Discussion Paper No. 07-028

Heterogeneity of Patenting Activity and Its Implications for Scientific Research

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Non-technical Summary

The increased engagement of university scientists in commercializing their discoveries over the past decades led to a discussion on potentially negative consequences for future science. Policy makers and analysts fear that significant commercialization activities of scientists may replace part of their research activities and also lead to a reduction in research quality as research contents might become increasingly applied, and inventions demanded by the market may not necessarily touch academic research frontiers. Recent studies, however, argue that contacts to scientists in the business sector are enriching for university researchers and that industry-science collaborations may even trigger new basic research.

Among other channels of commercialization, there is a growing number of academic scientists filing patent applications over the past decade, either as single inventors or in collaboration with industrial researchers. Scholars who studied the relationship between the incidence of patenting and the scientists' publication output found mostly evidence in favor of the arguments on cross-fertilization between academic research and its commercialization, i.e. studies identified a positive relationship of patenting activities and publication outcome and quality.

We contribute to this literature by accounting for patent heterogeneity. The fact that patents are different (beyond the fact that they receive different numbers of citations as prior-art in future patents) has been ignored in this strand of literature. University patents may differ systematically from corporate patents. Where the former typically protect more basic research results and thus coincide with research tasks of universities, the latter rather cover applied inventions. Scientists may engage in patenting with business partners for the sake of research, e.g. to get access to lab equipment, but also their research budgets or personal income might play a role. Hence it is not ex-ante clear how business collaborations cross-fertilize scientific research. Therefore, we dig deeper in patent-publication relationships than the existing literature by distinguishing the type of patents taken out by university scientists. We differentiate among patents assigned to corporations, university patents and those assigned to other not-for-profit institutions.

By means of bibliometric/technometric indicators and econometric methods we shed some light on the questions how different patenting patterns relate to university scientists' publication output and citation impact as a proxy for patent quality. While previous research

largely relies on publication counts and numbers of received citations, we employ more elaborate measures that have been developed in bibliometric research over the past decades. Those control for heterogeneity of research fields and/or academic journals.

Our analysis is based on a newly created large sample of German university professors. We establish a link between the scientists' patents and their publication records. This yields a large sample of about 3.000 patenting professors holding more than 10.000 patents and having more than 40.000 publications in several fields of science.

Our results contribute to the literature on the incidence of patenting and publishing of researchers by uncovering whether the often documented positive relationship between patenting and publication activities of scientists persists if heterogeneity in patenting is taken into account. We confirm previous international findings in the sense that we find a positive relationship between patenting and publication outcome and quality for German professors. However, we find that heterogeneity in patenting matters. Whereas patenting with not-for-profit organizations does not reduce publication output and even increases citation impact, collaborations with corporations have a negative impact on publication outcome and impact. We thus conclude that the underlying effort to generate such patents distracts scientists from their other more fundamentally orientated research tasks.

Heterogeneity of Patenting Activity and Its Implications for Scientific Research[1]

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Abstract

The increasing commercialization of university discoveries has initiated a controversy on the impacts for future scientific research. It has been argued that an increasing orientation towards commercialization may have a negative impact on more fundamental research efforts in science. Several scholars have therefore analyzed the relationship between publication and patenting activity of university researchers, and most articles report positive correlations. However, most studies do not account for heterogeneity of patenting activities ranging from university patents to corporate patents. While the former may have closer links to basic research, this is not what we expect from the latter. We argue that such efforts will indeed distract scientists from other activities, as collaborations with companies are usually assumed to have an applied character and do not necessarily coincide with basic research tasks. This paper investigates the incidence of patenting and publishing distinguishing between different types of patents for a large sample of professors active in Germany. Our results show that, while university patents as well as patents assigned to not-for-profit institutions complement publication quantity and quality, corporate patents yield negative effects.

Keywords: Entrepreneurial universities, academic inventors, industry-science linkages, patents, technology transfer

JEL Classification: O31, O32, O34

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1 Introduction

Academic researchers become increasingly active in commercializing their discoveries as becomes impressively visible from the growing number of academic scientists among inventors on patents over the past decade (Henderson et al., 1998, Thursby and Thursby, 2002, Azoulay et al., 2006, Meyer et al., 2003, Lissoni et al., 2006, etc.). Many European governments actively promote commercialization activities of university scientists in order to enhance the usage of scientific research in industry through governmental funding programs. Often, such policy initiatives do not only encourage the commercialization of inventions through university spin-offs, but also industry science collaborations. Despite some clear benefits of academia-industry collaboration and the involvement of scientists in commercialization activities, some analysts are rather sceptical about the long-term consequences for science: Does academic orientation towards commercialization reduce research efforts, for instance, expressed by publication activity and its citation impact? Over the last years a fierce controversy emerged among policy makers and academics on the potential effects for the future of scientific research.

There is no doubt that close relationships between academia and industry have many positive aspects as the realization of complementarities between applied and basic research (Azoulay et al., 2006), the generation of new research ideas (Rosenberg, 1998) and the overcoming of the "underfunding" of basic research through the private sector (Agrawal and Henderson, 2002). It is, however, unclear whether these benefits outweigh suspected consequences for output and "quality" of scientific research.

Given that scientists heavily depend on their academic reputation (Merton, 1968) a complete "crowding out" of scientific activities by commercialization endeavours is considered as highly unlikely (Azoulay et al., 2006, Thursby et al., 2005, Scotchmer, 2004). Scientific reputation is helpful - if not even necessary – for commercialization activities of scientists. Academic prestige and a strong position in the scientific community reduces uncertainties in the commercialization process and serves as a signal in the post-discovery period. It might play a crucial role in order to attract potential industrial collaboration partners and financiers or new scientific personal. Recent empirical evidence broadly agrees on a positive relationship between patenting and publication activities of academic researchers for the US and European countries (e.g. Agrawal and Henderson, 2002, Markiewitz and DiMinin, 2005, Stephan et al., 2006, Czarnitzki et al., 2006). Murray (2002) even argues that patents as commercialized discoveries are found to be rather “by-products” of scientific work than substitutes.

A perhaps more serious concern than a possible replacement or significant reduction of scientific outputs by commercialization activities is that the quality of research might suffer. Inventions demanded by the market are typically rather applied and do not necessarily touch academic research frontiers (Trajtenberg et al., 1997). Recent studies, however, argue that contacts to scientists in the business sector are rather enriching for university researchers (Agrawal and Henderson, 2002, Breschi et al., 2007) and that industry-science collaborations might even trigger new basic research (Rosenberg, 1998, for the US chemistry). Most empirical evidence supports a positive relationship of patenting activities and publication outcome and quality (e.g. Van Looy et al., 2006, Czarnitzki et al., 2006, Breschi et al., 2007, Azoulay et al. 2006, etc.). However, Azoulay et al. (2006) point out that they cannot rule out that patenting activities shift the scientist’s interest towards research questions of commercial interest.

We contribute to this literature by taking patent heterogeneity into account in the analysis of the patenting-publishing relationship. The fact that patents are different (beyond the fact that they receive different numbers of citations as prior-art in future patents) has been ignored in previous papers. University patents and patents owned by the scientists themselves differ systematically from corporate patents (Trajtenberg et al., 1997). Whereas university patents typically protect more basic research, corporate patents rather cover applied inventions. Scientists may engage in patenting with business partners for the sake of research, e.g. to get access to lab equipment, but also their research budgets or personal income might play a role. Hence it is not ex-ante clear *how* business collaborations cross-fertilize scientific research. Therefore, we dig deeper in patent-publication relationships than the existing literature by distinguishing the type of patents taken out by university scientists. We differentiate among patents assigned to corporations, university patents and those assigned to other not-for-profit institutions. Collaborating with a non-university not-for-profit organization, such as the Max-Planck Gesellschaft or the Fraunhofer Gesellschaft in Germany, is supposed to provide scientists access to more professional support for commercializing inventions as compared to universities. Further, the research projects conducted at those institutions are supposed to have closer links to basic research than projects in collaboration with business partners.

By means of bibliometric/technometric indicators and econometric methods we shed some light on the questions how different patenting patterns relate to university scientists' publication output and citation impact as a proxy for patent quality. While previous research largely relies on publication counts and numbers of received citations, we employ more elaborate measures that have been developed in bibliometric research over the past decades. Those control for heterogeneity of research fields and/or academic journals.

Our analysis is based on a newly created large sample of German university professors. We established a link between the scientists' patenting files and their publication records. This yields a large sample of about 3.000 patenting professors holding more than 10.000 patents and having more than 40.000 publications in several fields of science. Our results contribute to the literature on the incidence of patenting and publishing of researchers by uncovering whether the often documented positive relationship between patenting and publication activities of scientists persists if heterogeneity in patenting is taken into account.

The remainder of the paper is organized as follows: the next section briefly summarizes the literature on the correlation between patenting and publishing, section 3 describes the construction of the database, section 4 presents some descriptive statistics on scientists' patent activities, section 5 shows the empirical analysis and the final section concludes.

2 Evidence on Scientists' Patenting and Publication Activities

The literature on the scientific performance of scientists that are active in the commercialization of their scientific discoveries has its seeds in the field of bibliometrics/technometrics. One major interest of this literature is to access the co-development and convergence of science and technology. The 'science-intensity' of technology and other aspects of the science-technology relationship are often mapped by citation-based measures as non-patent references (NPRs) in patents (e.g., Narin and Noma, 1985) and patent references in scientific publications (e.g., Hicks, 2000, Glänzel and Meyer, 2003). The general conclusion from these bibliometric/technometric analyses is that in those areas where science and technology have a common interface, science and technology are getting increasingly closer over time.

The strength of links established through publication citations in patents (and patent citations in scientific publications) is, however, somewhat limited. This is, among other factors, a consequence of the citation behaviour of authors, inventors and examiners as well as of the different functions citations have in scientific papers and in patent literature (Michel and Bettels, 2001, Glänzel, 2005).[2] Meyer (2006b) argues that citation linkages hardly present a direct link between cited paper and citing patent. Much stronger – and maybe even more meaningful – links are established trough collaborative knowledge production expressed by inventor-author relations as analyzed by Noyons et al. (1994) and Meyer (2006a). Meyer (2006a) focuses on patenting scientists active in nano-science and nano-technology. Based on a bibliometric analysis, he concludes that patenting scientists outperform other scientists in terms of their publication and citation record. He concedes, however, that co-active scientists do not have the lead in the top-performance class.

Bibliometric/technometric analyses typically use qualitative and descriptive research methodologies, but several recent papers on the incidence of patenting and publishing employ econometric methods (e.g. Stephan et al., 2005, Azoulay et al., 2006, Markiewitz and DiMinin, 2005, Breschi et al., 2006, Czarnitzki et al., 2006). The major methodological advantage of those approaches is probably that individual-specific effects that are unobservable for the researcher can be taken into account, e.g. the scientists' ability to conduct research that has the potential to be published and their motivation (see Czarnitzki et al., 2006, for details).

Independent of the methodology used recent studies broadly confirm the finding that science and technology are complementary. Stephan et al. (2005) investigate the correlation between publishing and patenting for a sample of Ph.D.'s in the US. Using instrumental variables regression they find that the commercialization of discoveries is positively related to scientific output. Markiewitz and DiMinin (2005) use a matched sample of patenting and non-patenting US scientists to analyze their publishing performance. Based on a fixed effects panel regression they confirm a positive correlation. Breschi et al. (2006, 2007) provide evidence on the positive correlation between patenting and publishing for a matched sample of Italian scientists. Agrawal and Henderson (2002) depict the positive relationship for patenting and citation measures for researchers at the Departments of Mechanical and Electrical Engineering at the Massachusetts Institute of Technology. Azoulay et al. (2006) focus on

[2] Agrawal and Henderson (2002) critically discuss the appropriateness of patent based measures to evaluate public funding of university departments.

university professors in the US. They find that patenting increases the number of publications, and that it has no impact on their quality. However, they cannot rule out that commercialization activities influence the content of the scientific research. Van Looy et al. (2006) find a positive correlation between patenting and publication activities for researchers at the Catholic University of Leuven. They further conclude that the journals in which academic patentees publish are not significantly more applied than those, to which their non-patenting colleagues contribute.

In summary, there is a well documented positive correlation between patenting and publishing activities of academic scientists, and at least, there seems to be no negative effect of commercialization activities on publication quality, but maybe on the content.

The previous literature does, however, not distinguish between different types of patents. University patents, which are supposed to protect very basic research, significantly differ from business patents, which are supposed to cover rather applied inventions (Trajtenberg et al., 1997). A further group of patents, those in collaboration with non-for profit organizations, is supposed to be different as well. Those patents are supposed to be more basic, i.e. more science-oriented, than patents in collaboration with business. We expect that this heterogeneity in patents is well reflected in the publishing figures of patenting scientists. Basic patents are supposed to be more likely to cover drastic innovations that might coincide with academic publications, whereas applied patents might protect marginal and incremental inventions that are not necessarily linked to original research activities worthwhile for journal publications. We contribute to the literature by investigating the correlation between patenting and publishing taking patent heterogeneity into account by distinguishing between university patents and patents that are applied for by not-for-profit organizations and corporations.

So far only Breschi et al. (2007) pay attention to patent heterogeneity. Based on descriptive statistics for a sample of 229 Italian scientists they conclude that there is the strongest correlation between patenting and publishing if patents are owned by business partners. They concede, however, that they have only a limited number of university patents in their Italian sample. In consequence, they do not go beyond a descriptive analysis of patent heterogeneity. Breschi et al. (2006) find a similar link for a larger sample of patenting scientists identified by the EP-INV database (described in Balconi et al., 2004). In this paper they find that collaborations with co-authors in business increases the publication output of university scientists.

3 Data sources

Our analysis is based on a newly created data set that contains patent applications and publication records for university professors active in Germany. The starting point is the database of the German Patent and Trademark Office (DPMA) which contains all patents filed with the DPMA or the European Patent Office (EPO) where the applicant requests patent protection in Germany from 1980 onwards. Patent applicants at the DPMA and the EPO must designate the inventor of the patent. Otherwise the patent application will be deemed withdrawn. We identified all inventors by using the persons' title "Prof. Dr." and variations of that. We checked whether the names of those people appeared in the patent database without the title but with the same address in order to verify that the title field is always filled in the data. The verification of a sample of persons had shown that we can identify university professors (or professors at other higher education facilities such as polytechnical colleges) by their title with high precision. It basically never happens that inventor names appear sometimes with "Prof. Dr." (or similar title) and sometimes without on other patents. Thus, we can safely argue that with focus on Germany this procedure delivers a listing of patents where professors are recorded as inventors. In total, we found 42,065 inventor records with professors. As there are sometimes multiple professors listed as inventors on one patent, the number of different patents with professors amounts to 36,223.

As the inventors had to be linked to publication data, we first had to identify a list of unique inventors from the identified patents, that is, we had to create a key that identifies the same person on multiple patents. This was conducted by both computer assisted text field searches and manual checks. First, we used a text field search engine on names and city of residence of the inventors (by putting a high weight on name similarity). The potential matches of identical person records on different patents were manually checked afterwards. If the text fields of last name and first name or initials and city were sufficiently similar we assigned "hits". In case the city was different, we cross-referenced with other information if the person is identical, that is, field of research, distance among cities and distinctness of names. This approach allows tracing professors who move during the observed period. Of course, there were occurrences where it was not possible to code records as identical persons. If very common names like "Müller" or "Schmidt" appeared with common first names and large or different cities we preferred to drop such inventors from the lists to avoid erroneous assignment by unresolvable homonyms. In total, we discarded 6.758 patents out of 36.223 patents, where we were not able to create a unique person ID. The remaining 29.465 patents turn out to contain 6.324 different professors.

In the next step, we coded the assignees of the patents with professors as inventors into three groups: assignee is

1. a for-profit entity (corporations);
2. a university or the professor himself or herself;[3]
3. a non-profit research institution or other non-profit entity.[4]

This grouping serves as the criterion to distinguish the different patent types in the upcoming empirical analysis. Group 2 is referred to as "university" throughout the remainder of the study.

The professors who were listed as inventors on the patents were traced in the Web of Science® database of Thomson–Scientific (Philadelphia, PA, USA). We used a similar search algorithm as described above, but the fact that the patent data contain the place of residence of the inventors while the bibliographic database records the authors' institutional address made additional manual cross-referencing necessary. The high amount of required manual checking of records forced us to restrict our further analysis on the linked data to a five-year period from 1997-2001 leaving us with 10.431 different patents with 2.936 different identified professors as inventors. In total, we matched 40.527 publications to the inventors for the observed five year period.

[3] Note that until 2002, German professors were entitled to exploit commercial value of inventions privately (legislative known as "Hochschullehrerprivileg"). Thus we also talk about a "university patent" if the professor herself or himself are recorded as assignee on the patent. Since 2002, however, legislation of intellectual property ownership in Germany changed and universities may exploit the inventions (similar to the Bayh-Dole Act in the US).

[4] Such institutions include the major public non-university research institutions in Germany (Max-Planck Gesellschaft, Fraunhofer Gesellschaft, Helmholtz Gemeinschaft, and others), but also associations, foundations and other non-commercial entities including the government.

4 Descriptive Analysis

4.1 Patenting Scientists Located in Germany

In this subsection we present some descriptive evidence using the identified patents with a professor as inventor. This covers the time period 1989 to 2002. Further descriptions using the data where we identified unique persons and linked their records to publication data follow in the next subsection, as we only cover publications between 1997 and 2001 in our linked patent-publication database.

A first general look at the patenting patterns of professors located in Germany shows a significant increase of patents filed by professors over time (see Figure 1). The number of patent applications by university professors identified from the DPMA and EPO inventor names increased by 137% over the period 1987-2002 with a temporary maximum in 2000. Figure 2 shows that also the number of patenting professors in Germany grew tremendously over the past 20 years.

Figure 1: 3-Year Moving Average of the Number of Patents Filed by Professors Located in Germany

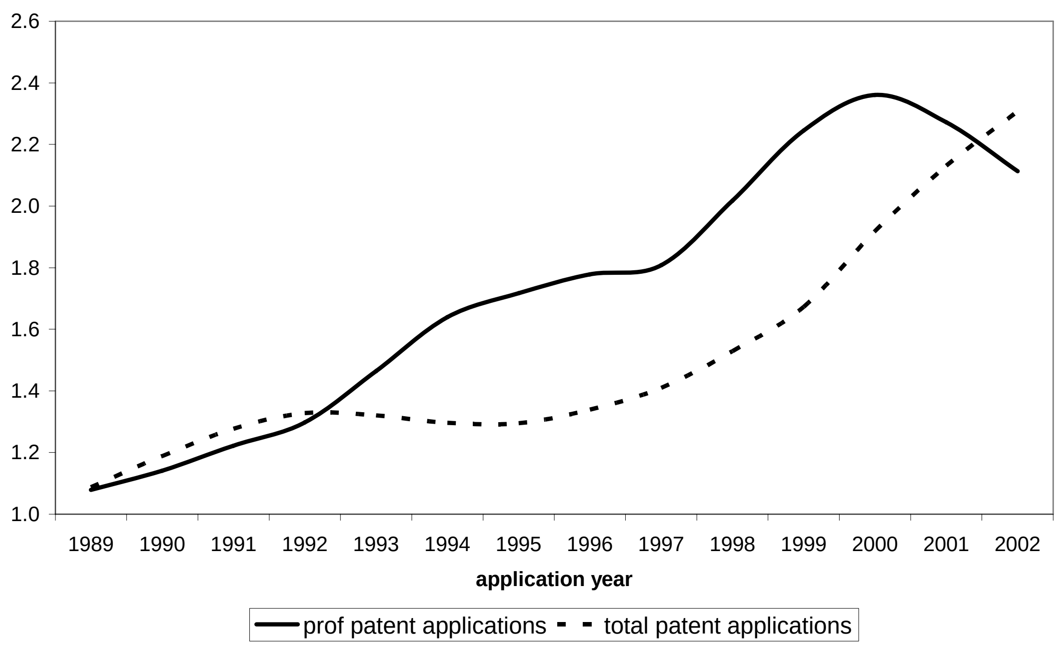


Figure 2: 3-Year Moving Averages of the Number of Patenting Professors Located in Germany

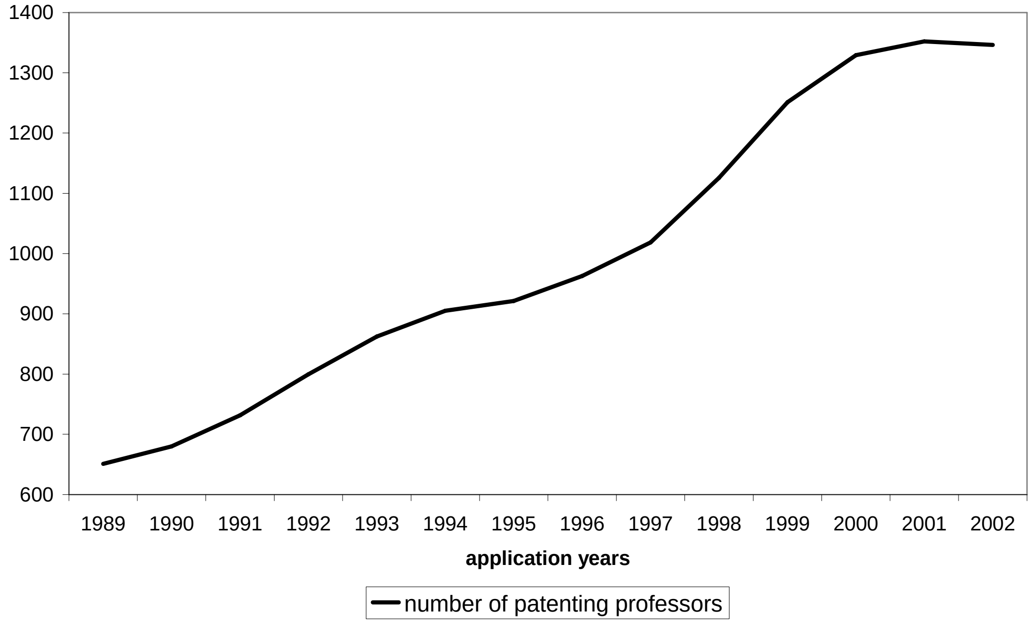
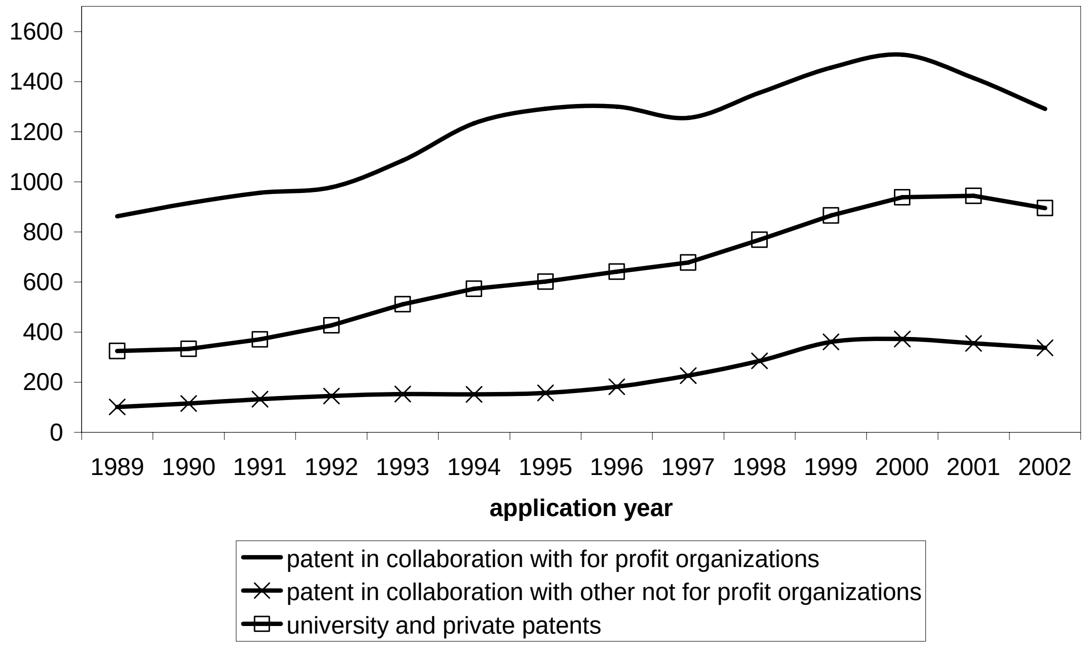


Figure 3: 3-Year Moving Averages of the Distribution of Professors' Patents by Type of Assignee



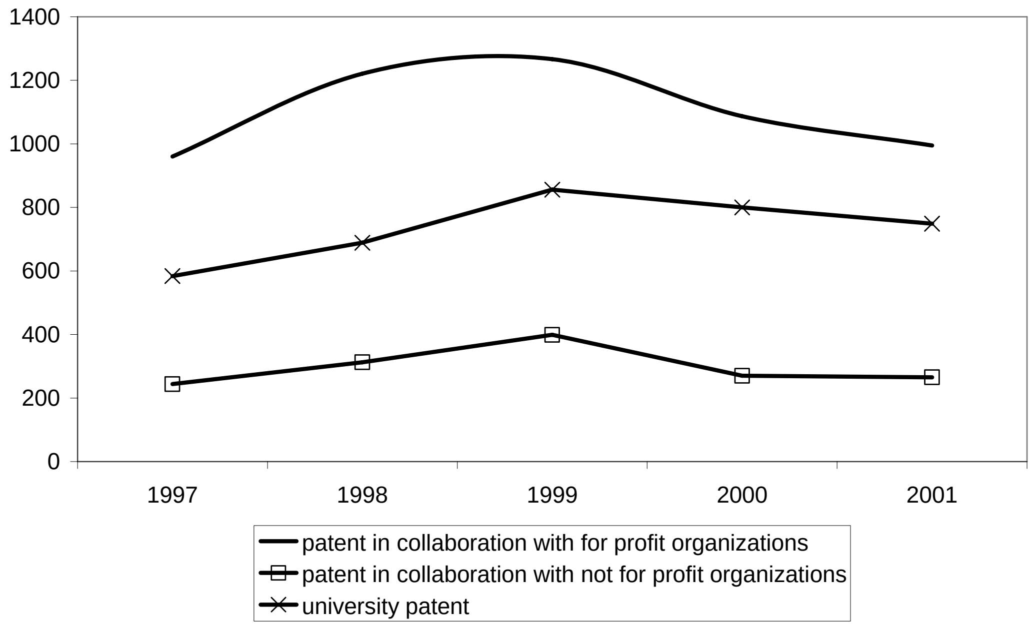
A look at the distribution of patents invented by professors according to their assignees (Figure 3) shows that, by far, most patents are filed in collaboration with companies (for-profit organizations). Approximately half as many patents are filed with a university (or are owned by the professor himself or herself). Patents in collaboration with other non-profit research institutions are least frequent.

4.2 Patenting Scientists Located in Germany

Switching to our sample of uniquely identifiable patenting professors in Germany, we find the same distributional patterns over different assignees for our five-year period where we linked the patent database with publication records (Figure 4).

On average, each professor in our sample applied for 3.6 patents in the period 1997-2001 (as we use patents with a one year lag, we focus on this period). As expected the patent distribution shows a considerable skewness. The mean professors applied for 2 patents and the most active professor applied for 103 patents in the same time window.

Figure 4: Distribution of Professors' Patents According to the Assignee – Sample Only



Focusing on the publication activities of professors the distribution of activity in our sample looks similarly skew. Whereas the average professor published 14 scientific articles in the observation period, the mean professors had only three publications and the most active person had 309 articles. The main fields of publication activity are chemistry and physics. More than 20% of the total publications are attributable to either one of the fields. More than 10% of the publications belong to the clinical and experimental medicine and the bioscience sector.

22% of all publications stem from inventors with university patents. About 46% of the publications belong to inventors that patented with companies and not-for-profit collaborations each. The percentages do not add up to 100% because almost 14% of the professors patent in collaboration with more than one type of assignee. 1% in engaged in all the three types of collaborations we defined.

4.3 Measuring Publication Activities

In order to measure publication activity we start with a simple count of publications per researcher per year. The number of citations received during a sufficiently large period provides insight into the reception of the published results by the scientific community. Although citations are not immediately an indication of research quality, Holmes and Oppenheim (2001) have shown that citation measures significantly correlate with other quality measures. On average, the total number of articles published by a professor in our sample gets 78 citations. The most cited person received 2,565 citations in total.

The bibliometric literature views citation counts as a measure that depends on too many factors not directly linked to quality issues. Therefore, this strand of literature proposes more sophisticated citation measures like the mean observed citation rate, the relative citation rate and the normalized mean citation rate – all based on a three-year citation windows:

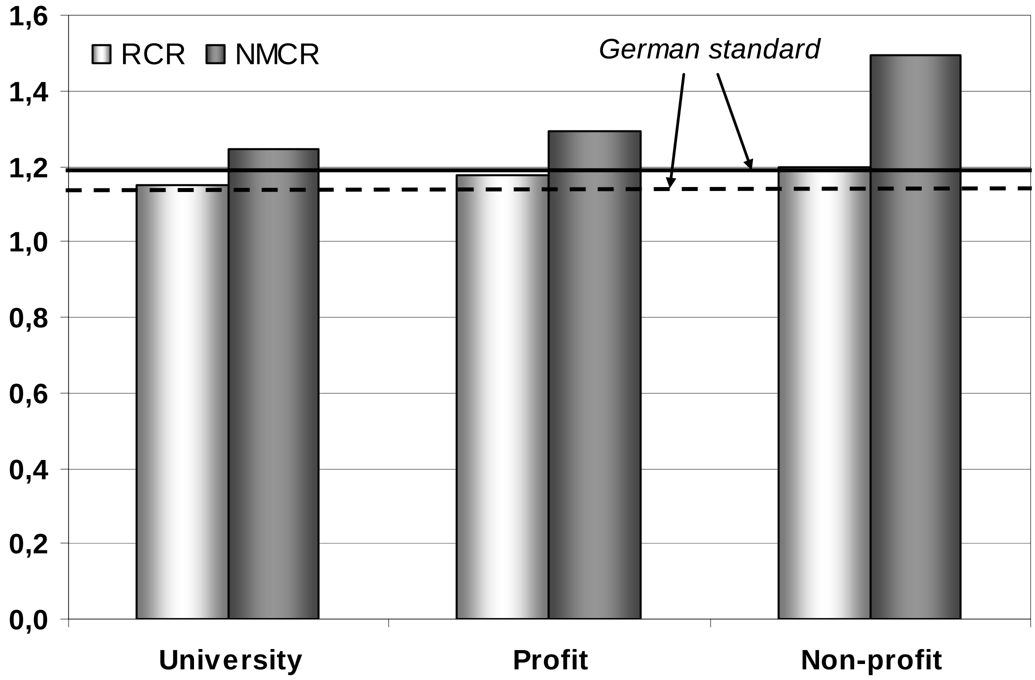
- The *Mean Observed Citation Rate* (MOCR) is defined as the ratio of citation count to publication count. It reflects the factual citation impact of a scientist's publication output independently of its size. Nonetheless, this measure is still influenced by subject characteristics, and is therefore – without further normalization – not appropriate for cross-field comparisons and multidisciplinary application (Glänzel and Moed, 2002) such as the patenting activity of German professors in this study.
- The *Mean Expected Citation Rate* (MECR) is needed to calculate the relative citation rate and therefore used as an auxiliary measure but not as individual variable in this study. MECR of a single paper is defined as the average citation rate of papers published in the same journal in the same year. For a set of papers assigned to a

particular scientist, the indicator is the average of the individual expected citation rates over the whole set.

- The *Relative Citation Rate* (RCR) is defined as the ratio of the Mean Observed Citation Rate to the Mean Expected Citation Rate per publication: RCR = MOCR/MECR. This indicator measures whether the publications of a particular scientist attract more or less citations than expected on the basis of the impact measures, i.e. the average citation rates of the journals in which they appeared. Since the citation rates of the papers are gauged against the standards set by the specific journals, it is largely insensitive to the big differences between the citation practices of the different science fields and subfields. An RCR that equals zero corresponds to uncitedness, RCR < 1 means lower-than-average, RCR > 1 higher-than-average citation rate, RCR = 1 if the set of papers in question attracts just the number of citations expected on the basis of the average citation rate of the publishing journals. RCR has been introduced by Schubert et al. (1983), and largely been applied to comparative macro and meso studies since.
- The *Normalised Mean Citation Rate* (NMCR) is defined analogously to the RCR as the ratio of the Mean Observed Citation to the weighted average of the mean citation rates of subfields. In contrast to the RCR, NMCR gauges citation rates of the papers against the standards set by the specific subfields. Its neutral value is 1 and NMCR >(<) 1 indicates higher(lower)-than-average citation rate than expected on the basis of the average citation rate of the subfield. NMCR has been introduced by Braun and Glänzel (1990) in the context of national publication strategy and to both subject-specific characteristics individual publication strategies in the particular choice of publication channels.

If we compare the (citation) impact of publication output of patenting professors with the average in Germany, we find that the citation-impact values of patenting professors are in line with the German average. Figure 5 shows the relative citation rate (RCR) and the normalized mean citation rate (NMCR). The RCR shows that the citation impact of patenting university scientists just slightly exceeds the German standard weighted by the journals where the scientists have published their papers. Co-activity of inventors in the university group actually resulted in the lowest impact according to the RCR while collaboration with the non-profit sector yields the highest one. The same patterns can be observed if disciplines are chosen for normalization of citation impact; however indicator values reach much higher values in this case: if the science field is taken into account as a broader benchmark it turns out that citation impact of patenting university professors lies distinctly above the corresponding German standard (NMCR). Finally, the comparison of the two relative citation measures clearly indicates that German patenting professors publish – on an average – in rather high impact journals (as compared with the German standard). This effect is most pronounced for the collaboration with non-profit organisations.

Figure 5: Citation Impact of Sample Publications Compared to the German Average



Note: The solid horizontal line represents the NMCR and the dotted line the RCR of all German publications, while the bars refer to our sample of patenting professors. The groupings on the x-axis refer to publications of professors that either have at least one patent with a university (or the patent is assigned to themselves), with a corporation (Profit), or with a non-profit institution, respectively. If professors patented with assignees of multiple groups, their publications are counted for each of them.

5 Regression Analysis

5.1 Pooled cross-sectional regressions

This section shows the empirical results for the correlation between patenting and publishing taking heterogeneity in patenting activities into account. We use a tobit model to access the impact of patenting on publishing activities. The estimated model is:

$$PUB_{it} = f(PAT_{it-1,} X_{it}) + \varepsilon_{it} \,, \qquad (1)$$

where ε_{it} is the error term of the model that accounts for all random effects not captured by the regressors. The function f is assumed to be linear. PUB_{it} is the measure for publication activity. Depending on the estimated model it measures simply quantity or quality adjusted by journal or field averages (MOCR, RCR, NMCR). The patent measures are included in the vector PAT_{it} which includes the number of patents, the percentage of patents in collaboration with companies and the percentage of patent in collaboration with not-for-profit organizations. University patents are the benchmark case. We choose the specification of the variables expressed as percent of all patents in order to avoid multi-collinearity among regressors.

All patent variables are timed by application year, and are included as a one-year lag in the regressions. As we intend to analyze whether commercialization activity is correlated with scientific output, it is desirable to contrast publication and patent activity that took place at the same time, that is, the time window when the scientist was most probably using his or her time for both activities in parallel. We observe the application date in the patent database, and thus we can assume that the researcher had worked on the underlying technology closely before filing the patent application. For the publications, however, we do not observe journal submission date but only publication year. The submission must necessarily have taken place a certain time before publication. In absence of a better guess, we model that the researchers submitted their papers about one year before the publication of the article in a journal. By using a "publication in period *t*" to "patent application in *t*-1" relationship as in eq. (1), we attempt to approximate a time window where the scientist worked on both the publications that appeared in year *t* and patents filed in *t*-1, such that the actual research for publishing and patenting took possibly place in year *t*-2. Of course, we are aware that publication lags may vary in time, but currently we do not have any better information at hand, which would improve the selection of a more appropriate time window.

As further control variables, *X*, we use a set of year dummies to control for a possible general trend in the publication activity, a gender dummy (equal to one if person is female) and the patenting experience of the researcher. Patenting experience is measured through the application year of the scientist's first patent filing. We use three experience cohorts in the regression analysis: first patent application (1) before 1987, (2) between 1987 and 1992, (3) between 1993-1998. The reference category are those scientists that patent first between 1998 and 2001.

Table 1 presents descriptive statistics. It becomes apparent that there is a clear trend toward becoming engaged in patenting activities over time. Whereas the percentage of scientists that belong to the cohort that started patenting before 1986 is small, the percentage of inventors that engages in patenting increases over time. A sharp increase can be observed in the 1990s where 22% of the inventors in our sample had their first patent, which is again drastically exceeded by the reference category: 64% of the inventors had their first patent later than 1998.

Table 1: Descriptive Statistics of variables used in the regression analysis

	mean	std. dev.	min	max
		# observations = 14,680		
PUB:				
#publications	2.76	5.52	0.00	73.00
#citations	15.64	44.68	0.00	768.00
MOCR	2.17	4.69	0.00	87.00
RCR	0.20	0.68	0.00	30.70
NMCR	0.51	0.95	0.00	15.68
PAT:				
# patents	0.71	1.79	0.00	36.00
% for profit patents	0.16	0.36	0.00	1.00
% not for profit patents	0.04	0.19	0.00	1.00
X:				
Female	0.02	0.15	0.00	1.00
Earlierst pat. exp. <= 1986	0.06	0.23	0.00	1.00
Earlierst pat. exp. 1987-1992	0.08	0.27	0.00	1.00
Earlierst pat. exp. 1993-1998	0.22	0.41	0.00	1.00

Finally, a look at the gender distribution of the professors shows that 97% of the patenting university professors in our sample are male. Only 2% of patents correspond to female university scientists.[5]

Note that we perform tobit regressions as this accounts for the left-hand censoring of the publication variables, that is, individual-year observations where the professor did not publish in a journal. Typically scholars compare publications and patents of scientists in a given time period. However, there may be many periods where professors either do not publish or do not patent. In descriptive studies where the data is often grouped, such zero outcomes are often neglected. This may result in a bias of the estimated relationship. In the worst case, professors may not publish as they used all their time to patent in a given period. As we employ data reflecting the population of patents filed by the professors in the sample and the population of their publications, we know that they did either not patent or publish in a year for which we did not find a record in either database. Thus, we can code the value of the variable with zero for those cases. As a result, we get a panel database where the full history of patenting and publishing can be traced over time for each professor.

Table 2 presents estimation results from pooled cross-sectional Tobit regressions. Subsequently, we will show panel data estimations where we control for unobserved heterogeneity among scientists (see next subsection). The first column in Table 1 shows the results for the correlation between patenting and the number of publications; the further columns show the results for the quality of publications measured as a simple citation count and the weighted citation measures described in the previous section. The results show that patenting is positively related to publishing activities in terms of the number of publications (column 1) and forward citations (column 2). This finding is in line with the previous literature showing positive correlations between patenting and publishing output and quality.

Focusing on patent heterogeneity it turns out that patents in collaboration with companies (“for-profit”) have a negative impact on the publication performance. The results should be interpreted as follows: while an increase in the pure number of patents leads to increases in publication output, this regression line is shifted downwards for corporate patents. The downward shift is larger, the higher the share of patents with companies is.

[5] 1% of the inventors in our sample could not be classified with respect to gender because their patent records contained initials only or because the first name was foreign and we were not able to determine whether it refers to a male or female.

Table 2: Effects of Heterogeneous Patenting on Publication Performance: Results from Tobit Regressions

Endogenous variable	**# publications**	**# citations**	**MOCR**	**RCR**	**NMCR**
	coeff. (std. err.)	coeff. (std. err.)	coeff. (std. err.)	coeff. (std. err.)	coeff. (std. err.)
# patents	0.31***	2.02***	0.05	-0.01	0.01
	(0.05)	(0.43)	(0.05)	(0.01)	(0.01)
% for profit patents	-2.72***	-23.03***	-1.98***	-0.16***	-0.36***
	(0.25)	(2.40)	(0.25)	(0.04)	(0.05)
% not for profit patents	-0.03	6.47*	1.17***	0.13**	0.26***
	(0.41)	(3.78)	(0.40)	(0.06)	(0.08)
Female	2.77***	26.80***	3.46***	0.34***	0.58***
	(0.50)	(4.62)	(0.48)	(0.07)	(0.10)
Earlierst pat. exp. <= 1986	12.42***	92.70***	10.18***	1.41***	2.21***
	(0.31)	(2.91)	(0.31)	(0.04)	(0.06)
Earlierst pat. exp. 1987-1992	13.18***	97.98***	10.49***	1.42***	2.23***
	(0.28)	(2.59)	(0.27)	(0.04)	(0.05)
Earlierst pat. exp. 1993-1998	12.24***	97.31***	11.07***	1.43***	2.32***
	(0.20)	(1.86)	(0.20)	(0.03)	(0.04)
1998	0.46*	1.11	0.00	0.00	0.04
	(0.25)	(2.36)	(0.25)	(0.04)	(0.05)
1999	0.34	0.27	-0.24	-0.01	0.00
	(0.25)	(2.37)	(0.25)	(0.04)	(0.05)
2000	0.32	0.65	-0.10	-0.01	0.00
	(0.25)	(2.38)	(0.25)	(0.04)	(0.05)
2001	0.13	1.02	0.03	-0.02	0.01
	(0.25)	(2.38)	(0.25)	(0.04)	(0.05)
Intercept	-6.75***	-70.07***	-6.76***	-1.08***	-1.33***
	(0.21)	(2.05)	(0.21)	(0.03)	(0.04)
# observations			14,680		
# professors			2,936		
Censored obs.	7,754	8,597	8,597	8,597	8,597
Model significance - χ^2	6,307.30***	4,407.03***	4,877.11***	3,988.18***	5,351.43***

The estimates of the pooled cross-sectional models employing the quality-adjusted publication measures reveal that the general, positive patenting-publishing relationship vanishes. However, patenting with companies reduces the citation impact of publication, referring to publication “quality” even if the citation impact of the researchers’ publication output per paper (MOCR) is corrected for the corresponding journal standard (RCR), and subject-field standard (NMCR), respectively. This finding is in line with the hypothesis that business patents might rather be technology-oriented than related to basic research and that they might have a negative impact on research performance as they do not necessarily touch scientific frontiers, but distract scientists from research tasks. Interestingly, the share of patents in collaboration with non-profit research institutions turns out to be positively significant. This may be due to a peculiarity of such German institutions. We come back to this issue after checking the robustness of results using the panel data estimator.

Further, Table 2 shows that female scientists outperform their male colleagues in terms of publication numbers and citations received by those articles including the quality adjustments. A final result is that the cohort of the youngest researchers, which have their first patent later than 1998 (i.e. the left-out benchmark group) are the least productive scientists and receive significantly less citations including papers’ quality adjustments than their more experienced colleagues. Those least experienced scientists that patent for the first time may have to devote lots of efforts into the invention process and patent application procedures which distract them significantly more from research tasks compared to their more experienced colleagues engaging in commercialization. The time dummies turn out to be jointly insignificant in all regressions.

5.2 Panel data estimations

Table 3 shows the regression results for a random effects panel model. This model allows to control for unobserved individual-specific effects:

$$PUB_{it} = f(PAT_{it-1}, X_{it}) + \alpha_i + \varepsilon_{it}, \tag{2}$$

where α_i, the individual-specific effect, denotes the unobserved ability of a scientist that might be caused by factors such as a better education, higher creativity, higher academic ambitions, family status etc. The regression model presented in eq. (2) will disentangle the influence of patenting and unobserved specific skills of each researcher causing heterogeneity in average publication activity over the cross-section of scientists in the sample. Note that individual specific attributes of the professor such as gender and experience are not included in the specification anymore. Those are now included in the individual-specific effect as they do not change over time.

There are two tests presented in Table 3 showing that individual effects are present. First, the estimated variance of α_i is estimated significantly differently from zero. If it was zero, the model would reduce to a pooled cross-sectional regression. As this is not the case here, we can conclude that there are unobserved attributes specific to a scientist which determine their average publication performance. The parameter ρ indicates how much of the total error variance is due to cross-sectional variance. For instance, in the model using the number of publications as dependent variable, 87% of the variance is explained by the variation over persons rather than variation over time.

The results now show that the number of patents increases both publication quantity and all measures of publication quality. Furthermore the results on the negative downward shift of the share with company patents persist in all specifications. Same applies to the positive upward shift of the patent-publishing relationship when the share of patents with not-for-profit institutions is considered.

What could explain the upward shift of the patent-publishing relationship when professors engage with not-for-profit institutions other than universities? Of course, we have to be somewhat speculative, but we believe that important institutional differences are at work here. First, we think that the research involved with such patents is more related to efforts for journal publications than the activities with companies. Thus, these activities should coincide well with publication tasks. Second, we believe that scientists engaging with such public institutions receive more administrative support in the patenting process than at universities. Unlike the large US universities, most German universities do not maintain professional technology transfer offices (TTO) that assist scientists in commercialization. In many cases, a TTO employs only 50% of one full time equivalent person which is, of course, not able to handle commercialization strategies of a whole university. Thus, inventors have to rely on themselves or their research team when it comes to patent administrative processes in most universities, which leads to distraction from research tasks. In other public research institutions such as the Max-Planck-Gesellschaft, for instance, researchers can count of highly professional and efficient support with respect to administrative issues in commercialization. Such institutions maintain large TTOs that deal with the technology management of all their German entities. This should result in less distraction from research when such an assignee exploits intellectual property rights.

To conclude this section we should note that our sample consists of patenting professors only. Hence, we can only interpret our results for professors in Germany conditional on being active in patenting. It would possibly be interesting to compare these findings with a control group of non-patenting professors. However, given the statistics in Figure 5, the publications of patenting professors differ not much from the total average with respect to quality. If at all, those are better than average. Therefore, we would expect that our estimated relationships would either not change much, or the estimated impact of the number of patents filed would go up.[6]

[6] Azoualy et al. (2006) attempt to control for such selectivity by deriving a "patentability" measure based on publication titles. They extract keywords from the titles and weight them by a measure that captures to which extend other scholars in the same technology field have patented their research. Hence, they claim that the patentability of a particular publication can be derived from the patent activity of researchers that publish in the same narrow research area.

Table 3: Effects of Heterogeneous Patenting on Publication Performance: Results from Panel Tobit Regressions

Endogenous variable	**# publications**	**# citations**	**MOCR**	**RCR**	**NMCR**
	coeff. (std. err.)	coeff. (std. err.)	coeff. (std. err.)	coeff. (std. err.)	coeff. (std. err.)
# patents	0.07***	0.59**	0.09***	0.02***	0.02***
	(0.02)	(0.26)	(0.03)	(0.01)	(0.01)
% for profit patents	-0.27**	-4.15***	-0.55***	-0.07**	-0.10**
	(0.12)	(1.31)	(0.18)	(0.03)	(0.04)
% not for profit patents	0.19	8.10***	1.33***	0.24***	0.31***
	(0.19)	(2.04)	(0.30)	(0.06)	(0.07)
1998	0.78***	3.20***	0.31*	0.05	0.12***
	(0.10)	(1.20)	(0.17)	(0.03)	(0.04)
1999	0.53***	1.43	-0.08	0.02	0.04
	(0.10)	(1.21)	(0.17)	(0.03)	(0.04)
2000	0.39***	1.26	-0.05	0.00	0.01
	(0.10)	(1.21)	(0.17)	(0.03)	(0.04)
2001	0.21**	1.20	0.03	-0.02	0.01
	(0.10)	(1.21)	(0.17)	(0.03)	(0.04)
Intercept	1.00***	10.77***	0.53***	-0.51***	-0.50***
	(0.10)	(1.04)	(0.14)	(0.03)	(0.04)
$Var(\alpha_i)$	8.12***	70.93***	6.30***	0.64***	1.48***
	(0.08)	(0.88)	(0.10)	(0.01)	(0.02)
ρ (= contribution of panel variance	0.87***	0.81***	0.61***	0.30***	0.36***
component, α_i, to total variance)	(0.00)	(0.00)	(0.01)	(0.01)	(0.01)
# observations			14,680		
# professors			2,936		
Censored obs.	7,754	8,597	8,597	8,597	8,597
Model significance - χ^2	78.81***	42.91***	46.60***	42.02***	48,08***

6 Conclusions

The increased engagement of university scientists in commercializing their discoveries over the past decades led to a discussion on potentially negative consequences for future science. Policy makers and analysts fear that significant commercialization activities of scientists may replace part of their research activities and also lead to a reduction in research quality. Empirical evidence for the US and European countries shows, however, that scientists do not publish less than other researchers if they engage in patenting. Scientists that do both publishing and patenting are rather found to be “stars” that outperform their non-patenting colleagues in terms of publication outcome and quality.

The contribution of our paper is that we do not assume that all patents have the same impact on publication activities, but that we take into account patent heterogeneity. We distinguish between university patents, patents in collaboration with other not-for-profit organizations and patents in collaboration with corporations. Whereas university patents are typically rather basic, corporate patents tend to be rather applied. Obviously one would expect corporate patents to be more likely to negatively impact scientific outcome as those patents might not necessarily touch research frontiers or coincide with research tasks qualifying for journal publications.

Our results are based on a large data base of German scientists that are active in patenting. We can confirm previous international findings in the sense that we also find a positive relationship between patenting and publication outcome and quality for German professors. However, we find that heterogeneity in patenting matters. Whereas patenting with not-for-profit organizations does not reduce publication output and even increases citation impact, collaborations with corporations have a negative impact on publication outcome and impact. The positive result for patents in collaboration with non-university not-for-profit organizations is most probably explained by the more professional support for commercializing of inventions those institutions provide as compared to universities. Further, the research projects conducted at those institutions is likely to be closer related to basic research than are projects in collaboration with business partners.

Our analysis is not without limitations. First, we cannot claim that the identified relationships between patent and publication measures are strictly causal. Rather we just identify multivariate correlations. In order to infer causality we would have to find instrumental variables that relate to patenting but are not influenced by publishing. Given the limitations of our data at this point, we have no convincing candidates for such instruments at hand, though. It would require collecting additional variables on the professors personal characteristics and their faculty environment which is difficult as no systematic databases exist.

As an interesting path for further research on German institutional circumstances, we identified the positive impact of collaborations with non-profit institutions. It may be interesting to construct structural variables describing the technology transfer capabilities present at the professor's institutions and their patent collaboration partners in the not-for-profit sector to estimate the surplus of well managed technology transfer institutions, or, possibly more interesting, the forgone benefit implied by the non-existence or dysfunctionality of such transfer establishments.

Finally, it should be noted that the negative impact of engagement in corporate patenting does not necessarily challenge the increased orientation towards commercialziation in academia. It may well result in a positive net-effect from a macroeconomic point of view, at least in short to medium term view. To find an ultimative answer one would have to contrast the economic loss of lower publication activity with possibly higher returns and growth in the business sector that may have been achieved through collaboration with academia in form of patent filings and thus intellectual property.

References

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

Azoulay, P. Ding, W. Stuart, T., 2006. The impact of academic patenting on the rate, quality and direction of (public) research. NBER working paper 11917, Cambridge, MA.

Balconi, M., Breschi S., Lissoni, F., 2004. Networks of inventors and the role of academia: an exploration of Italian patent data. Research Policy, XXXIII (2004) 127-145.

Braun, T., Glänzel, W., 1990. United Germany: The new scientific superpower? Scientometrics 19(22), 513-521.

Breschi, S., Lissoni, F., Montobbio F., 2007. The scientific productivity of acvademic inventors: New evidence from Italian data. Economics of Innovation and New Technology 16(2), 101-118.

Breschi, S., Lissoni, F., Montobbio F., 2006. University patenting and scientific productivity. A quantitative study of Italian academic inventors. CESPRI working paper n.189, Milan.

Czarnitzki, D., Glänzel, W., Hussinger, K., 2006. An Empirical Assessment of Co-Activity among German Professors. ZEW Discussion Paper No. 06-080, Mannheim.

Glänzel, W., Meyer, M., 2003. Patents cited in the scientific literature: An exploratory study of 'reverse' citation relations in the triple helix. Scientometrics 58(2), 415-428.

Glänzel, W., Moed, H.F., 2002. Journal impact measures in bibliometric research. Scientometrics 53(2), 171-193.

Henderson R., Jaffe A.B., Trajtenberg, M., 1998. Universities as a source of commercial technology. Review of Economics and Statistics 80(1), 119-127.

Hicks, D., 2000. 360 Degree linkage analysis. Research Evaluation 9(2), 133-143.

Holmes A., Oppenheim C., 2001. Use of citation analysis to predict the outcome of the 2001 research assessment exercise for unit of assessment (UoA) 61: library and information management. Information Research 6(2), available at: http://InformationR.net/ir/6-2/paper103.html.

Lissoni F., Sanditov B., Tarasconi G., 2006. The KEINS database on academic inventors: Methodology and contents. CESPRI working paper n. 181, Milan.

Markiewicz, K.R., DiMinin, A., 2005. Commercializing the laboratory: faculty patenting and the open science environment. Working Paper, University of California.

Merton, R.K., 1968. The normative structure of science, in: Merton R.K. (Ed.), The sociology of science: theoretical and empirical investigations. Chicago, IL: The University of Chicago Press.

Meyer, M., 2006a. Are patenting scientists the better scholars? An exploratory comparison of inventor-authors with their non-inventing peers in nano-science and technology. Research Policy 35(10), 1646-1662.

Meyer, M., 2006b, Inventor-authors: knowledge integrators or weak links? Scientometrics 68(3), 545-560.

Meyer M., Sinilainen T., Utecht J.T., 2003, Toward hybrid triple helix indicators: A study of university-related patents and a survey of academic inventors. Scientometrics 58(2), 321- 350.

Michel J., Bettels B., 2001, Patent citation analysis. A closer look at the basic input data from patent search reports. Scientometrics 15(1), 185-201.

Murray, F. 2002. Innovation as co-evolution of scientific and technological networks: Exploring tissue engineering. Research Policy 31(8-9), 1389-1403.

Narin, F., Noma E., 1985. Is technology becoming science? Scientometrics 7(3-6), 369-381.

Noyons, E.C.M., Van Raan, A.F.J., Grupp, H., Schmoch, U., 1994. Exploring the science and technology interface – inventor author relations in laser medicine research. Research Policy 23(4), 443-457.

Rosenberg, N., 1998. Chemical engineering as a general purpose technology, in: Helpman E. (Ed.), General purpose technologies and economic growth. Cambridge: MIT Press, 167-192.

Schubert, A., Glänzel, W., Braun, T., 1983. Relative citation rate: A new indicator for measuring the impact of publication, in: Tomov D., Dimitrova, L. (Eds.), Proceedings of the 1st National Conference with International Participation on Scientometrics and Linguistic of the Scientific Text, Varna, 80-81.

Scotchmer, S., 2004. Innovation and incentives, Cambridge, MA: MIT Press.

Stephan, P., Gurmu, S., Sumell, A.J., Black, G., 2006. Who's patenting in the university? Economics of Innovation and New Technology 16(2), 71-99.

Thursby, J.G., Thursby, M.C., 2002. Who is selling the ivory tower? Sources of growth in university licensing. Management Science 48(1), 90-104.

Thursby, M.C., Thursby, J.G., Mukherjee S., 2005. Are there real effects of licensing on academic research? A life cycle view. NBER Working Paper 11497, Cambridge, MA.

Trajtenberg, M., Henderson, R., Jaffe, A.B., 1997. University versus corporate patents: A window on the basicness of invention. *Economics of Innovation and New Technologies* 5(19), 19-50. Van Looy, B., Callaert, J., Debackere K., 2006. Publication and patent behaviour of academic researchers: Conflicting, reinforcing or merely co-existing? Research Policy 35(4), 596-609.