

# The relationship between academic patenting and scientific publishing in Norway

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Received: 7 August 2008 / Published online: 10 June 2009  
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**Abstract** This paper adds to the growing empirical evidence on the relationship between patenting and publishing among university employees. Data from all Norwegian universities and a broad set of disciplines is used, consisting of confirmed patent inventors and group of peers without patents matched to the inventors by controlling for gender, age, affiliation and position. In general, the findings support earlier investigations concluding that there is a positive relationship between patenting and publishing. There are, however, important differences among fields, universities and possibly types of academic entrepreneurs, underscoring the need to look at nuanced and contextual factors when investigating the effects of patenting.

**Keywords** Academic patenting · Academic entrepreneurship · Scientific publishing · Commercialisation of research

## Introduction

Academic patenting—university researchers represented in patent applications as inventors and/or applicants—has increased all over the world the last decades (Geuna and Nesta 2006). Following the example of the U.S., many countries have aimed at strengthening commercialization of academic research by changing legislations and setting up incentives for technology transfer offices and other support units. Norway changed two laws in 2003: the so-called “teacher exemption clause” was removed and the higher education institutions were given a more formal responsibility for ensuring that “patentable inventions” find their way into “societal use”. Many other countries, especially in the OECD area, have implemented similar policies (see Geuna and Nesta 2006; OECD 2003).

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Despite the recent attention in the literature and in policy, academic patenting is not a new phenomenon. Like elsewhere, Norwegian examples date back to the 19th century. One of the most renowned Norwegian scientists, physics professor Kristian Birkeland (1867–1917), was granted 59 patents. Twelve of them were behind the core technology of chemical multinational Norsk Hydro, co-founded by Birkeland in 1905 and Norway’s most important industrial company ever since. His entrepreneurial activities did not seem to affect his academic productivity negatively: Birkeland had more than 70 articles in international journals (more than half of them in French, the rest in German, English and Norwegian) and three influential monographs. Such anecdotal evidence has been supplemented the last years by more systematic investigations of the relationship between patenting and publishing.

### Earlier research and perspectives

Increased commercialization—or at least policy emphasis on commercialization—is much debated (see e.g. Mowery and Sampat 2005; Nelson 2001). Some are worried about a possible decrease in long-term research or changed research agendas, tensions between the culture of open science and increased commodification and commercialization, and increased pressures on the researchers and the traditional teaching and basic research tasks they carry out (Geuna 2001; Geuna and Nesta 2006; Nelson 2001; Slaughter and Rhoades 1996; Vavakova 1998). This has been termed “drift of epistemic criteria” (Elzinga 1983) or “skewing” and “secrecy” problems (Florida and Cohen 1999). On the other hand, it has been argued that universities may strengthen 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 (Clark 1998; Etzkowitz 1998; Etzkowitz and Leydesdorff 2000). Instead of being a question of either-or, successful universities and university researchers manage to combine academic excellence with entrepreneurial contributions (Godin and Gingras 2000; Gulbrandsen and Smeby 2005; Van Looy et al. 2004).

However, it is clear that patenting and other types of commercialization are highly context-dependent. Three central contextual aspects may be pointed at. First, the national level may be important, not least due to differences in legislation and differences in when, for example, ownership of research results was transferred to the higher education institutions. Although U.S. investigations tend to explain the surge in patenting with many other developments than the Bayh-Dole Act from 1980, it is clear that the legislation inspired many universities to start technology transfer offices and similar initiatives (Mowery et al. 2004). Furthermore, legislative changes do not effect organizations and local contexts until many years after the changes (Baldini et al. 2006).

Second, the university (institutional) level can be of importance, e.g. the “entrepreneurial culture” at the institutions involving peer influence and role models, and the existence of technology transfer units. There are large variations in the types and profiles of universities (e.g. Martin 2003), and empirical investigations have found that institutional affiliation affects the likelihood to patent (Azoulay et al. 2007). Rules for distribution of licensing income, engagement in spin-off companies etc. may be found both at the university and national/regional levels.

Third, the technological and disciplinary context is relevant when it comes to the importance of patents and the relationship between patenting and other aspects. Commercialization processes may for example differ between life science and physical sciences

(Owen-Smith and Powell 2001). The growth of patenting can be tied to the rise biotechnology and a few other fields and to more fundamental epistemic and cultural changes in certain disciplines (Coupé 2003; Etzkowitz 1998; Henderson et al. 1998; Mowery and Ziedonis 2002; Nelson 2001; Zucker et al. 1998). Finally, it should be added that there are also many individual differences between academics in their interest in patenting, and their entrepreneurial activities may be due to very specific scientific opportunities that emerge irregularly over an academic career (Azoulay et al. 2007).

This means that although there has been a growth in the number of scientific investigations of academic patenting and its consequences, much more evidence is still needed. Several interesting studies have been published, but they are most often concerned with data from the U.S.—which is probably a “special case” when it comes to academic patenting—or they contain empirical material from a single university or single discipline within one or a few countries only. Biotechnology and a few other fields (nanotechnology, materials science) are overrepresented. Identifying inventors is often a time-consuming process requiring surveys and/or complex database mergers, not least in countries where it is likely that many patents involving academics will neither contain a university name nor address. In Europe and some other countries, it has been common for university employees to own the rights to research results, and the higher education institutions have rarely been involved in patenting.

Three possible effects of patenting on scientific publishing may be discussed.

*The reinforcement effect* (or complementarity effect, see Stephan et al. 2007) is where patenting and publishing mutually complement and/or reinforce each other. This may happen in either direction: if patenting opens up new scientific opportunities, leads to new ideas, creates/maintains scientific networks etc., or if patenting is the result of particular scientific opportunities (Azoulay et al. 2007; Breschi et al. 2005). Some researchers have in interviews indicated that patents are sometimes based on the first draft of a scientific paper—and the patent application is written by a specialised professional (cf. Gulbrandsen 2005). There may thus be several types of synergies between patenting and publishing.

Most of the empirical evidence supports the reinforcement effect or hypothesis (Blumenthal et al. 1996; Breschi et al. 2005; Calderini and Franzoni 2004; Calderini et al. 2007; Godin 1998; Meyer 2006; Stephan et al. 2007; Van Looy et al. 2006). This is partly a “star scientist” effect—individuals with exceptionally high performance are frequently involved in both patenting and publishing (cf. Zucker et al. 1998)—as well as a more general finding across a wide range of disciplines where patenting contributes a “leverage” effect. There are of course exceptions; when looking at single disciplines or universities, non-inventors sometimes outperform inventors in scientific productivity or academics’ publication activities seem unaffected by patenting (Van Looy et al. 2006). The general message is nevertheless that “inventors systematically publish more than their colleagues who are not engaged in patenting activities” when comparing faculty members with similar specialisations, age and career profiles (ibid, p. 694). Patenting is most often seen as a result of new scientific opportunities, as the most fine-grained analyses show how patenting is often preceded by “bursts” of publishing (Azoulay et al. 2007; also Breschi et al. 2005).

Some authors point at what they call a “compounded Matthew effect” (Merton 1968, 1988; Van Looy et al. 2004). Patenting could lead to more recognition and more resources, not least from commercialization-obsessed funding agencies, which puts the researcher and her or his unit into a virtuous circle. All these findings could be taken as an indication that, at least in some disciplines or specialities, basic research and application/technology development are closely related, and that there is little extra work or negative side-effects of becoming involved in patenting. Breschi et al. (2005) underscore that this does not

necessarily exclude potential damaging effects on cumulative research, i.e. limitations due to others' patents, but at the individual level, patents are "just a by-product of good research" (p. 98).

*The substitution effect* is where patenting suppresses scientific publishing. Patenting most often involves a delay of publications. It could be that this makes it more difficult to publish a scientific paper—the research frontier could have shifted, the researcher's attention could have moved on to other problems, it may be intellectually or psychologically challenging to start working on a delayed paper etc. The patenting process also involves secrecy at some time. In interviews, some academic inventors in Norway described that they could not talk about their most recent research at their speciality's annual conference because the patenting opportunities had not been sorted out yet (Gulbrandsen 2005). There may thus be a tension between secrecy and the culture of open science. Over time, norms of "partial" or "temporal" secrecy could negatively affect publication productivity but also sharing of research materials and other beneficial aspects of academic culture (Geuna and Nesta 2006; Nelson 2001). Finally, patenting demands time and attention (the "time squeeze" problem). Some researchers may decide to devote their time to patenting, resulting in less time spent working on publications. It should be added that substitution does not necessarily only involve reduced publication productivity, but could imply publishing in less prestigious journals, reduced impact of published works etc.

As mentioned, most of the empirical evidence does not support the substitution effect or hypothesis. Studies of delays furthermore point at other explanations for it than patenting. Geuna and Nesta (2006) 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 individuals will be able to be academically *and* commercially productive. Blumenthal et al. (1997) found that 19.8% 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. A later study of 1800 U.S. genetics researchers found that 47% had been met with rejections on requests to colleagues for more information, data or materials (Campbell et al. 2002). The authors do not explain this finding with increased patenting, however, but instead with lack of resources and professional priorities.

*No obvious effect:* Investigations may find that there is no correlation between patenting and publishing, like Agrawal and Henderson (2002) based on a study of professors at MIT and Gulbrandsen and Smeby (2005) based on a large-scale Norwegian survey. In the latter, however, the question was whether the faculty members' research had *led* to patents without necessarily involving the researcher. Still, it might be that patenting and publishing in many cases are quite different activities with few synergies but also with few tensions. Not many researchers patent and the ones that do, do it rarely. On the other hand, this finding could be based on a combination of substitution effects and reinforcement effects, either at the individual level or at the discipline level.

Seniority may as noted above make a difference whereby only senior scientists are able to avoid delays (Geuna and Nesta 2006). Another possible set of influences on patenting are the motives for patenting. Earlier investigations find different types of academic entrepreneurs with different motivations for entering commercialization processes based on different "norms of entrepreneurial science" (cf. Etzkowitz 1998). Meyer (2003)

distinguishes between “academic entrepreneurs” and “entrepreneurial academics”, the latter referring to professors who adapt their basic research agendas to new funding climates and new settings, but without a growth motive. This is similar to Gulbrandsen’s (2005) distinction between “basic research-oriented inventors” and “liminal academic entrepreneurs”. The latter—more frequently found in technological disciplines—are sceptical towards traditional academic values and the “publication race”. They may willingly choose patenting over publishing, especially if they are in a fixed senior position and do not need further academic credentials for promotion. In other words, individual motives for commercialization and for doing R&D work may matter when it comes to determining the relationship between patenting and publishing. It could also be that smaller delays are acceptable and have no negative consequences in some disciplines but not in others. For example, Owen-Smith and Powell (2001) found large differences between the health sciences and the “physical sciences” when it comes to motives for and effects of patenting.

Finally, it may be mentioned that many university patents, not least many of the most lucrative ones, do not concern basic research at all—and should therefore not be seen as a “synergy” between basic research and commercialisation. Famous examples of highly successful academic patents like Taxol, Trusopt and Gatorade are not based on scientific breakthroughs. However, it has more generally been found that inventors’ publications are not more “applied” than those of comparable non-inventors (e.g. Breschi et al. 2005).

In the following we investigate the relationship between patenting and publishing based on a Norwegian matched pairs dataset. From the above review of the literature, we expect that academic inventors will be more scientifically productive than their non-inventing peers, indicating a reinforcement effect. Possible differences when it comes to disciplines, university types, academic positions and more can add to the growing international empirical evidence from the perspective of a small country which recently changed its IPR legislation and gave the universities a clearer responsibility for commercializing patentable inventions.

## Methods and data

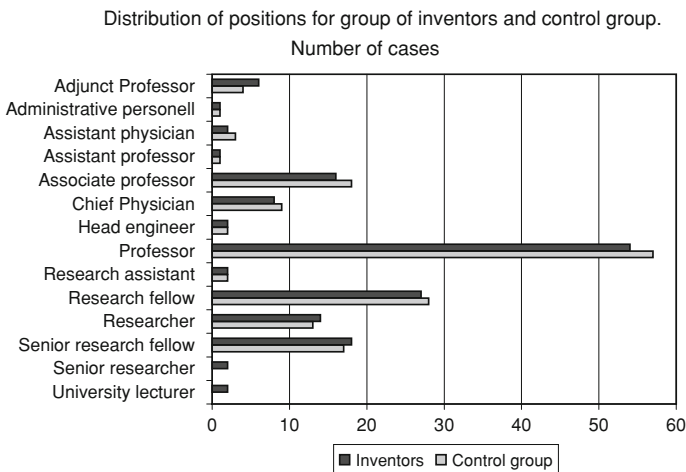
Our data source is initially based on a matching of two databases: a patent database with applications to the Norwegian patent office from 1998 to 2003 (7780 patent applications involving 6684 different inventors with a domestic address) and the so-called Research Personnel Registry with information on all scientific and administrative personnel at public research organisations—including colleges and research institutes—in Norway (for more on the matching see Iversen et al. 2007). Before validation we identified 800 possible “public R&D inventors” involved 1800 times in 1500 separate patents. A questionnaire was sent to them asking for confirmation of patenting but also about characteristics of their research, motives, incentives, the support structure, commercialisation results, relation to scientific publishing etc. We received 316 positive responses, around 60 percent of the identified public sector research inventors when adjusting for the researchers who reported back that they had not been involved in patenting at all. Of these 316 inventors, 161 work in research institutes or regional colleges that do not have specific goals or incentives to contribute to the scientific literature. We are therefore left with 155 *academic inventors* for our investigation of the relationship between patenting and publishing.

The University of Bergen had 19 inventors (12% of the total), the University of Oslo 53 (34%), the University of Tromsø 23 (14%) and the Norwegian University of Science and

Technology (NTNU) 62 inventors (40%). Two universities have later been established in Norway—they were defined as colleges at the time of the initial investigation and are barely presented in the larger population of inventors. NTNU is a technical university comparing itself e.g. to Chalmers in Sweden, ETH in Switzerland and MIT and Stanford in the U.S. The other ones are traditional comprehensive/general universities.

To estimate publishing activities, we used the three science citation indexes provided by Thomson/ISI on Web of Science and the National Citation Report NCR for Norway 2003 matched with the National Science Indicators on Diskette NSIOD Deluxe Edition. We looked at development over time, intensity (number of papers), co-authorship (general, international, industry), impact and specialisation for the inventors and a matched control group. Inventors were matched one by one with colleagues who were not registered as inventors, controlling for age, gender, position, affiliation and year of last registration in the personnel registry. In addition we cross checked the control group in Thomson Delphion against inventor names in EPO and U.S. patent applications as well as against the Norwegian base. None in the control group is listed in any Norwegian, EPO or U.S. patent application—latest filing year 2003.

The matching process was based on information from the Research Personnel Registry. We used personnel information for 1997, 1999, 2001 and 2003 and the matching process was based on the same entry year. The mean difference between the inventor's age and the age of the peer in the control group was 0.7 years. The average inventor's age is 8 months higher than the average in the control group, but there are a few outliers. All peers in the control group have the same gender as the matched inventor. We saw this as important, as many of the earlier investigations mentioned above have found differences in patenting and commercialization activities between men and women. There are 19 female and 136 male inventors in the Norwegian data sets. The matching of positions was complicated because of few available individuals for the control group in some departments, but we achieved a good match in the end (see Fig. 1). Note that only about half of the inventors formally have the title “professor” (full, associate, adjunct, assistant), while the rest worked as “researchers”, “research fellows” (PhD students), “senior research fellows” (PhD or post.docs) “head engineer” etc.



**Fig. 1** Distribution of positions for group of inventors and control group. Number of cases

The matching of affiliation was done on several levels: university, faculty and department or similar. At the university and the faculty level the matching is 100% accurate. Problems arose at the department level, where we either had difficulties finding researchers with similar age and gender or difficulties in finding researchers without patents (in some research units, all scientists are listed as inventors on patents). In 16 cases we therefore had to find researchers for the control group in a slightly different department but in a related technology or science field and at the same faculty.

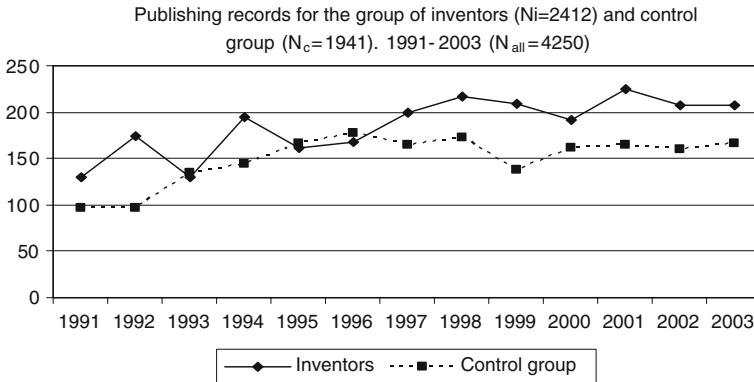
After this matching, we scrutinized the inventors and non-inventors' publications in ISI from 1991 to 2003. The first rough sorting revealed that many of the researchers have a portfolio of publications that encompass several areas, e.g. ICT and medicine, agriculture and engineering, chemistry and basic life science, earth science and medicine etc. (see below for more details). Almost all thinkable combinations were found, and some researchers' publications were classified in five different areas. This may indicate that both inventors and non-inventors often work in the boundaries between different specialisations. We gave a percentage score to each individual based on the proportion of publications within each area. Combining this with information about the department and/or group the researchers worked, we classified each as either "life sciences" (medicine and basic life science plus combinations where these two dominate or are combined with e.g. agriculture) and "physical sciences" (engineering, earth sciences, mathematics/physics and combinations of these with agriculture). 144 of the researchers (46.5%, half of them inventors) were labelled "life sciences", while 166 (53.5%) were labelled "physical sciences". There is a strong overlap between this classification and the university affiliation. 62% of the "physical science" researchers are found at the technical university NTNU, constituting 83% of all the researchers in the sample from NTNU. In the statistical tests below, the differences tend to be larger when we look at NTNU compared to the three other universities than when we compare life sciences to physical sciences. As seen in several interview studies (e.g. Gulbrandsen 2005), there is probably a strong and fairly particular institutional culture at NTNU which is partly related to the strong presence of technological disciplines. This is discussed further below.

## Results

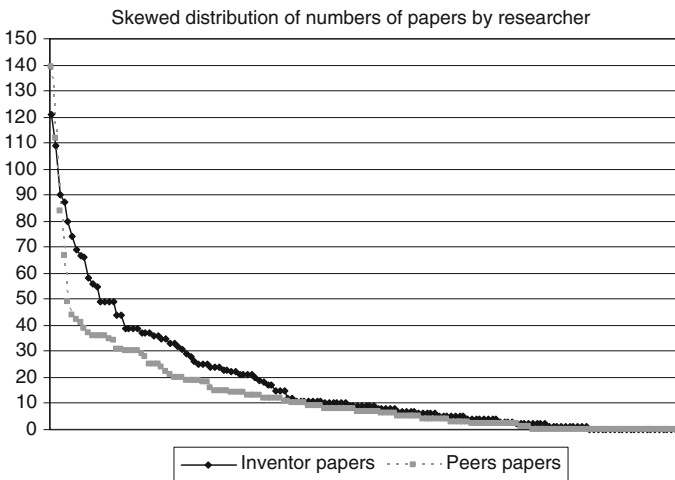
One hundred and thirty-two of the 155 inventors (85%) were active in scientific publishing, compared to 118 (76%) in the control group. Most of the ones with no publications are presumably early in their scientific careers as they are research fellows and senior research fellows. It is still noteworthy that there are a few professors who have been active in patenting and not in publishing, and that there are PhD students and postdocs who have patented but not (yet) published.

We identified 2412 inventor papers and 1941 papers in the control group—in the calculation of the sums we controlled for co-authorship to avoid double counts by using fractional counts of papers (see Fig. 2). Both groups have a growing number of publications over the time period, but the inventors' volume of publishing increased the most.

The inventors published on average 17.6 articles while the non-inventors published 12.9 (again controlled for co-authorships), and this difference is as expected from the literature review. It is statistically significant at the .05 level (*t*-test, one-tailed distribution allowing for differences in standard deviation). The distribution of articles per individual is a lot more skewed for the control group (see Fig. 3).



**Fig. 2** Publishing records for the group of inventors ( $N_i = 2412$ ) and control group ( $N_c = 1941$ ). 1991–2003 ( $N_{all} = 4250$ ). *Source:* NCR 2003/NIFU STEP



**Fig. 3** Distribution of numbers of papers by researcher. *Source:* NCR 2003/NIFU STEP

If we look at the distinction between the technical university and the three traditional comprehensive universities, an interesting picture emerges (see Table 1). There is no significant difference between the publication productivity of researchers at the technical

**Table 1** Publication productivity (number of papers)—comparison between inventors and non-inventors

	Inventors	Non-inventors	<i>N</i>	Significance
All researchers	17.6	12.9	310	**0.04
NTNU (technical university)	12.2	13.0	124	NS 0.81
Other universities	21.2	12.8	186	***0.01
Life sciences	23.9	14.7	144	***0.01
Physical sciences	12.1	11.3	166	NS 0.77



university, while the difference is very large at the three other ones. The same appears when we compare life sciences and physical sciences.

If we run a linear regression analysis (Table 2), however, the university type difference is not statistically significant. Field of science is still a good predictor of publication productivity along with age and gender (men have higher productivity)—and the dummy variable denoting inventors (inventors have higher productivity). The field differences make the Norwegian results stand out a bit from earlier studies, which will be discussed more below.

It should be noted that we classify the other three Norwegian universities as one category (a small number of inventors in Bergen and Tromsø does not allow us to make a more detailed distinction). This may be an oversimplification as there are differences in research cultures at all these institutions. As mentioned in the previous section, there are 11 different categories of positions in the data material, and they are not easily classified into a more simplified scheme. We have run several regressions to take position into account, and being a full professor (rather than adjunct professor, head engineer, doctor etc.) is a good predictor of publication productivity, but for the other types of position, the picture is mixed. In the regression reported above, we have taken age as an indicator of seniority.

The share of co-authored papers was almost the same for both groups: for inventors 98% and for the control group 97%. There are large differences in mean and standard deviation of the number of co-authors, which are mainly caused by a large number (128) of papers in the control group with more than 500 authors. The mean number for the inventor papers was 4.9 (standard deviation 3.23) and 41.3 for the control group (standard deviation 136.14). The median number of co-authors, however, was 4 for both groups of papers.

International co-authorship was similar in both groups: 36% of the inventor papers and 39% of the control group papers were internationally co-authored. For both groups we see a tendency of increased international co-authorship. 13.2% of the inventor papers and 9.3% of the control group papers were co-authored with Norwegian industry. The difference is statistically significant but this is mainly due to the development in the last part of the time

**Table 2** Publication productivity, linear regression

Model		Unstandardized coefficients		Standardized coefficients	<i>t</i>	Sig.
		Beta	Std. error			
1	(Constant)	-4.367	5.724		-.763	.446
	Field = physical sciences	-8.727	2.600	-.209	-3.357	.001
	University = general	1.016	2.594	.024	.392	.696
	Age	.443	.095	.254	4.688	.000
	Gender = female	-7.834	3.523	-.123	-2.224	.027
	Inventor = yes	4.457	2.226	.107	2.002	.046
		Sum of squares	df	Mean square	<i>F</i>	
1	Regression	18090.929	5	3618.186	9.430	.000 <sup>a</sup>
	Residual	116643.264	304	383.695		
	Total	134734.194	309			

<sup>a</sup> Predictors: (Constant), Inventor (control: non-inventor), Gender = female (control = male), University = general (control = technical), Age, Field = physical sciences (control = life sciences)

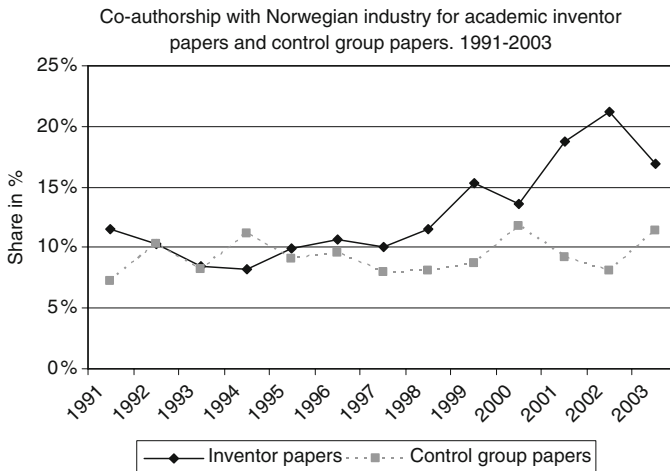
period (see Fig. 4). There is an increasing tendency to collaborate with industry for the university inventors ( $R^2 = 0.666$ ), but this tendency is not seen in the control group ( $R^2 = 0.0709$ ).

The average number of citations per paper for the inventor papers was 13.96. The average expected citation rate for these papers was 12.67. The impact was 1.10 and the development of the impact was fairly stable (see Fig. 5). Average number of citations per paper for the control group papers was also 13.96 and stable. As the average expected citation rate for these papers was 11.48, the impact was slightly higher (1.22).

In general, the average impact is higher for the control group papers, but when computing the impact for sub-fields a more nuanced result appears. In “agriculture, aquatic and food sciences”, “chemistry”, “earth and environmental sciences” and in “mathematics, physics and astronomy” the inventor papers have a higher impact than those of the control group, and in the engineering sciences the impact is equal for the two groups’ papers.

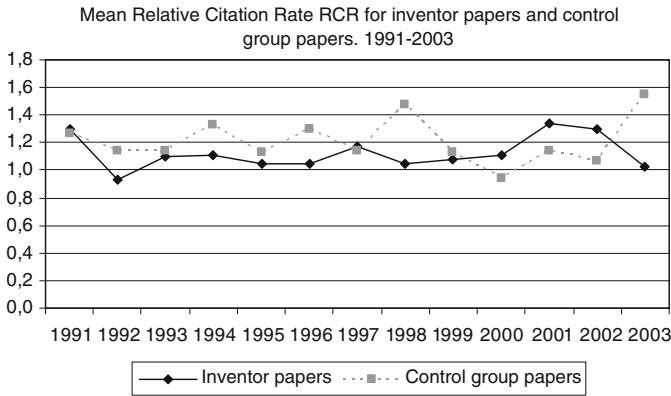
So far it has been shown that the publication productivity of Norwegian academic inventors is higher than for comparable non-inventors, and that this is mainly due to differences in the life sciences. In the physical sciences and at the technical university NTNU, there is no difference in publication productivity between the two groups. The impact of the publications is similar, however.

The analysis of specialisation is based on weighted field shares, using the CATCODEs provided by Thomson ISI to categorize the papers into nine field groups.<sup>1</sup> In the case of 95 papers the codes were missing and the classification had to be done manually. Despite careful control for the scientific specialisation of the inventors when the matched pairs control group was established, the volume of production in some of the filed groups differs considerably. The inventor group has a much stronger position in medicine and deontology and the control group has stronger concentration in earth and environmental sciences (Fig. 6).

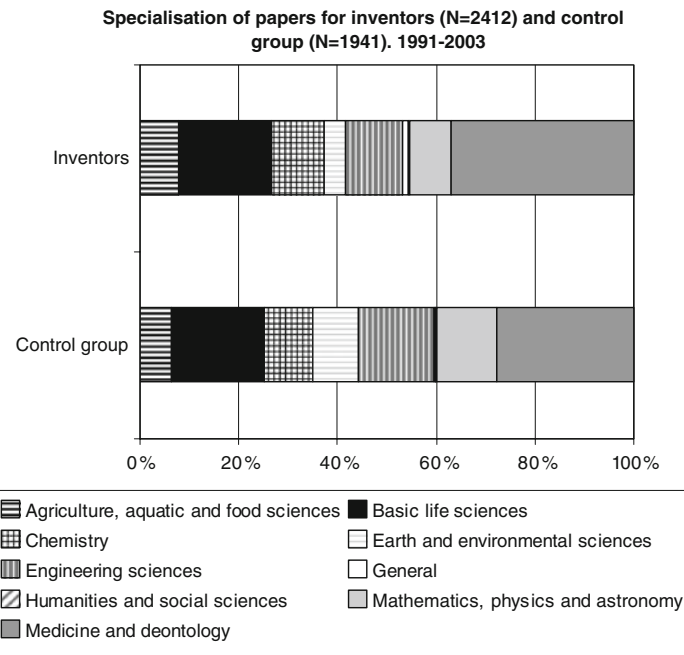


**Fig. 4** Co-authorship with Norwegian industry for academic inventor papers ( $N = 318$ ) and control group papers ( $N = 181$ ). 1991–2003. Source: NCR 2003/NIFU STEP

<sup>1</sup> The grouping of the ISI CATCODEs can be retrieved from following webpage: [http://www.nifustep.no/norsk/innhold/aktiviteter/bibliometri/grouping\\_of\\_isi\\_catcodes](http://www.nifustep.no/norsk/innhold/aktiviteter/bibliometri/grouping_of_isi_catcodes) (downloaded 7th December 2007).

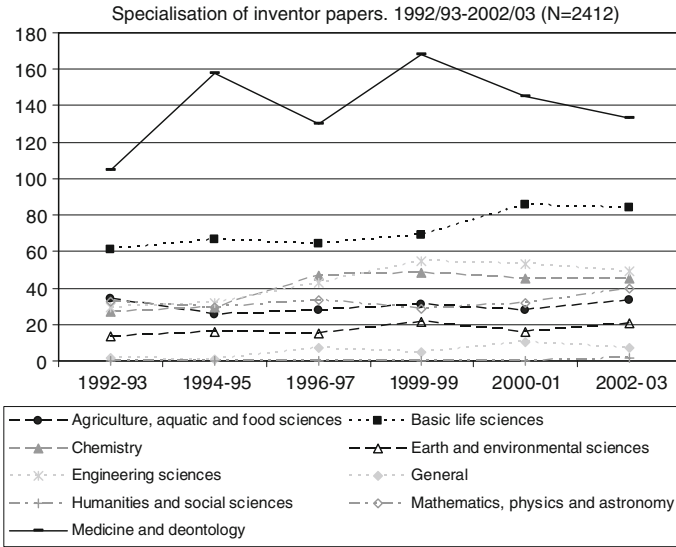


**Fig. 5** Mean Relative Citation Rate RCR (=CPP/XCR) for inventor papers and control group papers. 1991–2003. *Source:* NCR 2003/NIFU STEP



**Fig. 6** Specialisation of papers for inventors ( $N = 2412$ ) and control group ( $N = 1941$ ). 1991–2003. *Source:* NCR 2003/NIFU STEP

The specialisation of the groups has developed very differently. For the inventor group, publishing has increased in all field groups, but especially in medicine/deontology, basic life sciences, engineering and chemistry (Fig. 7). The control group on the other hand has seen a particularly strong development in basic life sciences, while medicine/deontology has been stable. The relative position of chemistry and earth and environmental sciences has been strengthened and the position of engineering and mathematics/physics/astronomy



**Fig. 7** Specialisation of inventor papers. 1992/93–2002/03 ( $N = 2412$ ). *Source:* NCR 2003/NIFU STEP

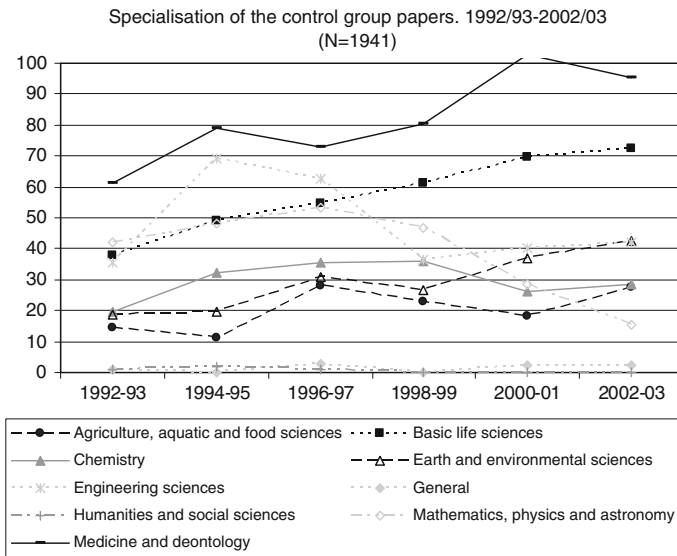
has been weakened for the control group (Fig. 8). In both groups the share of “general” articles (*Science* and *Nature* tend to fall into this category) is very low.

Co-authorship differs between the fields. The highest shares of international co-authorship are seen in mathematics, physics and astronomy for both the inventor paper and the control group papers. Industry co-authorship is highest in the engineering sciences for the inventors but in earth and environmental sciences for the control group.

To further explore disciplinary differences, we compared the specialisation in larger fields like engineering sciences and medicine and deontology. The calculations are based on weighted field shares.<sup>2</sup> Twenty nine percent of the inventor papers in engineering were co-authored with Norwegian industry, compared to 16% in the control group. International co-authorship differs even more: 17% of the inventor papers and 33% of the control group papers had co-authors from abroad. In other words, this indicates a more fundamental different mode of working between the inventors and the non-inventors. While their productivity and impact is similar, the inventors prefer working with national industry. Non-inventors have a more traditional basic research profile working with international colleagues, although some of them also publish with industry.

A similar analysis in medicine/deontology revealed a strong position of the university inventor papers in immunology and in oncogenesis/cancer research. This is also consistent with the results of a comparison of the inventor papers with all university papers. Both these fields denote areas of relative strength of the small Norwegian biotechnology cluster. The impact for both inventors and control group’s papers is fairly stable, although a peak in 1998 for the non-inventors disturbs the picture somewhat. Six percent of the inventor papers and 3% of those of non-inventors were co-authored with Norwegian industry. Thirty seven percent of the inventor papers were internationally co-authored, compared to 29% of

<sup>2</sup> Weighted field shares have been calculated based on the CATCODEs in the NCR. Every paper is categorized into at least one field, in the case of several fields ( $f$ ) the field share for each field is weighted ( $1/f$ ).



**Fig. 8** Specialisation of the control group papers. 1992/93–2002/03 ( $N = 1941$ ). Source: NCR 2003/NIFU STEP

the control group papers. In other words, in medicine/deontology we do not find any strong evidence of differences in research profiles as we did in engineering. In medicine, inventors and non-inventors seem to have fairly similar profiles.

## Discussion and conclusion

Our analysis of the relationship between patenting and publishing has largely confirmed the main findings of earlier investigations (e.g. Azoulay et al. 2007; Breschi et al. 2005; Calderini and Franzoni 2004; Calderini et al. 2007; Meyer 2006; Stephan et al. 2007; Van Looy et al. 2006). On average, inventors have significantly higher publication productivity than colleagues with comparable disciplinary profile, age and position. There is no trend over time to indicate that inventors publish less after they have patented—the development of productivity is fairly similar both for inventors and non-inventors. Although the productivity is higher for inventors, we do not find any difference in the impact of their publications.

But whereas earlier studies find differences in productivity in a broad set of disciplines (e.g. within Italy in Breschi et al. 2005; the U.S. in Stephan et al. 2007; at a university in Belgium in Van Looy et al. 2006), this is not the case in our set of Norwegian university-affiliated patent inventors. Only in the life sciences, broadly defined, do we see much higher publication productivity among inventors. In the physical sciences in our sample, there are no significant differences between the two groups (unlike e.g. Italian materials science in Calderini et al. 2007 and nanotechnology in three European countries in Meyer 2006). Almost two-thirds of the researchers representing physical sciences in our sample and 40% of all inventors work at the technical university NTNU, so we cannot exclude an institutional explanation. Qualitative studies have found major distinctions between the entrepreneurial cultures in different fields at Norwegian universities (e.g. Gulbrandsen

2005). Many professors at NTNU in particular have in interviews criticised academic norms of publishing, stating that (technology) professors' main tasks should be to develop useful new applications and patent when necessary. Our study may therefore reflect the culture in the technological disciplines and/or at NTNU, thus echoing Agrawal and Henderson's (2002) investigation of MIT professors. Incidentally, MIT has probably been the most important role model for NTNU since the 1950s. One reason for the slight divergence in the Norwegian data could be that earlier "matched pairs" studies have matched for disciplinary affiliation, age and position rather than institutional affiliation (e.g. Breschi et al. 2005). Differences between institutional cultures may therefore become masked and probably deserve more attention in future studies.

When we explore our dataset further, some additional interesting nuances between various academic inventors appear. In the physical sciences, the inventors co-author their scientific papers more frequently with industry, compared to the control group of non-inventing peers. The latter group, however, are more frequently involved in international co-authorship. If we take co-authorship as a proxy for networking, this could denote two different ways of working in certain disciplines—one is more entrepreneurial and local, the other more global and oriented at research goals. The impact of the two groups' publications, however, is the same. In the life sciences, we find no such difference in co-authorship patterns between inventors and non-inventors.

This supports earlier research accentuating distinctions between life science and physical science and/or differences between types of academic entrepreneurs (Etzkowitz 1998; Gulbrandsen 2005; Meyer 2003; Owen-Smith and Powell 2001), but more research is needed. Although some disciplinary differences are built into the framework of Pasteur's Quadrant (Stokes 1997), maybe there are different types of "Pasteur" in different fields of research? It should be added that the scientific publication profile of the Norwegian university inventors is somewhat different from their peers (which might point at problems of the matching procedure, however). Patenting seems logically enough to occur with researchers who focus on areas of national industrial strength like metallurgy and automation.

Thus, our analysis does not indicate that, on average and in many disciplinary subfields, there is a substitution effect between patenting and publishing. At least for the researchers at traditional comprehensive universities and/or in the life sciences, there may be a rather strong reinforcement or complementarity effect between the two activities. The situation in the physical/technological sciences and at the technical university deserves further attention. The impact of the papers published by university inventors and their peers does not differ much, also when we look only at technological and medical papers. We may interpret this as an argument against the thesis that university inventors publish in less prestigious journals.

Patenting is a small-scale activity at Norwegian universities and there are relatively few professors involved. In the medical sciences, they are quite similar to their peers when it comes to collaboration and impacts. In the technological sciences, on the other hand, university inventors may be involved in a mode of knowledge production that in some respects is very different from traditional disciplinary basic research. Although this fits well into a long research tradition on disciplinary differences (e.g. Becher 1989), it serves to emphasise the contextual nature of university-industry relations and commercialization. One must in all cases be cautious with generalizations.

**Acknowledgements** Funding for this study was provided by NIFU STEP, while the earlier patent database match was funded by the Research Council of Norway's KUNI and FORNY programmes. We would also like to thank Loet Leydesdorff and two anonymous reviewers for their insightful and valuable comments.

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