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University patent data

Academic patents as an indicator of useful research? A new approach to measure academic inventiveness

Martin Meyer

Academic patents may be a more accurate measure of inventive output generated by academics than university-owned patents. Using Finnish data, a comparative analysis suggests that number of academic patents is higher not only than the number of university-owned patents but also than patents citing domestic science. Also different linkage intensities could be identified. The second part of the study tries to identify areas for further analysis and introduces some results with respect to concentration of academic inventive activity, academic contributions to national patenting and utilization of patented inventions. Finally, limitations and applicability of the overall approach are discussed.

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KEITH PAVITT (1998) RAISED THE question whether patents reflect the useful research output of universities. His answer was rather skeptical. Based on earlier analyses, Pavitt concluded, university patents give a partial and distorted picture of the contributions university research makes to technical change:

> Patenting by universities is not a potentially useful measure of university research performance, because there is so little of it, and because it offers a very restricted and distorted picture of the contributions of university research to practical applications. This is because, in general, university research feeds into invention and innovation, and is not a substitute for it. This is why measures of the contributions of university research to patenting activity is a more fruitful line of enquiry. (Pavitt, cited after working paper, pages 10-11)

University research feeds into inventions or innovations by generating a (scientific) body of understanding that may prove relevant in technological development or in educating scientists and engineers who then may move to industry. One conclusion with respect to analyzing patent data in this context was that tracking references of scientific outputs that are listed in patents by way of patent citation analysis is a more appropriate way of tracking useful contributions of university research.

This paper compares patent citation analysis with a different approach of tracking patents that are

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related to universities by their inventors rather than university ownership. For this purpose, data on Finnish academic and university-owned patents as well as patent citations of Finnish scientific papers in Finnish publications are presented. The findings confirm Pavitt's skepticism about university-owned patents but also indicate that academic patents can be an alternative and less distorted measure of university researchers' contribution to technological development than patents owned by universities. In the particular case of Finland, academic patents appear to establish a stronger linkage between university science and technology than even patent citations.

Background

University and academic patents

There are at least two different types of university-related patents — patents that are owned by the university, and patents that were invented by researchers who are employed by universities. While the former are usually referred to as university patents, the latter could be referred to as academic patents. The two types tend to overlap but not necessarily. While it seems reasonably safe to assume that university researchers were among the inventors of university(-owned) patents, the university (or its transfer organization) may not necessarily own academic patents.

The extent to which these types of questions occur depends on the prevailing transfer mode. Figure 1 presents an overview of three possible technology transfer modes in universities: Technology transfer in the *direct* mode takes place between academic inventor and an interested third party. No technology transfer organization at the university is involved substantially. In the *mediated* mode, the technology transfer office is involved in utilizing the research since the university or related organizations own the intellectual property rights (IPR). Finally, there is the *intermediary* mode in which universities do not own the IPR to the invention but the transfer office is involved as a facilitator of transfer assuming the role of an 'innovation agent'.

Country differences

The extent to which the outlined transfer modes are practised varies from country to country. There are differences within Europe and between European countries and the USA. The Organization for Economic Cooperation and Development is currently surveying the different regulatory regimes of intellectual property rights in universities. Considerable differences can be found (see e.g. OECD, 2002). In some Nordic countries, for instance, university researchers still have the right to utilize their inventions themselves while in a number of other European countries universities own all the rights to all their employees' inventions. In the USA, universities can patent and exploit research results of federally funded projects. Therefore, it is generally acknowledged that most university-based patents in the United States of America are taken out by universities. In many instances the analyst can track patent data by tracing universities in the assignee categories.

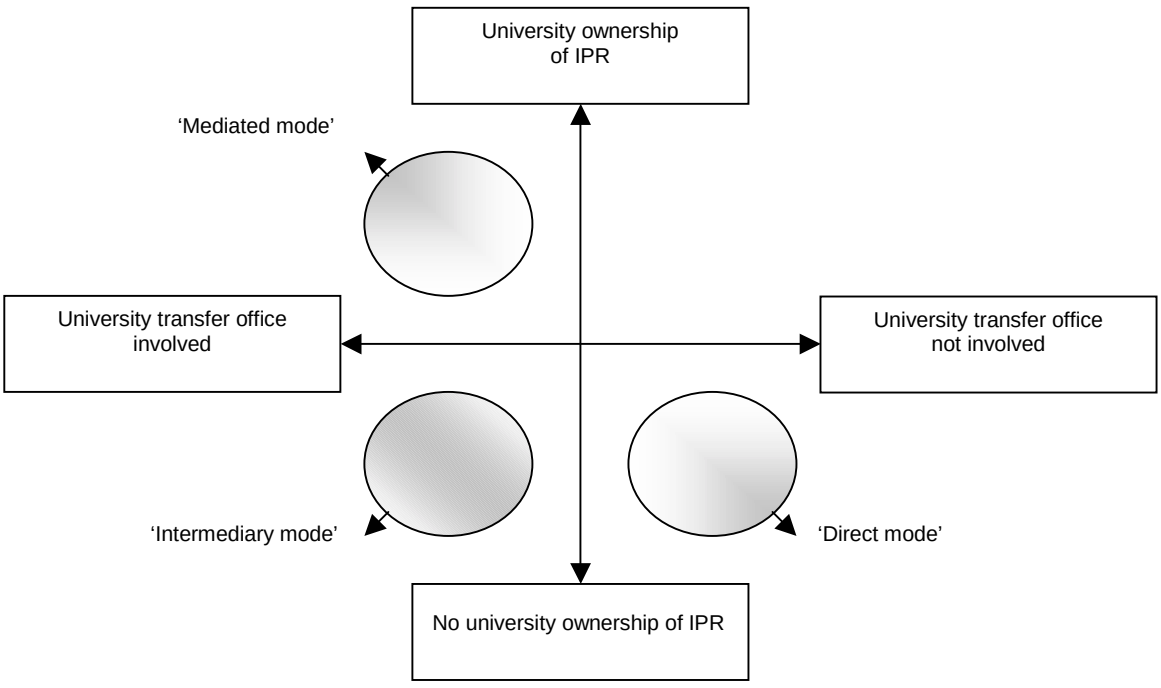

Figure 1. Different technology transfer modes

Yet less 'mediated' patent practices — in which the inventor remains the owner of the patent, or a company that (partly) sponsored the research is the assignee — are difficult to trace. In these instances, the academic researcher is usually listed as a private person only in the inventor section of the patent document. Only their private address is given, which does not allow the analyst to trace any university relation directly.

This is a challenge especially for analyzing university-related, academic inventions in countries in which university faculties still have the privilege of owning the rights to their inventions. However, recent research indicates that the share of non-university assignees or owners of academic patents is not negligible (Du Plessis and Meyer, 2003).

Purpose and research issues

Identifying useful output of university research has become a relevant topic in many countries. Some science policy analysts speak of the emergence of the 'entrepreneurial university' in which the commercialization of knowledge has become the third mission next to teaching and research. It is generally acknowledged that the science system has to contribute to economic growth. Over the past few years more attention has been dedicated to the accountability of research. In this general context, demonstrating usefulness of university research is an area that has aroused some interest and received considerable attention.

The focus of this article is on tracing direct, or more immediate, contributions of university researchers. This is not to say that other contributions are not important. Cultivating human resources through training scientists and engineers can be seen as one of the key contributions of science to a country's innovation system. Also, this paper does not contest the importance of basic research as useful output of university research, nor does it suggest that publications in scientific journals were not the major category of explicit knowledge generated in universities.

The purpose of this paper is to illustrate that patents *can* be an appropriate, if partial, indicator of useful university research. The paper will introduce a methodology that allows analysts to identify a significantly higher number of patents than is possible by just tracking university-owned patents. It thereby illustrates that there is far more patent-directed inventive activity in universities than one might have assumed by looking at university-owned patents exclusively. In that way this research contributes to better measuring inventiveness of university researchers and identifying more direct or immediate contributions of university research than increasing the body of general knowledge, which undoubtedly has a considerable, if hard-to-measure, long-term impact on technical change.

Method and data

Data sources

This study will compare three different ways of relating patent output to science:

1. tracing patents owned by universities or public organizations funding university research;
2. tracking patents citing domestic papers indexed in the SCI;
3. identifying patents in which one of the inventors is an academic researcher.

Consequently, this research draws on three data sources: a patent database, a publication database, and a database compiled on the basis of personnel registries. The patent database comprises all Finnish-invented or assigned US patents granted between 1986 and 2000. The publication database contains 61,000 Finnish SCI papers for the period 1986-1999.[1] Personnel registry data was collected from Finnish universities for the most recent year available (typically 1999) and 1997, which is the year in which most patent filings occurred in our database. This type of data was collected from all university-rank organizations with technical and natural science faculties. Universities that were dedicated exclusively to arts, humanities and social sciences were excluded from the analysis. Also business schools were excluded since tests indicated hardly any inventive activity of their researchers in the US patent system.

Identifying academic patents

While tracking university-owned patents is a comparatively effortless exercise,[2] identifying patents with university researchers as inventors is a more challenging task. As the affiliation of inventors is not directly visible in the patent document, a matching procedure between inventor names and researcher names listed in the personnel registries was carried out to identify identical researcher/name pairs. The matching procedure was based on first and family names of inventors and researchers who were employed by universities in the years 1997 and 1999/2000. Lists of inventor/researcher name pairs are the result of the bibliometric matching procedure. As these pairs could link patents to individuals

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who happen to have the same name as the inventor but are not related to the patent in any other way, a manual validation procedure is necessary.[3] The validation procedure identified links based on homonyms only, which were removed subsequently. For this purpose, we tried to contact all potential inventors in our lists by telephone, email or fax. The contacted individuals had to confirm that they were (one of) the inventor(s) before a patent was considered to be 'university-related'.

Identifying patent citations

Not unlike linking academics as inventors to patents, identifying patent citations requires matching certain data sets. For the purpose of this research, search keys were defined for each record in the Finnish publication database (journal, volume, publication year, beginning and end pages). The search keys for each publication were traced in the '*other references*' section of the patent documents. The author draws on data kindly provided by Olle Persson of Inforsk at Umeå University.

Results

This section first presents the patents that are identified by examining the universities or their transfer organizations or public sources of funding as the owner of the patent. Then a comparison with patent citations follows. After this, patented inventions will be introduced that were found by tracing university researchers listed as inventors in patents.

Patents owned by the universities

The search for university-owned patents confirmed the results Pavitt (1998) reported for the UK. A search in the USPTO online database identified 36 patents that were owned by the universities,[4] their transfer companies (Aboatech, Oulutech, Licentia, Tamlink, Helsinki University Licensing) or public R&D-related funding institutions (such as SITRA, Tekes, the Academy of Finland). This example illustrates why scholars have criticized university-owned patents as a weak and distorted indicator of science-technology linkage or useful academic research. However, the number of science-related patents increases if one tracks patents that cite scientific papers and differs even more if one defines university patents as patents that were invented by at least one university researcher.

Patent citation analysis

In his 1998 paper, Keith Pavitt mentioned that patent citation analysis would be a less distorting indicator of science-technology linkage than university-owned patents are. He referred to a range of studies pioneered by Francis Narin. Indeed, a search for Finnish scientific articles that are cited in Finnish US patents leads to a greater number of science-related patents. All in all, 282 (of 61,000) Finnish SCI papers were cited by 99 (of 6,800) Finnish US patents in the non-patent references section. This number is higher than the number of university-owned patents we found.

Where they occurred, citations linked the scientific domains of molecular biology, medical and cardiovascular research with technological areas of biotechnology and pharmaceuticals/cosmetics. The main field of chemicals/pharmaceuticals accounts for 213 of the 280 classified citations (see Table 1). Instruments-related patents contain 41 patent citations, mostly in the areas of analysis, measurement and control. These results are not surprising since all fields of technology that have citation links to the scientific journal literature are said to be highly science-related. Surprisingly, an area of high technology, such as telecommunications, appears to have only relatively weak connections with the journal literature. This raises the question whether this area is really not related to the science base at all or whether one can track this connection in a different way.

Patented inventions by university researchers

Previous research also explored other ways of linking science and technology. For instance, Coward and Franklin (1989) investigated the science-technology interface by combining two sets of quantitative data by defining the 'science universe', defining the 'technology universe' and identifying the 'intersect'. Three possible types of patent-paper intersections were investigated:

1. individual name matches between patent inventors and paper authors;
2. institutional name matches between patent assignees and organizations listed as affiliations by authors; and
3. examiner-cited literature references found in patents and base literature papers from the model.

The authors concluded that author-inventor name matches appear to be the best approach.

Inspired by this approach and similar studies,[5] we tried to devise a matching scheme that relates inventor names to the names of researchers. Linking patents to inventors who are scientists seems to be a more appropriate way of tracing inventive activity in universities than tracking patents that are owned by universities. Even in countries where universities own the rights to researchers' inventions, universities may have transferred the ownership of the patent to a company. Therefore, it seems more reasonable to identify patents that are invented by researchers working in academe than using patents assigned to (owned by) universities if one wants to track useful research output of universities.[6]

Table 1. Patent citations by technological sector

Technological sector Main class	Technological sector Sub-class	Patent citations
Chemicals – Pharmaceuticals	Biotechology	105
	Organic, fine chemistry	42
	Pharmaceuticals, cosmetics	62
	Other*	4
	Sub-total	*213*
Electricity – Electronics	ICT**	4
	Electrical Devices – EE	2
	Sub-total	*6*
Instruments	Analysis, measurement, control	32
	Medical Engineering	9
	Sub-total	*41*
Process engineering	Chem., petrol, basic materials chemistry	10
	Material processes	5
	Other ***	5
	Sub-total	*20*
Grand total		**280**

Key: *Macromolecular chemistry, polymers; materials, metallurgy)
** Incl. audiovisual, information, telecom technology
*** Incl. environment, pollution, general technological processes, thermal processes and apparatus, surfaces, coating
Note: Patent data drawn from a database of Finnish US patents granted 1986–2000, publication data drawn on a database covering Finnish SCI papers in the period 1986–1999; source: O Persson / Inforsk

Applying such an approach results in a *substantially higher* number of patents that can be related to universities than does identifying patents owned by universities and their funding agencies or identifying patents that cite (domestic) science. A total of 530 US patents were related to Finnish university researchers in this manner. Compared to the total number of Finnish utility patents in our database, this amounts to a share of at least 8%. The total inventive activity of university researchers may be even higher since

- we had only two years of personnel registries (1997 and 1999/2000) available for analysis;
- the patent database encompassed patent grants issued between 1986 and 2000; and
- there are limitations in identifying patents of researchers who may have changed their names because of marriage or divorce.[7]

A closer examination of the 530 university-related patents allows us to track links between university researchers and fields of technology (see Table 2 for details). Interestingly, telecommunications and instrument-related patents have the largest shares, with more than 12%. Pharmaceuticals/cosmetics and biotechnology account for about 9–10% of the university-related patents. The next largest sector is organic, fine chemistry.

A comparison with the distribution of technological sectors based on a count of patent citations (as presented in the previous section, see Table 1) seems interesting. Around 76% of the patent citations were linked to the area of pharmaceuticals and chemistry. Biotechnology was the largest technological subsector in this area, accounting for almost 38% of all patent citations, followed by pharmaceuticals and cosmetics with about 22%. Instruments are the largest sector outside the life-science/chemicals cluster with a share of more than 11% of the patent citations. Information and communication technologies (ICT), however, account for less than 2% of all patent citations.

Table 2. University-related patents by technological sector

Technological area	Patents	%
Telecommunications	68	12.8%
Analysis, measurement, control	66	12.5%
Pharmaceuticals, cosmetics	51	9.6%
Biotechnology	50	9.4%
Organic, fine chemistry	43	8.1%
Medical engineering	37	7.0%
Material processing	32	6.0%
Electrical devices – electrical engineering	23	4.3%
Machine tools	20	3.8%
Macromolecular chemistry, polymers	17	3.2%
Handling, printing	14	2.6%
Surfaces, coating	14	2.6%
Information technology	12	2.3%
Materials, metallurgy	12	2.3%
Chemical industry and petrol industry, basic materials chemistry	11	2.1%
Other (10 patents or fewer)	60	11.3%
Total	**530**	**100%**

The analysis of university-related patents differs to some extent from this development. While there is also a focus on pharmaceuticals and chemicals as well as instrumentation, it is less strong than in the case of patent citations. ICT featured much more prominently, which may be closer to the distribution one might have expected in light of the strong specialization of the Finnish economy in telecommunication technologies.

At this stage, we can conclude that academic patents, if defined as patents invented by at least one university researcher, seem to be an alternative measure to patent citations as an indicator of science-technology linkage. In our Finnish case study, they connect more patents to scientists than either the conventional approaches of tracking university-owned patents or patent citations of scientific literature. Having said this, one must bear in mind that we studied only the domestic science-technology connection. Citation data was available only for Finnish scientific papers cited in Finnish patents. More patent citation connection may be found if one could include the entire SCI publications in the citation analysis. However, other studies seem to suggest that ICT would not necessarily have played a much more prominent role than in the small patent citation analysis we presented here, at least not in comparison to biotechnology and other pharmaceuticals-related technologies (see e.g. Verbeek *et al*, 2001).

We believe that the share of university-related patents in total national patenting is sufficiently high to consider them an indicator of useful university-related research output that is worthwhile to be explored further. The following section will present some more detailed findings of how one could analyze university-related patents.

Suggestions for analyzing academic patents

While the previous section presented a methodology that allows analysts to identify a number of academic patents that is sufficiently large to be analyzed statistically, this section will explore what type of information the patent data could reveal with respect to inventiveness in universities.

Academic patents, if defined as patents invented by at least one university researcher, seem to be an alternative measure to patent citations as an indicator of science-technology linkage

Key actors

One point that was stressed in the first part of this paper is that patents may be viewed as useful output of university research but they are not the primary result of academic research. This was one of the key points Pavitt (1998) made with respect to university patents. Therefore, identifying who are the actors who engage in inventive activities should be one of the first tasks an analysis of academic patents should address.

Such a question can be approached in different ways: first at the organizational level, then at the level of individuals. Capitalizing knowledge generated in the university system has become an issue in most European universities only relatively late. The emergence of the entrepreneurial university is a relatively recent phenomenon in Europe (see, e.g., Etzkowitz, 2002). Before commercializing research results in the USA became a widely accepted third mission in US universities, most inventions could be related to a small number of universities. Therefore, one could assume that most of the inventive activity is concentrated in a small number of universities.

The data confirms this assumption. Inventive activity among Finnish university researchers appears to be concentrated on key institutions. As shown in Figure 2, university-associated patents are concentrated in a very small number of institutions. Almost half of the 530 patents can be related to researchers working in only two of all 12 universities. About three-quarters are associated with researchers in four universities.

In terms of individuals who can be associated with inventive activity, a similar pattern should be expected. This should be so in particular because of the legal situation in Finnish universities. Researchers own all the rights to their inventions and are free

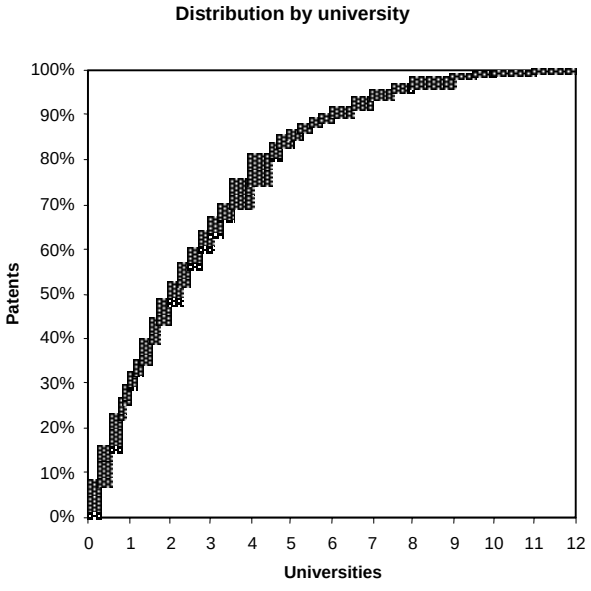

Figure 2. Academic patents in Finnish universities
Note: The figure shows the *accumulated* percentage of *universities*

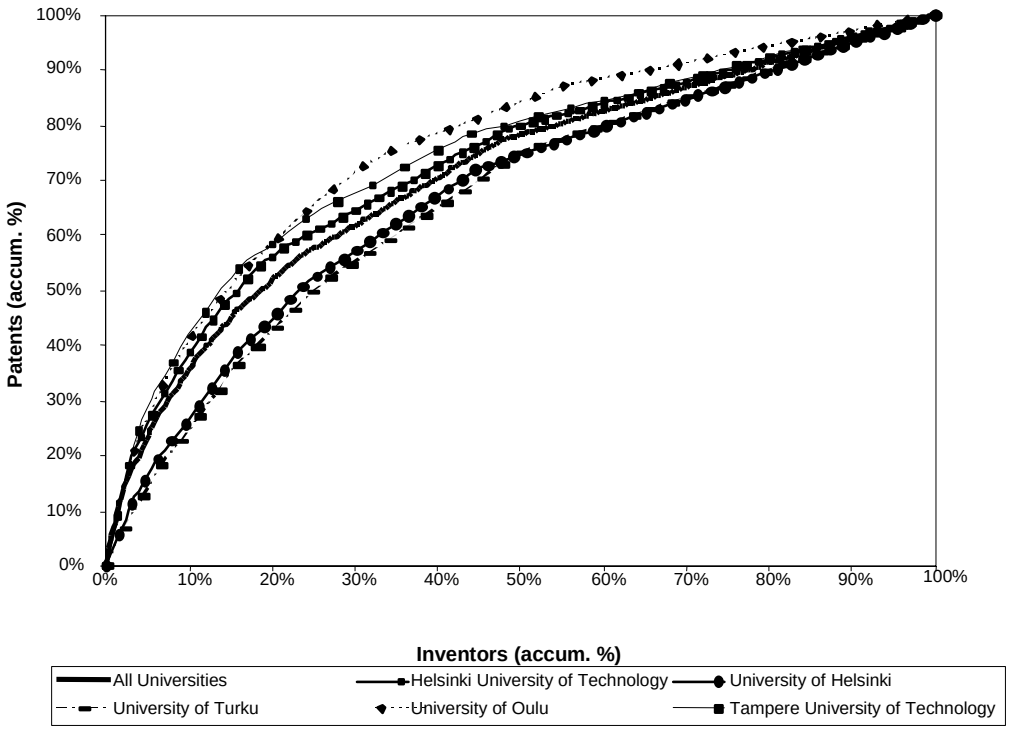

Figure 3. Concentration of patents on key inventors at selected Finnish universities

to handle patenting and further commercialization as they wish. In most areas patents play only a secondary role in evaluating the individual researcher or the research unit. Hence, it seems reasonable to assume that academic patents are concentrated on a small number of academic inventors.

The data also confirms this suggestion. Key inventors seem to account for most of university-related inventiveness. Figure 3 shows the concentration of patents for a selected number of Finnish universities. The *x*-axis describes the accumulated percentage of inventors (in descending order), while the *y*-axis gives the accumulated percentage of patents. This way one can see what percentage of inventors invented a certain percentage of patents. For instance, for all the universities that are included in this study, one can say that the most active 10% of the inventors in Finnish universities account for more than a third of the university-related patents. About 20% of the inventors accounted for half of the university-related patents.

However, there are considerable differences between the universities. For instance, while the top 10% of the inventors at Oulu University account for more than 40% of the patents associated with this university, the top 10% of inventors from Turku University account for a quarter of the patents.

Contributions to national patenting

Patents are not the primary output of universities but what is the impact of academic patents on the national economy? Is it possible to define areas in which universities contribute over-proportionally to national patenting? One way of addressing these issues is by relating the degree to which academic patents are specialized in a given field to the share the field has in terms of all national patenting. Figure 4 presents the results of this analysis.

The *x*-axis depicts the share of the university-related patents in total Finnish patenting in each of the 30 technological areas, divided by the aggregate share of university-related patents in all the fields. In other words, the relative importance of academic patents in each field is illustrated (in a national context). The *y*-axis shows the share of each technological area in relation to all national patents. This indicates the importance of each area with respect to a country's patenting.

Four sectors can be distinguished:

- The *core* contributions describe technological fields in which university-related patents are considerably specialized and that account for a relatively large share of all university-related patenting activity.
- *Background* contributions are made in areas where overall patenting activity is comparably high but university-related inventiveness is not as strong.
- When there is little patenting, university researchers can make *niche* contributions. In this instance they are relatively specialized.[8]
- *Marginal* contributions are made in those technologies where both overall and university-related activities are relatively low.

Biotechnology, pharmaceuticals/cosmetics, semiconductors and organic chemistry are areas in which academic patents make *niche* contributions. *Background* contributions are made in medical engineering, analysis/measurement/control, macromolecular

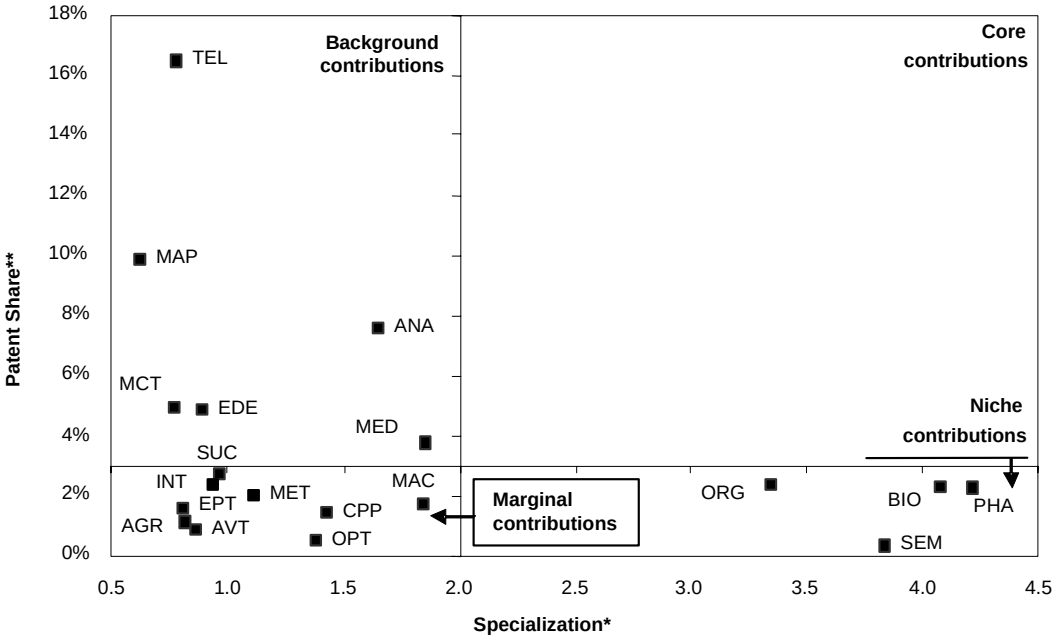

Figure 4. Revealed inventive contributions to national patenting
Key: * Share of field among academic patents/share of field among all Finnish patents
** Share of field among all Finnish patents
For a key to technological areas, see the Appendix.

chemistry/polymers, telecommunications, electrical devices/electrical engineering, materials processing and machine tools. *Marginal* contributions can be associated with optics, surfaces engineering, chemical and petrol industry/basic materials chemistry, materials and metallurgy, information technology, audiovisual technology, agriculture/food and environment/pollution. There is no area in which academic patents appear to make *critical* contributions in the national context.

This finding and the fact that telecommunications patents do not appear to make a 'critical contribution' appears somewhat counter-intuitive and requires more detailed interpretation. Pharmaceuticals/ cosmetics and biotechnology are defined as areas in which university researchers exhibit a relatively high degree of inventive activity yet appear to limit themselves to niche contributions only. However, compared to other technological areas, biotechnology and pharmaceuticals do not (yet?) have the same weight as other fields that are more established in the Finnish economy. Here one must bear in mind the time lag that is associated with US patents used in this analysis. The examination of life-science patents can take between five and seven years, which is longer than the patent examination lasts in other fields.

Finland has the reputation of being one of the most ICT-intensive economies (see e.g. Kuusisto and Meyer, 2002). Therefore, the categorization of telecommunications as an area in which academic patents have the role of background contributions seems problematic, especially since the previous section indicated that telecommunications is the area with the most academic patents. In this context one should bear in mind that the share of telecommunications among all Finnish patents is higher than 16% while this area accounts for less than 13% of all academic patents. In other words, academic patents are related to the telecommunications field but the Finnish economy as a whole is even more specialized in this area than university patents. It is important to bear in mind that this analysis is made in a *national* context. If one were to compare specializations across countries on an international basis, the results would most probably be different.

Finally, one should remember when interpreting this type of data that only direct inventive output of university researchers was tracked. Several authors rightly point to the many and multifaceted other contributions science and scientists make to technical development (see e.g. Brooks, 1994; Salter and Martin, 2001).

Utilization of academic patents

Patent data as we retrieved it can help identify key institutions and key individuals as well as the extent to which academics contribute to inventiveness in different technological areas. However, another important question especially since the advent of notions, such as the 'entrepreneurial university' (e.g.

Patent data can help identify key institutions and key individuals as well as the extent to which academics contribute to inventiveness in different technological areas

Table 3. Top three assignees of academic patents (by university)

University	Top 3 assignee organizations (in alphabetical order)
A	Ahlstrom – Kone – Wartsila
B	University Licensing – Orion – Soundek
C	Fortum – Instrumentarium – Nokia
D	Nokia – Orion – Valio
E	Nokia – Orion – Valmet
F	Leiras – Orion – Wallac
G	Biocon – Bionx Implants – Kone
All universities	**Nokia – Orion – Valmet**

Etzkowitz, 2002; Etzkowitz *et al*, 2000), relates to the extent to which academic *inventiveness* translates into academic *entrepreneurship*. Case studies indicated that academics may have the capacity to act in an entrepreneurial style (certainly when securing research funding) but may have trouble becoming entrepreneurs in a commercial environment (e.g. Meyer, 2003). In which way can an examination of academic patents further our understanding of commercialization processes?

Tracking assignees of academic patents

Following academic patents to their owners should give the analyst an idea about the extent to which academic inventions are utilized in start-up companies. A look at the assignee data, however, indicates that *most of the university-related patents appear to be assigned to large companies*. Table 3 lists the most frequent assignee firms for a selection of Finnish universities as well as for all university-related patents. Mostly large firms are engaged in patent-based collaboration with university researchers. Start-up companies are only ranking among the best three in very few instances. A university licensing company is also strong in one instance. However, large firms appear to dominate the picture otherwise. At the aggregate level for all universities, Nokia is the top assignee with 10.7% of the total amount of patents. Orion Corporation follows with 6.8% of all patents, closely followed by Valmet with 6.6%. The top three assignees account for a share of 24.1% compared to all patents.

Tracing 'unassigned' patents

Another approach toward tracing the exploitation of academic inventions (or the lack of it) is to track 'unassigned' patents; that is, those patents for which no assignee, or owner, is listed. In many but not all cases,9 the analyst can usually assume that the patent belongs to the inventors.

There are considerable variations between the universities. For instance, there are a small number of universities with a few patents where all of them were assigned to a company or other organization. In other cases, however, a considerable number of patents are still owned by individual inventors. In one instance, 45.5% of all academic patents were not directly owned by a company. In three other cases, the rate was between a quarter to a third of all patents related to the respective universities. Figure 5 illustrates for a selection of Finnish universities the extent to which academic patents are 'unassigned'.

While the data indicates differences between university and to some extent fields (the two universities with the highest rate of unassigned patents are specialized in the life sciences), interpreting the data remains a challenge. Can one simply assume that such a patent is owned by individual researchers who utilize it? If so, what could one say about the mode of utilization? Or, could one not just as well interpret the lack of a corporate owner as a lack of economic use?

The patent data here is ambiguous. It shows where individuals own the patents and a corporate user of the inventions is not immediately visible. However, this does not mean individual inventors have not licensed the patent to one or several companies for further utilization, or use it in their own, private firm. Here, one would need to go beyond a pure analysis of patent data and follow up inventions through a survey approach.

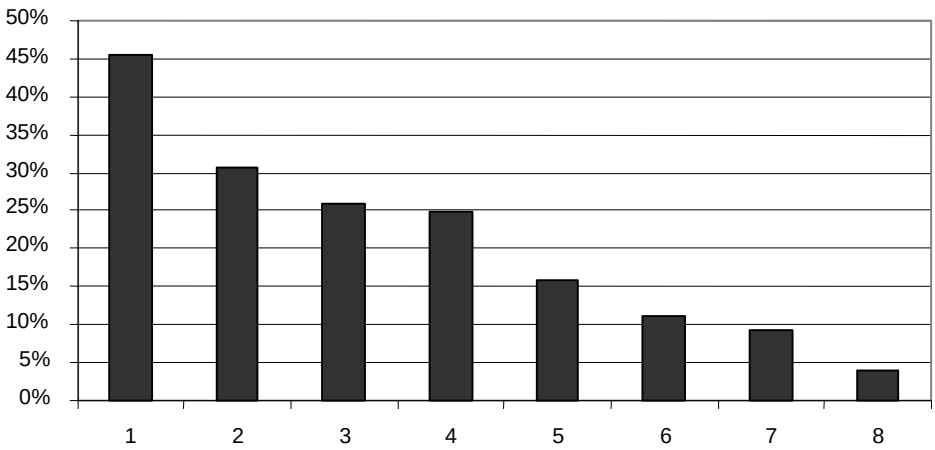

Figure 5. Share of 'unassigned' patents for selected Finnish universities

Discussion and conclusions

This paper started out with Keith Pavitt's rather skeptical evaluation of patents as an indicator of useful research output of universities. Using data on the Finnish innovation system, it confirmed Pavitt's view that patents *owned* by universities are not a solid indicator of the inventive output of academic researchers. However, we believe that we have illustrated that patents *invented* by university researchers are indeed a reasonable indicator of technological work by university scientists. This is illustrated in a significantly higher number of university-invented than university-owned patents.

However, this study does not question that publications are main explicit output and trained scientists and engineers more important contributions of universities to technical change. This research merely demonstrates that university researchers are involved in more patented inventions than a look at patent statistics may suggest. Also one should bear in mind that this study was carried out in a country where the university or funding authorities do not own the rights to inventions by academic researchers.

A comparison with results of a limited analysis of patent citations referring to domestic scientific literature seems to suggest that a stronger link is established between university research and industry by inventor-researcher pairs than by way of patent citation analysis. However, the patent citation analysis presented here suffered from a lack of access to non-Finnish SCI records.

Telecommunications does play a considerable role in terms of academic patents but hardly any in terms of the patent citation connection. This raises the question whether different methodologies measure the same or different types of science-technology interaction.

This paper introduced a new approach that allows the analyst to identify a much larger number of patents in whose inventions university researchers were involved than by simply tracking universities as owners. This helps analysts to get a better idea of where academics engage in applied technological work. In this sense, the coverage of academic inventive activity has been improved. This is a relevant finding, especially for countries in which university researchers own the rights to their invention.

Future research needs to address the question to what extent this type of approach can be applied also to countries in which universities principally own the rights to their inventions. Preliminary findings seem to indicate that this approach can reveal an additional number of patents that resulted from university/industry collaboration.[10]

Another question that will need to be addressed is to what extent this approach is transferable to countries that are larger than Finland. Finland is a small country with no more than 20 university-rank institutions. A manual validation process was central to the methodology applied in this research. Analysts who choose to study these types of relations in larger countries will face practical problems in dealing with a large number of inventor-researcher name pairs.

The Finnish case study, however, points to the strong concentration of inventive academic activity on organizational and individual key actors. Future research could investigate to what extent this pattern occurs in other countries. An alternative approach would be to see to what extent the results of this study concur with a study that matches inventor with author names retrieved from databases, such as the SCI. Here, other challenges are to be faced, such as a clear assignment of addresses and author names.

Finally, the results presented with respect to utilization of academic patents in this paper raise the questions to what extent it is really the academic entrepreneur who functions as an instrument of technology transfer or to what extent the utilization of academic inventions takes place through different, more established channels of university/industry collaboration. Here, patent information alone is not sufficient. A combination with a survey methodology that allows the researcher to inquire about type and place of a patent's use would be helpful.

Appendix: Technological areas

PHA	Pharmaceuticals, cosmetics	SUC	Surfaces, coating	THE	Thermal processes and apparatus
BIO	Biotechnology	INT	Information technology	HAP	Handling, printing
SEM	Semiconductors	EDE	Electrical devices – electrical engineering	MEC	Mechanical elements
ORG	Organic, fine chemistry			GEN	General technological processes
MED	Medical engineering	AVT	Audiovisual technology	AFM	Agricultural and food machinery and apparatus
MAC	Macromolecular chemistry, polymers	AGR	Agriculture, food		
ANA	Analysis, measurement, control	EPT	Engines, pumps, turbines	NUC	Nuclear engineering
CPP	Chemical industry and petrol industry, basic materials chemistry	TEL	Telecommunications	TRA	Transport
		MCT	Machine tools	CON	Consumer goods and equipment
OPT	Optics	MAP	Material processing	CIV	Civil engineering, building, mining
MET	Materials, metallurgy	ENV	Environment, pollution	SPW	Space technology, weapons

Note: The technological areas are based on a classification originally developed by the Fraunhofer Institute in Karlsruhe and the French OST in collaboration with INPI. The scheme is based on the International Patent Classification and provides a more aggregated view of patenting by distinguishing thirty technological sectors. For more detailed information on how the subclasses of the IPC are categorized in technological sectors, see OECD (1994), The measurement of scientific and technological activities using patent data as science and technology indicators. Patent Manual (1994) (OECD, Paris) OCDE/GD(94)114.

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Notes

1. The database was compiled by Persson and colleagues (Persson *et al*, 2000).
2. The assignee field in patent documents should point to a university.
3. In this context, personnel register information of the universities has proven to be most helpful. Finnish universities provided us with this type of information which included in many instances also office contact details of individual researchers.
4. We searched initially for yliopisto and korkea$ as in 'korkeakoulu' in the assignee field to identify universities and institutes of technology as well as univ$ with restriction to Finland as assignee country. In addition the names of technology transfer companies and funding organizations of university research were searched separately. As our focus is on university researchers' inventive activity, we did not include the intermediary, non-university research sector in our analysis. The sector is relatively large. The Technical Research Center of Finland (VTT) employs more than 3,000 people, has a turnover of about 200 million euros and over 5,000 customers. VTT owns about 60 US patents.
5. For instance, see Meyer-Krahmer and Schmoch (1998), Noyons *et al* (1994), Schild (no date).
6. Unlike the previous studies we did not track author-inventor pairs using the SCI. A reason for choosing personnel records was that SCI records do not provide sufficient address information for validation procedures.
7. A detailed account of the methodology can be found in Meyer *et al* (2003).
8. The distinction between core and niche contributions on the one hand and background/marginal contributions on the other is made somewhat arbitrary. The cut-off point is a specialization value of two, meaning that the share of an area is twice as high for academic patents than for all Finnish patents. This value was chosen to separate highly specialized areas of academic patents from areas of moderate or under-specialization. A specialization index = 1 means that the share of academic patents in a given technological areas corresponds to the overall share of the field in comparison with all Finnish patents. A specialization >1 means a stronger specialization on the side of academic patents than the field's share of all Finnish shares would suggest. The index indicates the extent to which the specialization of university patents exceeds the overall specialization of the country. A specialization in a given area <1 indicates that the university researchers' inventions are less frequent in this area than at the level of the entire patenting economy.
9. In an ongoing research project on 'unassigned' patents we could track some patents that were not owned by their inventors but by their company; yet the patents were 'unassigned'.
10. Unpublished results by Du Plessis and Meyer (2003) indicate for the Belgian region of Flanders that applying such an approach can reveal a considerable number of patents that are not owned by the universities but in which university researchers are listed as inventors.

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