but the impact of funding is the same in all of them. Thus, hypothesis 1 is at least partly confirmed. Industry funding is related to applied research rather than development work, however, and the respondents with no external funding at all more frequently characterise their activities as "development work".

The relevance of these categories can of course be questioned (see e.g. Calvert, 2004; Nowotny et al., 2003 and other literature referred to in Section 2.1). Empirically, it is interesting to note that while 6 percent of the respondents did not answer this question ("Would you characterise your research as primarily basic research, applied research or experimental development?") in the 1982 census, the corresponding share was 29 percent in 2001. Some could be unable to characterise their research as mainly one type, while others may consider basic and applied two different dimensions of a body of work rather than a dichotomy (Stokes, 1997; also Calvert, 2004). The distinction between basic and applied research might furthermore make more sense when a researcher is actively involved in contracted work for industry. The proportion that did not answer the question in 2001 is lower among those with funding from industry (19 percent) than among those with other types of external funding (29 percent) and those with no external funding (42 percent). Some of the respondents without any external funding might not be actively involved in research at all.

The impact of funding is confirmed by respondents' assessment of the consequences of contract research (Table 3). A quarter of the respondents report that contracts introduce new and interesting research topics in their department, and that it is prerequisite to accomplishing expensive and interesting projects. Nearly 20 percent report that contracts are problematic with regards to autonomy and independence of research. Professors with industrial research funding agree to a greater extent to the two first statements, and to a less

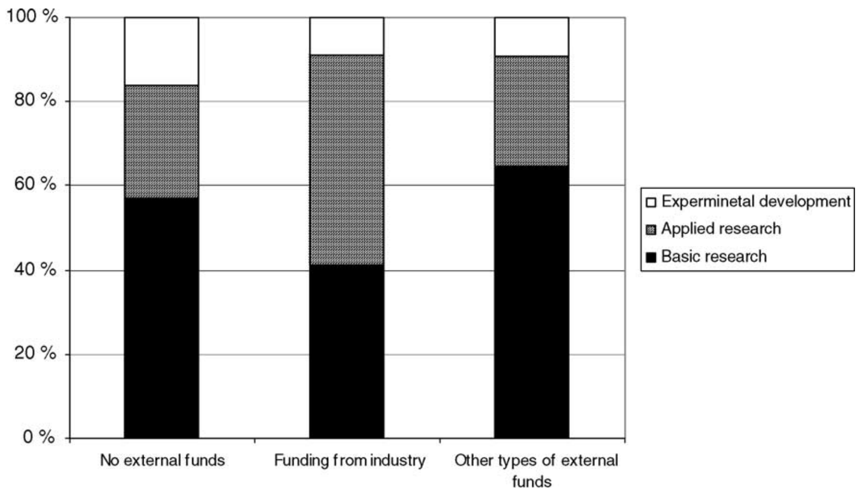

Fig. 3. Percentage of faculty members that characterise their research as primarily basic research, applied research and experimental development by type of research funding the last 5 years (1996–2000).

Table 3
Percentage of faculty members that agree to the following statements about the consequences of contract research in their department, by type of research funding the last 5 years (1996–2000)

	No external funds	Funding from industry	Other external funds	Mean
Introduces new and interesting research topics	23	43	20	26
Is prerequisite to accomplish expensive and interesting projects	21	38	18	24
Is problematic with regards to autonomy and independence of research	22	12	20	19
N	302	393	841	1536

degree with the last one, than professors without such funding. These patterns are the same in all academic fields.

This can be interpreted in several ways. On the one hand, it may indicate that scepticism against contracts at least to some extent is ideological and based on professional norms and values. Those with contracts may be less sceptical towards such funding because they personally have had positive experiences. On the other hand, it could also be that professors without industry funding, at least some of them, have avoided contract research because of possible negative influences on autonomy, intellectual property rights and other issues, while those who are conducting contract research are less willing to admit negative aspects.

4.2. Collaboration patterns

Funding also seems to have a significant impact on respondents' collaboration patterns (Table 4). The main difference is between those who have external research funding of any kind and those who have not. One reason for this is that funding of research often presupposes collaboration and also constitutes an opportunity for collaboration. There is a general cumulative tendency; those who collaborate with one category of researchers are more likely to collaborate with the other categories as well. However, those with industrial funding report more frequent research collaboration with colleagues in their own department, in colleges and in research institutes, in other countries and especially with researchers in industry and business, than their colleagues with other types of funding. This pattern holds for all fields of learning.

The data confirm hypothesis 2; applied research demands more intense contacts with more groups than basic research. It is interesting that the ones with private sector funding and collaboration have more frequent contacts both in academic and non-academic circles. There may be different personal preferences for researchers where some favour a highly collaborative mode and others do not. Knowledge production in some areas is probably also becoming more collaborative due to epistemological and institutional developments as described in the "Mode 2" and the "Triple Helix" literature (e.g. Nowotny et al., 2003; Etzkowitz and Leydesdorff, 2000). Our data thus indicate that there is no clear conflict between traditional academic science and newer types of knowledge production. New patterns of communication could still

Table 4
Percentage of faculty members that reported regular research collaboration with researchers in different types of institutions, by type of research funding the last 5 years (1996–2000)

	No external funding	Funding from industry	Other external funds	Mean
Own department	43	78	67	64
Other university departments	35	70	65	59
Colleges	7	17	11	12
Research institutes	11	56	31	31
Industry/business	5	72	9	21
Foreign research institutions	35	81	74	66
N	472	412	1083	1967

Table 5
Faculty members' average number of various types of publications, by type of research funding the last 5 years (1996–2000)

	No external funding	Funding from industry	Other external funds	Mean
Journal articles	2.3	7.2	5.6	5.2
Book chapters	1.4	4.0	2.5	2.5
Books	0.5	0.4	0.5	0.5
Reports	0.3	1.4	0.8	0.8
Popular science articles	1.9	1.8	2.1	2.0
Article equivalents	5.0	8.8	7.6	7.2
N	458	407	1072	1937

cause stress and tensions due to their complexity and intensity.

It may be added that not all respondents with industry funding reported regular collaboration with researchers in companies. Around one-third of the 448 professors with industry funding in a 5-year period, did *not* have regular co-operation with industry colleagues. Conversely, one-third of the 446 professors with regular research collaboration with industry had not received funding from companies the last 5 years. Although there is a positive relationship between funding and co-operation with industry, our data show that there are also other reasons for collaboration with researchers in industry and that university professors are important partners in Mode 2 types of networks (as in Godin, 1998).

4.3. Academic output

Funding also has a significant correlation with scientific publishing, confirming hypothesis 3 (Table 5). Professors who have external research funding publish more than colleagues without external funding. Moreover, professors who have had funding from industry publish more than their colleagues who have received other types or funding. The only exception is that there are no differences between these groups when it comes to publication of books and publication of popular science articles. The implication of funding for publication is the same for all fields of learning. The differences are statistically significant within all fields when comparing those who have external funding and/or industry funding with those who have no external funding at all, but the difference between professors with funding from industry and funding from other sources is, however, only significant in the social sciences and medicine (Table 6).

In the table for the different types of publications, we have not distinguished between single and multiple authorships. Since funding is related to research collaboration, the differences between respondents with different types of research funding may therefore be due to different publication patterns rather than varying individual productivity. However, the productivity index (article equivalents) with different weight to different types of scientific publications and single and multiple authorships confirms the impact of funding on scientific productivity. Professors with no external research funding published 5.0 article equivalents, professors with industrial funding published 8.8 article equivalents, and professors with other types of research funding published 7.6 equivalents. These results are still statistically significant (also within each academic field), but the absolute differences are smaller.

Table 6
Percentage of faculty members reporting various types of commercial outputs from their research, by type of research funding the last 5 years (1996–2000)

	No external funding	Funding from industry	Other external funds	Mean
Patents	1	24	4	7
Commercial products	6	25	6	10
Establishment of firms	1	20	4	7
Consulting contracts	18	60	25	31
N	472	412	1083	1967

Our results confirm that traditional university–industry relations defined by industry funding and cross-sector research collaboration do not seem to conflict with more traditional academic goals and rewards (see Rosenberg and Nelson, 1994; Nowotny et al., 2003). Excluding entrepreneurial outputs (discussed below), industrial funding and attention obviously seems related to the Matthew effect in science (cf. also Van Looy et al., 2004). By looking at different types of publications, the present study gives even stronger evidence to this point—there are for instance no differences between the productivity of industry-funded researchers and other researchers when it comes to popular science contributions. A limitation in our analysis is that it only includes data on the number of publications. Other studies that have looked more closely at the reputation or impact of journals, nevertheless confirm that industry orientation does not conflict strongly with academic values and activities (Godin and Gingras, 2000; Van Looy et al., 2004). Another limitation is that our data are only reports from individuals. Although we do adjust for co-authorship, it could nevertheless be that the successful scientists more often benefit from group work, i.e. better access to human and other resources than their less successful colleagues.

4.4. Commercial output

Respondents were asked whether their R&D activities ever had resulted in “commercial results”: 7 percent reported patents, 10 percent “commercial products” and 7 percent that their R&D had led to the establishment of new firms. Finally, 31 percent reported consulting contracts. Contrary to the patterns found for scientific publishing, the main differences when it comes to commercial outputs emerge between those with industrial funding and those with no or other types of research funding. The only difference between researchers with other types of funding and no external funding is that the former have somewhat more frequent consulting contracts than the latter. As expected, these commercialisation outputs are mainly found in technology and the natural sciences, although all these results were reported by some respondents from all fields of learning, and even by (a few) respondents with no industry funding and contacts.

Logistic regression analyses have been conducted to examine the relationship between commercial results and research funding as well as selected other variables (Table 7). The demographic background variables academic position, age and gender only have limited and weak relation to commercial results. Patents are positively correlated with academic position – full professors report more patents than assistant and associate professors – while male respondents more often report that their R&D has led to establishment of firms than female respondents do. Age has no impact on any of the commercial results. It may be that patents require a certain level of seniority or experience more than the other types (cf. Geuna and Nesta, 2003).

Industry funding and collaboration are significantly correlated with various types of commercial results like patents, establishment of new firms, commercial products and consulting agreements. In other words, there does not seem to be a tension between relationships with existing industry and entrepreneurial contributions. It is still interesting to find that these entrepreneurial outputs, despite being more prevalent among respondents from natural science, technology and with industrial funding and/or collaboration, can also be seen in all academic fields and among respondents with no industry funding and contacts. We find that collaboration with research institutes (there are many of these in Norway, most of them are oriented at shorter term contract research for private companies and government agencies) has a negative effect on patents and commercial products. We have no obvious explanation for this. It could be that when a research project is carried out as a collaboration between industry, an institute and a university, the latter representatives become responsible for the parts that yield no direct commercial outcomes (e.g. doctoral students). Given the important discussion of the role of research institutes in many parts of the world, and the recent claims that institutes are a “barrier” to developing good university–industry relations (cf. Arnold et al., 2001), these issues deserve further study.

Since the logistic regression coefficients cannot be interpreted directly, we have conducted some calculation to illustrate the strength of the variables that have the strongest interrelations. If a professor has no industrial funding, the probability for conducting R&D leading to patents is 1 percent, given average values on the other variables. The corresponding probability is 7 percent if the professor has industrial funding. Moreover, if a professor has industrial funding *and* collaborates with

Table 7
Logistic regression analyses of probabilities that faculty members report commercial outputs in terms of patents, commercial products, establishment of firms and consulting contracts

	Patents		Commercial products		Firms		Consultant contracts	
	B	S.E.	*B*	S.E.	*B*	S.E.	*B*	S.E.
Demographics								
Full professor	0.558*	0.266	−0.160	0.193	0.223	0.252	−0.096	0.127
Age	0.008	0.012	0.011	0.010	0.005	0.012	0.013	0.007
Female	−0.687	0.424	−0.321	0.253	−1.187*	0.479	−0.208	0.148
External funding								
Funding from industry	1.703***	0.522	1.195***	0.312	1.217**	0.471	1.156***	0.207
Only other external funds	0.793	0.507	0.200	0.262	0.458	0.443	0.169	0.158
Research collaboration								
Universities	0.047	0.314	0.308	0.238	0.340	0.329	0.320*	0.153
Research institutes	−0.435	0.226	−0.404*	0.192	−0.227	0.223	0.417***	0.122
Industry	1.293***	0.258	0.896***	0.227	1.218***	0.267	0.611***	0.162
International	0.123	0.263	−0.241	0.192	0.269	0.269	0.203***	0.129
Scientific publications								
Article equivalents	0.000	0.012	0.019*	0.010	0.001	0.012	0.025***	0.007
Academic field (natural science ref. group)								
Humanities	−2.163**	0.739	0.193	0.267	−1.184*	0.496	0.308	0.174
Social Sciences	−2.688***	0.730	−0.287	0.260	−0.993**	0.364	0.622***	0.153
Medicine	0.005	0.245	−0.034	0.232	−0.302	0.266	−0.187	0.165
Technology	0.447	0.264	0.506*	0.257	0.116	0.277	1.066***	0.228
Constant	−4.509***	0.842	−3.555***	0.616	−4.197***	0.815	−2.896***	0.418
−2 Log likelihood	731.470		1120.638		759.048		2078.260	

Impacts of demographics, external funding, research collaboration, publications and academic field. Unstandardised coefficients (*B*) and standard errors (S.E.), ($N = 1937$).
* $p < 0.01$.
** $p < 0.05$.
*** $p < 0.001$.

colleagues in industry, the corresponding probability is 18 percent – if the person also represent a technology discipline, the probability is 49 percent. The probability for conducting R&D leading to a new firm is 2 percent if a professor has no industrial funding, given average values on the other variables. The corresponding probability is 8 percent if the professor has industrial funding, 18 percent if the professor has industrial funding *and* collaborates with colleagues in industry. Moreover, if we also specify that the academic field is technology, the probability is 30 percent.

4.5. Commercial and academic outputs

There is a significant positive relationship between number of publications and the different commercial outputs. Fig. 4 shows that professors whose research had resulted in patents or establishment of firms published approximately 1.5 article equivalents more that colleagues without such outputs. Professors whose research had resulted in establishment of firms or consultant contracts had published two article equivalents more than those who did not report such outcomes. The patterns are the same in all academic fields, but most of the differences within each field are not statistically significant.

The logistic regression analyses (Table 7) confirm that there is a positive relationship between scientific publishing and the entrepreneurial outputs, but the relationships are very weak. A professor publishing 10 article equivalents has an increased probability for commercial products of only 0.5 percent and an increased probability of consultant work of 2 percent, compared to a colleague with half the number of

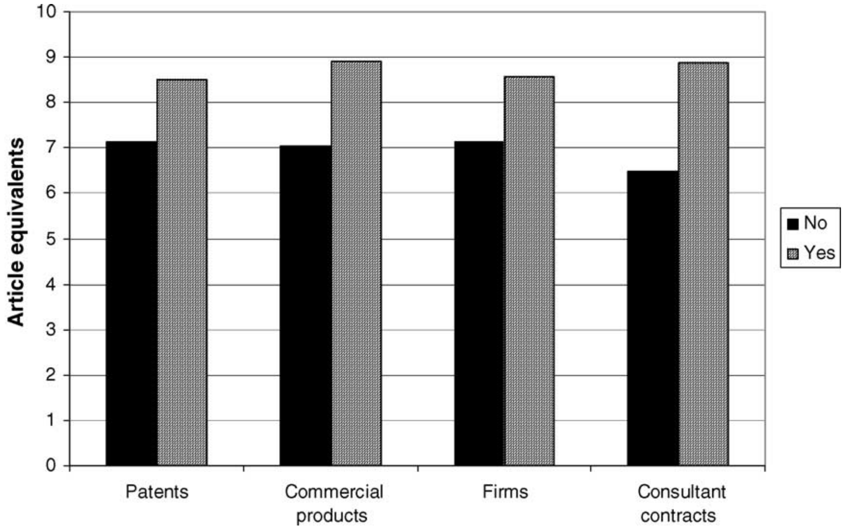

Fig. 4. Average number of publications (article equivalents) among faculty members which had and had not conducted research that resulted in patents, commercial products, establishment of firms and consultant contracts.

publications. Furthermore, there is no relationship between publishing on the one hand and patents and establishment of firms on the other. It is therefore reasonable to conclude that scientific productivity does not increase the probability of commercial output notably. One reason could be "time squeeze" or "secrecy" problems, but more research is needed into this as our data due to time lag cannot address this issue directly (see also Florida and Cohen, 1999).

The fact that professors with entrepreneurial outputs do not publish fewer scientific publications than their non-entrepreneurial colleagues also when controlling for other variables, may indicate that entrepreneurial and academic achievements are not substitutes. There are however, two reasons why such a conclusion cannot be drawn on the basis of our analyses. First, we do not know whether the respondents are directly involved in entrepreneurship or if these activities mainly are carried out by others. We also do not know when the commercialisation took place or the number of the different types of commercial outcomes.

Secondly, even if we presuppose that publication and commercialisation patterns are relatively stable over time, it is not clear whether entrepreneurial professors would be even more productive if they concentrated on academic efforts. The patterns may be an outcome of the Matthew effect in science (Merton, 1968, 1988). It has been recognised that there are accumulative and self-reinforcing mechanisms that tend to reward successful individuals and groups with access to means that increase their probability of being successful in the future (Geuna, 2001; Geuna and Nesta, 2003). Earlier academic (and possibly entrepreneurial) performance is an important criterion for achieving external funding and those who have some types of external funding are more likely to succeed when they apply for other types of funding, also from industry. Van Looy et al. (2004) refer to this as the "compounded" Matthew effect. A productive researcher is involved in many more activities other than "strictly academic" research (Godin, 1998). Nevertheless, it should be emphasised that we do not find a negative relationship between academic and commercial efforts. Even though our data is not appropriate to examine whether there is a "time squeeze" between these activities, professors seem to be able to combine entrepreneurial activities with an average level of scientific publishing, at least over time.

5. Conclusions

This article has examined the relationship between commercialisation of research and professors' research performance. We have found support that commercialisation in terms of industrial funding is significantly related to university professors' research activity, but that commercialisation in terms of entrepreneurial output is not significantly related to academic performance:

- Industrial funding is significantly related to applied research, but not to development work. However, one-third of the respondents did not answer the question about characterisation of own professional activities indicating that many researchers find the distinction between basic and applied research problematic or of limited relevance.
- The industry-funded claim to a greater extent that contract research introduces new and interesting research topics and is prerequisite to accomplishing expensive and interesting projects, and they are less worried about negative influences on autonomy.
- Industrial funding is related to a highly collaborative mode of research. University professors with funding from companies collaborate a lot more than others with companies and research institutes, but also more with foreign research institutions, the university college sector and with colleagues in their own department.
- Industrial funding is strongly correlated with high publication productivities, even when adjusting for types of publication and co-authorships.
- Industrial funding and collaboration is strongly correlated with producing patents and commercial products, the creation of spin-off companies and involvement in consulting work (called commercial/entrepreneurial outputs).
- Academic publishing and commercial outputs are neither significantly positively nor negatively correlated.

Our results on the relationship between industrial funding and academic performance are consistent with Blumenthal et al.'s (1996) investigations of U.S. life science faculty as well as Godin's (1998) analyses of Canadian university faculty. Godin concludes that Mode 1 (traditional academic disciplinary work) and Mode 2 (trans-disciplinary work in the context of application) are not two alternative modes of research—there is a high degree of heterogeneity in academic research (Godin, 1998; Godin and Gingras, 1998), just as we have found. There also seems to be a complex relationship between the "traditional" type of commercialisation – funding from and collaboration with industry – and "new" forms of commercialisation related to patenting and the creation of new firms.

Due to limitations in our data, our conclusion that academic and entrepreneurial outputs are neither positively nor negatively related has to be tentative. Moreover, the lack of significant relationships may also be due to contrary experiences and patterns. It is reasonable to assume that conflict of interest and commitment between entrepreneurial and academic activities (see Etzkowitz, 1996) as well as the time-squeeze problem differ not only between types of commercial efforts as our data may indicate, but also between fields and contexts. For example, interviews with entrepreneurial professors in Norway indicate both a major dividing line between the health sciences and the physical sciences (including technology and natural sciences), and another major dividing line between entrepreneurs with a basic research orientation and more professional academic entrepreneurs who maintain a certain distance both to academic and commercial values (Gulbrandsen, 2004). Health science and professional entrepreneurs (the latter may be termed "liminal" due to their position in between the academic and the commercial world), generally describe situations where academic and entrepreneurial work may be effortlessly integrated. Basic research-oriented entrepreneurs and many respondents from the physical sciences are on the other hand often somewhat sceptical towards the increase in patenting because it may constitute a barrier not only to further research but also to innovation. Patents, not only in software, may be a defensive mechanism to hinder competitors from carrying out research and innovative activities within a certain area.

Patenting may in some cases make the research process more expensive and time-consuming, as Nelson (2001) has suggested—while entrepreneurial activities cause no significant problems and may even be profitable for scientific publishing in other cases. Important issues for further research are to explore the conflict and nexus between academic publishing and different types of entrepreneurial activities and how much professors may engage in entrepreneurial activities before, if ever, it causes problems for their academic performance. Furthermore, even if there is no significant negative relationship between patenting and publishing on the individual level, the effects on the system level should also be examined. If patenting is partly motivated by hindering others from patenting or hindering others from adopting a particular research agenda, the individual's publication productivity might not be reduced. Patenting could nevertheless hamper the productivity of other researchers. This issue deserves further attention.

The ability to handle tensions between academic performance and industry collaboration differs also on the individual level. A relatively small proportion of university professors are responsible for the majority of publications (Kyvik, 2003). Our data confirms that this is the case also for the entrepreneurial outputs. As suggested by Geuna and Nesta (2003), perhaps only the most experienced researchers will be able to be academically as well as commercially successful. Interviews again indicate that particularly elite health scientists seem to be able to combine patenting and publishing (Gulbrandsen, 2004). Some technology professors, on the other hand, seem to prefer to patent or in other ways contribute to industrial innovation directly, rather than to create an impressive publication record. Studies of scientists tend to focus on the successful elites. As demonstrated in the data section we probably have a bias in our data in direction of elite performers academically as well as commercially. To shed light on unintended consequences of funding structures there may also be a need for studies of the trajectories of the less successful. This furthermore means that later investigations could benefit from having a more systemic perspective, as it could be that possible negative effects of increased industrial contacts and funding at the universities are first and foremost noticed in the other parts of the public R&D sector—the research institutes and the state colleges, many of the latter struggling to obtain university status and increase their research activities.

Finally, the "skewing problem" is an important issue for further research. Our data indicate that industrial funding is related to applied research. The relevance of the distinction between basic and applied research as well as between "Mode 1" and "Mode 2" is, however, controversial. For example, a bibliometric study does not verify that entrepreneurial academics publish in more applied types of journals than their non-entrepreneurial colleagues (Van Looy et al., 2004). Our findings also indicate a direct link between basic research and commercial results across a broad range of academic disciplines, which means that the contributions of universities in innovation are not mainly confined to training of the workforce and contributions to the basic stock of knowledge. It has been claimed that university research may be connected more extensively and efficiently with industry if the "division of labour" between universities and industry is respected (Rosenberg and Nelson, 1994, p. 347). Apart from the direct entrepreneurial results (still modest in most disciplines), perhaps this is exactly what has happened. The growth in industrial funding of university research may be an indicator of improved respect in the companies for the particular goals and culture of academia. As has been found elsewhere, increased commercialisation and industrial contacts may also enhance the researchers' awareness of the importance of basic research, leading the research groups to organisational responses that nurture and protect the long-term activities (cf. Ylijoki, 2003).

References

Arnold, E., Kuhlman, S., van der Meulen, B., 2001. A Singular Council. Evaluation of the Research Council of Norway. Technopolis, Brighton.

Benner, M., Sandström, U., 2000. Institutionalizing the triple helix: research funding and norms in the academic system. Research Policy 29, 291–301.

Blumenthal, D., Campbell, E.G., Anderson, M.S., Causino, N., Louis, K.S., 1997. Withholding research results in academic life science—evidence from a national survey. The Journal of the American Medical Association 277, 1224–1228.

Blumenthal, D., Campbell, E.G., Causino, N., Louis, K.S., 1996. Participation of life-science faculty in research relationships with industry. New England Journal of Medicine 335 (23), 1734–1739.

Calvert, J., 2000. Is there a role for 'basic research' in Mode 2? VEST Journal for Science and Technology Studies, 13.

Calvert, J., 2004. The idea of 'basic research' in language and practice. Minerva 42, 251–268.

Campbell, E.G., Clarridge, B.R., Gokhale, M., Birenbaum, L., Hilgartner, S., Holtzman, N.A., Blumenthal, D., 2002. Data withholding in academic genetics. The Journal of the American Medical Association 287, 473–480.

Clark, B.R., 1998. Creating Entrepreneurial Universities. Organizational Pathways of Transformation. Pergamon, New York.

Coupé, T., 1998. Science is golden: academic R&D and university patents. Journal of Technology Transfer 28, 31–46.

Elzinga, A., 1983. Research, Bureaucracy and the Drift of Epistemic Criteria. Gothenburg University, Department of Theory of Science, Gothenburg.

Ernø-Kjølhede, E., Husted, K., Mønsted, M., Wenneberg, S.B., 2001. Managing university research in the triple helix. Science and Public Policy 28, 49–55.

Etzkowitz, H., 1996. Conflicts of interest and commitment in academic science in the United States. Minerva 34, 259–277.

Etzkowitz, H., 1998. The norms of entrepreneurial science: cognitive effects of the new university–industry linkages. Research Policy 27, 823–833.

Etzkowitz, H., 2003. Research groups as 'quasi-firms': the invention of the entrepreneurial university. Research Policy 32, 109–121.

Etzkowitz, H., Leydesdorff, L., 2000. The dynamics of innovation: from national systems and 'Mode 2' to a Triple Helix of university–industry–government relations. Research Policy 29, 109–123.

Florida, R., Cohen, W.M., 1999. Engine or infrastructure? The university role in economic development. In: Branscomb, L.M., Kodama, F., Florida, R. (Eds.), Industrializing Knowledge. University–Industry Linkages in Japan and the United States. MIT Press, Cambridge MA/London, pp. 589–610.

Freeman, C., 1987. Technology Policy and Economic Performance. Pinter, London.

Geuna, A., 1997. Allocation of funds and research output: the case of UK universities. Revue d'Économie Industrielle 79, 143–162.

Geuna, A., 1999. The Economics of Knowledge Production. Funding and the Structure of University Research. Edward Elgar, Cheltenham.

Geuna, A., 2001. The changing rationale for European university research funding: are there negative unintended consequences? Journal of Economic Issues XXXV, 607–632.

Geuna, A., Nesta, L., 2003. University Patenting and its Effects on Academic Research, SPRU Electronic Working Paper Series No. 99, Brighton, SPRU.

Gibbons, M., Limoges, C., Nowotny, H., Schwartzman, S., Scott, P., Trow, M., 1994. The New Production of Knowledge. The Dynamics of Science and Research in Contemporary Societies. Sage Publications, London.

Godin, B., 1998. Writing performative history: the New New Atlantis? Social Studies of Science 28, 465–483.

Godin, B., Gingras, Y., 1998. The place of universities in the system of knowledge production. Research Policy 29, 273–278.

Godin, B., Gingras, Y., 2000. Impact of collaborative research on academic science. Science and Public Policy 27, 65–73.

Gulbrandsen, M., 1997. Universities and industrial competitive advantage. In: Etzkowitz, H., Leydesdorff, L. (Eds.), Universities and the Global Knowledge Economy. Pinter, London, pp. 121–131.

Gulbrandsen, M., 2004. 'But Peter's in it for the money'—the liminality of entrepreneurial scientists. In: Paper Presented at the 4S/EASST Conference in Paris, 26–28 August.

Guston, D.H., Kenniston, K., 1994. Introduction: the social contract for science. In: Guston, D.H., Kenniston, K. (Eds.), The Fragile Contract. MIT Press, Cambridge/London, pp. 1–41.

Hellström, T., 2003. Governing the virtual academic commons. Research Policy 32, 391–401.

Jacob, M., 2000. 'Mode 2' in context: the contract researcher, the university and the knowledge society. In: Jacob, M., Hellström, T. (Eds.), The Future of Knowledge Production in the Academy. Society for Research into Higher Education & Open University Press, Buckingham, pp. 11–27.

Katz, R., Allen, T.J., 1982. Investigating the Not Invented Here (NIH) Syndrome: a look at the performance, tenure, and communication patterns of 50 R&D project groups. R&D Management 12, 7–19.

Kleinman, D.L., Vallas, S.P., 2001. Science, capitalism, and the rise of the 'knowledge worker': the changing structure of knowledge production in the United States. Theory and Society 30, 451–492.

Kyvik, S., 1991. Productivity in Academia. Scientific Publishing at Norwegian Universities. Scandinavian University Press, Oslo.

Kyvik, S., 2003. Changing trends in publishing behaviour among university faculty, 1980–2000. Scientometrics 58, 35–48.

Latour, B., Woolgar, S., 1979. Laboratory Life. The Construction of Scientific Facts. Sage Publications, Beverly Hills.

Lundvall, B.-Å. (Ed.), 1992. National Systems of Innovation. Pinter, London.

Martin, B.R., Etzkowitz, H., 2000. The origin and evolution of the university species. VEST Journal for Science and Technology Studies 13, 9–34.

Martin, B.R., 2003. The changing social contract for science and the evolution of the university. In: Geuna, A., Salter, A.J., Steinmueller, W.E. (Eds.), Science and Innovation. Rethinking the Rationales for Funding and Governance. Edward Elgar, Cheltenham.

Merton, R.K., 1968. The Matthew effect in science. Science 159, 56–63.

Merton, R.K., 1988. The Matthew effect in science II. Cumulative advantage and the symbolism of intellectual property. ISIS 79, 606–623.

Nelson, R.R. (Ed.), 1993. National Innovation Systems: A Comparative Analysis. Oxford University Press, New York.

Nelson, R.R., 2001. Observations on the post-Bayh-Dole rise of patenting at American universities. Journal of Technology Transfer 26, 13–19.

Nowotny, H., Scott, P., Gibbons, M., 2001. Re-Thinking Science: Knowledge and the Public in an Age of Uncertainty. Polity Press, Cambridge.

Nowotny, H., Scott, P., Gibbons, M., 2003. Mode 2 revisited: the new production of knowledge. Minerva 41, 179–194.

OECD, 1994. Proposed Standard Practice for Surveys of Research and Experimental Development: "Frascati manual" 1993. Organisation for Economic Co-Operation and Development, Paris.

Pfeffer, J., Salancik, G.R., 1978. External Control of Organizations: A Resource Dependency Perspective. Harper and Row, New York.

Rosenberg, N., Nelson, R.R., 1994. American universities and technical advance in industry. Research Policy 23, 323–348.

Salter, A.J., Martin, B.R., 2001. The economic benefits of publicly funded basic research: a critical review. Research Policy 30, 509–532.

Slaughter, S., Leslie, L.L., 1997. Academic Capitalism. Johns Hopkins University Press, Baltimore.

Slaughter, S., Rhoades, G., 1996. The emergence of a competitiveness research and development policy coalition and the commercialization of academic science and technology. Science Technology & Human Values 21, 303–339.

Smeby, J.-C., 2001. Forskningsvilkår ved universiteter og vitenskapelige høyskoler, NIFU skriftserie nr. 16/2001. Norwegian Institute for Studies in Research and Higher Education, Oslo.

Stokes, D.E., 1997. Pasteur's Quadrant. Basic Science and Technological Innovation. Brookings Institution Press, Washington, DC.

UNESCO, 1978. Recommendation Concerning the International Standardization of Statistics on Science and Technology. United Nations Educational, Cultural and Scientific Organisation, Paris.

Van Brussel, H., Carlsson, J., Hutchinson, P., Cederwall, K., Terndrup Pedersen, P., Currie, P., 2004. Evaluation of Research in Engineering Science in Norway. Report of the Principal Evaluation Committee. Research Council of Norway, Oslo.

Van Looy, B., Ranga, M., Callaert, J., Debackere, K., Zimmermann, E., 2004. Combining entrepreneurial and scientific performance in academia: towards a compounded and reciprocal Matthew-effect? Research Policy 33, 425–441.

Vavakova, B., 1998. The new social contract between governments, universities and society: has the old one failed? Minerva 36, 209–228.

Ylijoki, O.-H., 2003. Entangled in academic capitalism? A case-study on changing ideals and practices of university research. Higher Education 45, 307–335.

Zucker, L.B., Darby, M.R., Brewer, M.B., 1998. Intellectual human capital and the birth of U.S. biotechnology enterprises. The American Economic Review 88, 290–306.