

**University Inventors and University Patenting Patterns at
Lund University:
*Conceptual- Methodological & Empirical Insights***

Devrim Göktepe¹

CIRCLE

Center for Innovation Research Competence in the Learning Economy
Lund Institute of Technology
devrim.goktepe@circle.lu.se

2007-08-20

Abstract

One of the most interesting indicators to show the change in the socio-economic role of universities in the last several decades has been the use of university patenting. However except some individual studies for European countries (e.g. Finland, Norway, Belgium, Italy, Germany and France) there has been no such a comprehensive data available for Sweden and most other European countries. The main motivation of this paper is therefore to obtain a systematic database on university patenting activities in Sweden. The main method of this research is data-matching between the EPO-patents and Lund University Faculty registers, and manual controls. The methodology of this research underlines the importance of searching for university-patents by the name of university inventors rather their affiliated university. The main findings of this research includes among others, the rate of patenting activity showed a positive trend between the years 1990 and 2004. 458 patents have been filed by Lund University researchers. The total number of inventors is 250. Although the number of large firms is lesser than the SMEs, the former group (e.g. Ericsson, Astra-Zeneca) has applied for a larger number of patents than the total number of patents of SMEs.

¹ The earlier versions of this paper has been presented in DRUID winter (2006) Conference and Technology Transfer Society (2005) Conference. Many thanks go to participants in those conferences. I acknowledge the comments of Martin Meyer, Henry Etzkowitz, Don Siegel, Ed Steinmueller, Maryann Feldman, Jesper Christensen and Elad Harison.

1. Introduction

In today's global world, knowledge, learning and innovation have become strategically important factors that foster competitiveness and economic growth of countries. Globalization, international knowledge exchange and an increasing global competition require a rapid transfer of scientific knowledge and understanding into everyday life. Technological change, the accumulation of knowledge and its spill-over into the production process is considered as the primary engine of economic development in the new growth theories (Romer, 1990, 2002; Grossman and Helpman, 1991). This trend has resulted in the full recognition of the role of knowledge and technology in economic growth. The roles of universities have changed. Universities are not only important organizations for basic research, but they are also expected to contribute to the industrially relevant technologies in modern knowledge-based economies. Consequently, governments throughout the OECD have launched different policy-programs to link universities more closely to industrial innovation and to increase technology transfer from universities to companies (Mowery and Sampat, 2004).

As a consequence of globalization in the most developed countries, there has been a shift from traditional manufacturing industries towards new-knowledge based economic activity. The question where the knowledge comes from and how it is generated remained uncertain despite the fact that universities emerged perhaps as the most crucial component to generate this new knowledge among others like private sector, research institutes etc. (Audretsch et al. 2005:59). In the past few decades, universities have therefore witnessed substantial changes in terms of research objectives and funding sources. They have become more proactive in their efforts to commercialize scientific discoveries (e.g., Jaffe and Lerner, 2001; Jensen and Thursby, 2001; Thursby and Thursby, 2002; Di Gregorio and Shane, 2003).

While universities have for long served as sources of knowledge, it has been argued that their relations with industry have intensified in the recent years. Stylized facts behind this intensification are: *(i) the development of new, high-opportunity technology platforms e.g. computer science, molecular biology, and material science; (ii) the more general growing scientific and technical content of all types of industrial production; (iii) the need for new sources of academic research funding created by budgetary stringency; (Bercovitz and Feldman, 2005:175) (iv) and the prominence of government policies aimed at raising the economic returns of publicly funded research by stimulating university industry technology transfer (Geuna, 2001:10).*

The general decline in public funding was partly compensated for by an increase in funding from non-profit organizations and by tighter relationships between university and industry. Overall, university researchers and university research centres are now clearly being encouraged to embark upon collaborations with private companies (Geuna, 2001:10). Universities are further suggested to get involved in technology transfer (patenting, licensing and spin-off company formation) in order to continue their missions and to retain their autonomy as a way of controlling their own destiny (Clark, 1998).

University Industry Technology Transfer (UITT hereafter) results from interactions between various actors and organizations. Key actors include: universities, researchers, private or public companies, technology transfer agencies, venture capitalists, financiers, and governments. The process of university patenting includes initiation of research projects, achievement of research results (e.g. inventions and invention disclosures to TTO) evaluation for patentability, patent applications and attempts to transfer to industry (i.e. license patent or initiate a new venture based on patent). In this understanding of the UITT process, each actor i.e. faculty, research groups,

TTO staff and firms play different and ever changing roles (Markman et al. 2005, Feldman and Bercovitz 2005, Lundqvist 2003, Large et al. 1995-2000).

There is a growing literature on university industry relations in general. The field has been explored from different theoretical and conceptual angles (i.e. systems of innovation, triple helix, innovation networks, academic entrepreneurship, firm formation and so forth). However there are not enough theoretical and empirical studies on the roles of university scientists per se. This is in fact due to the novelty, complexity and difficulties in capturing the roles of individuals in social sciences in general. In spite of the large amount of research on university industry relations, university scientists have been relatively neglected in the university industry relations research. The aim of this study is to understand *who* are involved in patenting and *what is the rate and patterns of university* patenting activities among scientists at a large research intensive university in Sweden. Rather than focusing on what universities do, it instead focuses on what university scientists do. Thus the main findings are about the commercialization of university research results are based on the actual activities of university inventors.

Interaction between researchers working in private firms and those working in publicly financed institutes such as universities is seen as particularly important because it may provide unique competitive advantages (e.g., associated with specific competencies of high-quality universities). The European Commission (2003) lists this as one of the six priorities for European universities in the immediate future, and concludes that it is vital that knowledge flows from universities into business and society. Subsequently, the two main technology transfer mechanisms i.e. patenting, licensing, and start-up company formation have been articulated as the most popular policy tool in the last two decades. This policy tool increased the debates over the role of intellectual property rights in the process of public-private knowledge transfer.

It is generally argued that with the introduction of the so-called Bayh-Dole act, U.S. universities got the right to patent discoveries resulting from federally funded research. Partly due to the passage of Bayh-Dole Act, university patenting in the US has increased substantially (Mowery et al. 2005). In addition, some success stories from US universities have induced European policy makers to also consider a Bayh-Dole-like legislation (OECD, 2003). This argument is made against a background of, often anecdotal, empirical evidence that European universities are not very active in patenting and far behind in the commercialization of university research results compared to the US. The US is believed to outperform Europe on the commercialization of university research results. This phenomenon is even named the *European Paradox*.

The aim of paper is not to provide a final answer to the question whether Europe needs a patent legislation similar to the Bayh-Dole Act or not. The aim is rather to present alternative definitions and methodological tools that may better suited to the European context. In this way this study provides the background information for further theoretical, empirical research.

The first objective of this paper is to construct a database by exploring the university research results in the forms of patents at Lund University.² In order to be very specific and sufficiently detailed for a meaningful analysis patenting activities at the Engineering Faculty (LTH), Natural Sciences (NS) and Medical Faculty (MF) are compiled into a database called Lund University Patent Database. This database makes the investigation of the main argument, i.e. lack of micro

² In Sweden, the law of University Teacher's Privilege (UTP, Lärarundantaget/ individual ownership of patents) exists since 1949. UTP is a common practice at Swedish Universities. This law implies that university employees own one hundred percent of his/her research results conducted at the university where s/he is employed. Therefore in Sweden while non-university public organizations retain the ownership of intellectual property, in the case of colleges and universities employees have the right of ownership in the absence of another contract. (Goktepe, 2004:37-38)

level research on university inventors, possible. It provides the basic information and profiles of university inventors.

This Chapter is organized as follows. After this introduction, a brief overview of the use of patents in university industry technology transfer is discussed under three themes. Section 3 reviews the methodology and the findings of the previous empirical work on university patents for some European universities. Section 4 describes the data collection and the construction of the Lund University Patent Database (LUP database hereafter). Section 5 presents the empirical findings. The empirical analyses are organized under three questions. First, it describes the basic characteristics of patenting patterns at LU. Second, it discusses the characteristics of inventors and finally it presents the applicants of patents. Section 6 summarizes the main findings and sketches the future work.³

2. Patents & University Industry Technology Transfer

2.1 Academic Side of the Coin: “who are the inventors?”

Most of the studies have focused on the organizational and institutional aspects or the outcomes of patenting. Such focuses preclude the identification of factors related to inventors.⁴ The literature is full of examples where the individuals are forgotten. For instance after the initial discovery of the basic technique for recombinant DNA, from Stanford University and University of California, San Francisco, or the discovery of enhanced vitamin-D in food from University of Wisconsin; and Tethalin from University of California etc, there have been an increasing amount of research and interest about commercialization of research, Most studies thus far have focussed on the role of institutions and organizations on the patenting, licensing and spin-off company formation rates of universities, TTO, Bayh-Dole etc. Inventors, or in general individuals, have not received the same amount of attention and interest as much as institutions and organizations did. Scholars have hardly asked the questions: *who were the inventors behind all the university inventions, what were their motivations to patent, how did they patent, did they have special skills, knowledge to patent, what were the problems that those inventors faced?*

In this research I assume inventors are one of the principal actors of the invention process. Still they are one of the most neglected units of analysis compared to organizations and institutions. Despite the importance of inventors, there is little knowledge on who at universities are patenting and how their work could be influenced by individual characteristics of scientists. For instance, at the initial stages the UITT depends highly on the decision of faculty to patent or not to. In Sweden due to the Law of University Teacher’s Exemption (UTE hereafter), the individual decision of faculty to patent or not is very critical. While in the US model, faculty are expected do invention disclosures to the university Technology Transfer Offices (TTOs hereafter), there is no such requirement for faculty employed at Swedish Universities. However up to date, we have not had any systematic data about university patents and university inventors in Sweden and even for most countries except the U.S.

³ This paper is a quantitative prelude for a better understanding of university patenting in terms of methodological empirical and theoretical dimensions.

⁴ A detailed literature review on university industry technology transfer (UITT specifically patenting, licensing and spin-off company formation) from both macro and micro approaches can be found in the following Chapter-2.

2.2 Policy side of the coin: “European Paradox”

The boom of university patents in the USA made policy makers and scholars in Sweden more and more interested in university patents. A better and faster utilization of university research results has become one of the most important issues in the policy agenda in Sweden. Among others, the intensification of interactions between universities and industry is related to the political interest as well. Governments have initiated policies aiming at raising the economic returns of public financed research by stimulating interaction between university and industry with the goal of increasing the technology transfer from universities (Geuna, 1999:4). In particular, the governmental push for more university patents and or industrially relevant research at the universities is of main concern.

Patenting, licensing and spin-off company formation has become one of the main political and economic objectives for many governments. The dominant myopic theoretical focus on the institutions and organizations of university patenting is also common to the political beliefs. There have been several attempts to show that utilization of university research results for economic and industrial needs is not at the desired level. It is claimed that there is a gap between high levels of scientific performance on one hand, and their minimal contributions to industrial competitiveness, licensing or new venture creation. This gap is also known as the *European [academic] paradox*. This perception is partly exacerbated by the impression that universities in the USA have higher performance in commercializing their research results. Subsequently, several European countries have started to implement the organizational ownership of intellectual property (patents) at their universities. These policy developments are mainly inspired by the Bayh-Dole legislation in the USA model. This policy emulation is purely reflecting how governments initiate top-down plans without considering the needs and expectations of the bottom. Against these top-down policy implementations, a group of researchers have warned about the risks of emulating the so-called USA model (Valentin and Jensen, 2006; Mowery et al. 2004).

The European Commission (2003) lists this as one of the six priorities for European universities in the immediate future, and concludes that “it is vital that knowledge flows from universities into business and society. Subsequently, the two main technology transfer mechanisms i.e. patenting, licensing, and start-up company formation have been articulated as the most popular policy tool in the last two decades. This policy tool increased the debates over the role of intellectual property rights in the process of public-private knowledge transfer.

With the introduction in 1980 of the so-called Bayh-Dole act, which gave U.S. universities the right to patent discoveries resulting from federally funded research, this debate was decided in favour of those supporting active patenting by universities. The rise in university patenting observed in the U.S., and the success stories of some university discoveries that yielded high-income streams from licensing have induced European policy makers to also consider Bayh-Dole-like legislation (OECD, 2003). This argument is made against a background of, often anecdotal, empirical evidence that European universities are not very active in patenting and far behind commercialization of university research results.

2.3 Invention, Innovation and Patent

This research mainly focuses on the university knowledge that can be patentable. A focus on university patents might seem to be a strange route to better understanding of the university industry technology transfer (Henderson et al., 1995:1). Since university patents are a small fraction of all patents (Henderson et al., 1995) and only a small fraction of university knowledge can be patentable. As a result one cannot learn about the full spectrum of university research and knowledge from patent data. This research focuses on a sub-set of university knowledge that is

patentable. Yet university patents are informative, they reflect research that the university [or academic inventor e.g. in Sweden] believes has direct commercial application (Henderson, et al., 1995). University patents are also interesting in their own right since they are a unique and highly visible method of “technology transfer” (Archibugi, 1992; Basberg, 1987; Boitani and Ciciotti, 1990; Trajtenberg, 1990). Similarly understanding the university patenting patterns over time is an important dimension to understand the relationship between university and industry (Blumenthal, 1986; Caballero and Jaffe, 1993; Dasgupta and David, 1987; David, Mowery and Steinmueller, 1992; Jaffe, Trajtenberg and Henderson, 1993; Mansfield, 1991; Pavitt, 1991).

A patent is an exclusive right granted for an invention. Patents are perhaps the most important legal instruments for protecting intellectual property rights. A patent confers to a patentee the sole right to exclude others from economically exploiting the innovation for a limited period of time (e.g. 20 years from the date of filing). In return for a government-enforced monopoly franchise on the commercial exploitation of an invention, the patentee must disclose and explain the invention, in principal with sufficient detail that a knowledgeable practitioner of the relevant technology could reproduce the invention using the patent document. When a patent is issued, a large amount of information is publicly recorded, and most of this information is now available in computerized form. The information that is available includes the following information: 1) the name(s) /or and postal address(es) of the inventor(s); 2) the organization, (applicant) if any, to which the patent property right was assigned or transferred when the patent was issued, and its legal address; 3) a detailed technological classification of the invention; 4) the patentee’s specific claims regarding what the invention can do that could not be done before; and 5) citations that indicate previously existing knowledge, embodied in prior patents or other publications, upon which the patent builds (Jaffe, 1998). Patents provide information on the temporal, geographical, technological and sectoral distribution of inventions. They are generally considered to be important indicators of technological activities (Archibugi 1992:358). The availability of data in electronic format has also increased the size of the datasets being used in the literature (Pavitt, 1998).

The large and growing literature studies the patterns of technological evolution, knowledge creation and diffusion, and firm technology strategy by using patent data. Key areas of research include: the geographic localization of knowledge flows (Almeida and Kogut, 1999; Jaffe, Trajtenberg, and Henderson 1993); knowledge diffusion across and within firm boundaries (Rosenkopf and Nerkar, 2002; Song, Almeida and Wu, 2003); technological positioning of firms (Podolny, Stuart, and Hannan, 1996); factors associated with the production of important innovations (Cockburn and Henderson, 1998; Gittelman and Kogut, 2003); the impact of the structure of knowledge on knowledge diffusion and firm strategy and (Sorenson, Rivkin and Fleming, 2002, Ziedonis, 2003) and university-firm technology transfer and universities as a source of important innovations (Henderson, Jaffe, Trajtenberg, 1998; Mowery, Sampat, and Ziedonis, 2003; Meyer, 2003; Saragossi and van Pottelsberghe de la Potterie, 2003; Azagra-Caro et al. 2003; Schmoch, 2000; Gulbrandsen et al., 2005; Balconi et al., 2003; Leydesdorff, 2003).

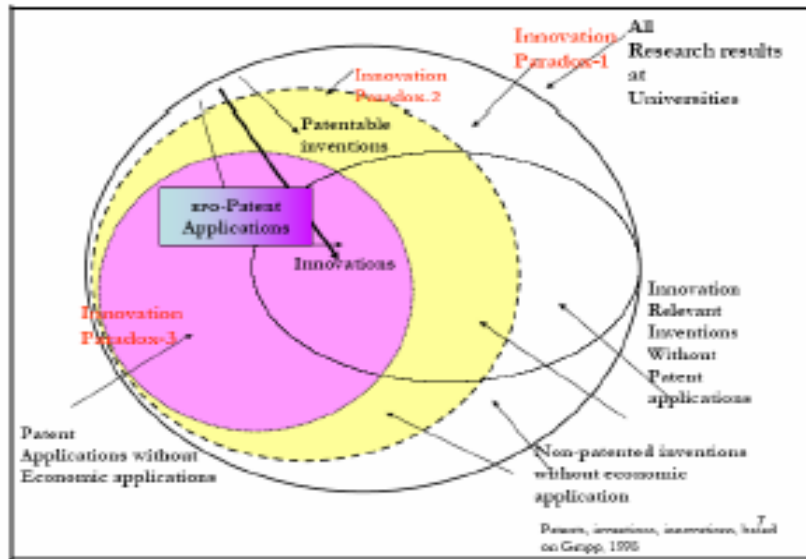
Regarding the university industry relations, Jaffe’s (1989) research relies upon the number of patented inventions registered at the U.S. patent office, which he argues is a ‘proxy for new economically useful knowledge’ (p.958). Jaffe’s (1989) Model provides statistical evidence that corporate patent activity responds positively to commercial spill-overs from university patents. However, despite its widespread use, patent data has its own drawbacks such as: the propensity to patent differs across country and industry, differences in patent regulations across countries, and changes in patent laws (difficult to analyze trends over the time), value distribution of patents is skewed, finally many inventions are not patented (Pavitt, 1998). Although patents are good indicators of new technology creation, they do not measure the economic value of these technologies (Hall et al., 2001). More specifically, to be able to give a fair image of the impact of

university knowledge on technological development, patent data should not to be confused with data on innovations.

Patents are a rather partial indicator of technological inventive activity. For instance while Jaffe's (1989) Model provides explanations to the role of university research to generate 'new economically useful knowledge', Scherer, 1983; Mansfield, 1984; and Griliches, 1990 have warned that measuring the number of patented inventions is not the equivalent of a direct measure of innovative output (Acs et al., 1992). According to Griliches (1979) and Pakes and Griliches (1980, p. 378), patents are a flawed measure of innovative output particularly since not all new innovations are patented and since patents differ greatly in their economic impact. Similar to these arguments, Pavitt (1998) also had a sceptical view of university patents as an indicator of useful university research. Pavitt (1998) further argued that patents granted to universities give a partial and distorted picture of the contributions of university research to technical change. Patenting by universities is not a potentially useful measure of university research performance. He further argued that citations in patents to published papers provide a better picture of the academic research contribution to technical change (Pavitt, 1998). However patent citations also have several drawbacks. The patent citations are done by patent attorney and patent examiners who do not represent knowledge spill-overs between the sources and users of knowledge.

Measures of technological change have typically involved one of the three major aspects of the innovative process: (1) a measure of the inputs into the innovation process, such as R&D expenditures; and R&D personnel, (2) an intermediate output, such as the number of inventions which have been patented; or (3) a direct measure of innovative output. During the 1950s and 1960s, our understanding of the economy was advanced by developing measures of research and development (R&D), an input measurement, as a proxy for innovative output. R&D suffer from measuring only the budgeted resources allocated towards trying to produce innovative activity (Acs et al. 2000:2) university and industry [i.e. contribution of university publications to technological development] (see Jaffe et al., 1993; Alcacer and Gittelman; 2004, Wong, 2005). The reasons behind this critical view on the use of patents in university industry relations could also be explained by Arrow's (1962) distinctions between general knowledge and economically relevant knowledge. Based on Arrow's distinction, knowledge is only partly economically useful and also to some extent utilized. Endogenous growth model assumes that there is no barrier to the diffusion of knowledge within countries [e.g. from university to industry or among firms] to commercializing knowledge, i.e., spill-overs are automatic and there is no distinction between knowledge and commercialized knowledge (Romer, 1990 and Grossman and Helpman, 1991). On the other hand, not all inventions are utilized and commercialized, and lead to innovations. In the same way Invention refers to an idea, a sketch, or a model for a new or improved device, product, process or system. Such inventions do not necessarily have to be patented and they do not necessarily lead to technical innovations.

Fig.1.Relations between Knowledge & Patents



This Fig.1 shows that knowledge -defined as codified R&D- is believed to be automatically transformed into commercial activities, or what Arrow (1962) classifies as economic knowledge. However the imposition of this assumption lacks intuitive as well as empirical backing. It is one thing for technological opportunities to exist but an entirely different matter for them to be discovered, exploited and commercialized (Acz et al. 2003).

An innovation is accomplished only with the first commercial transaction involving the new product, process system or device, although the word is also after used to describe the whole process (Freeman & Soete 1997:6). Thus not all innovations are patented and some innovations are not necessarily need to be patented. The relation between inventions, innovations and patents is summarized by Grupp (1998), based on a similar argument already made by Arrow (1962). Similar theoretical grounds could be also found according to Narin's and his colleagues (1976) typology of research. Narin et al. (1976) classified research into four: Applied technology; engineering science-technological science; applied research and targeted basic research and basic scientific research. It is difficult to assume which of these research groups yield more patents or no patents at all.

Universities are therefore expected to produce general knowledge (e.g. in the forms of publications, books, conference papers, lectures and so forth), educate students and generate knowledge that can also be patentable. While the former type of knowledge will contribute and increase the public knowledge, it is difficult to measure the direct contribution of e.g. publications and students in any specific industrial innovation per se. It is certainly plausible that the pool of talented graduates, the ideas generated by faculty, and the high quality libraries and other services of universities facilitate the process of commercial innovation in their regions [e.g. Silicon Valley, Route 128 etc.], but there has been very little systematic empirical evidence for this phenomenon (Jaffe, 1989:957) due to difficulties in measurements. Keeping all these limitations in mind, within the scope of this research I cover only a sub-set of university knowledge, which is codified in the forms of patents.

While patenting can be considered as the tips of the iceberg, other more generic mechanisms can be seen as the deeps of this iceberg. Therefore even though a substantial amount of technology transfer may also take place through more general mechanisms (Goktepe 2004, OECD, 2002a), it

is difficult to generalize, identify and measure these mechanisms in terms of technology transfer (Audretsch et al 2005). However in the case of most European Countries, e.g. in Sweden even the university patenting is taking place beneath the surface which needs further research to identify inventors and the extent of patenting. Thus the choice of patenting to study UITT is not at all due to practical choices i.e. availability of databases etc. Second the focus on patenting would not undermine the importance of other mechanisms. Thus, although patent indicators reflect an important part of the overall innovation process, they should not be used in isolation. They show only one aspect of innovation, thus a consistent picture of technological change can only be achieved by combining several indicators and other qualitative works (Sirili 1992, and Grupp 1990 in OECD 1994).

3. Selected Studies on University Patenting under non-Bayh-Dole Systems

A number of scholars have shown that the number of USPTO patents applied for by U.S. universities has increased dramatically over the last 20 years coinciding with the so-called American Bayh-Dole Act. Over the same years the number of science-based university spin-offs has also grown (*among others see Henderson et al. 1998, Etzkowitz, 2002, Mowery et al. 2004*). Although the effects of the Act on the increase of patenting is far from definite and conclusive, universities increased their share of patenting from less than 0.3% in 1963 to nearly 4% by 1999 (Mowery and Sampat, 2005). As a result, it seemed that there is a positive relation between the numbers of university patents the Bayh-Dole Act.

On the other side of the Atlantic, the propensity of university patenting, licensing, spin-off company formation in Europe has been claimed to be low especially relative to the investments in higher education institutes in Europe. This phenomenon has been labelled as the “European Paradox”, according to which European countries have strong science base, but are not good at transferring research results into commercially viable new technologies (EC, 1995, 1993). University patenting seems to be limited in Europe. Although there *has been no* a systematic attempt of measuring it, it is well-known fact that no European university holds as large patent portfolio as MIT or Stanford, it is believed that many European Universities do not have patents at all (OECD, 2003).

This belief put the institutions and organizations behind university industry technology transfer into question. Given the impression of the “higher number of university patents, spin-offs and higher licensing revenues of the U.S. universities”, the emulation of the U.S. Bayh-Dole model has been considered as the main solution by many European policy makers. *Countries such as Germany, Denmark, Austria, and Norway adopted the Bayh-Dole model, while it is an ongoing debate in Sweden, (see Goktepe, 2007)*

Some concerns have been raised that policy suggestion are based to a large extent unrealistic and wrong assumptions. First of all, most information on university patenting, licensing, and spin-off company formation came from surveys submitted to university-TTOs, from newly established TTOs, or from searching for university names as the applicants. Remedies to the lack of systematic data on patents for European universities and further investigations of the “European Paradox” have been suggested by the European scholars.

In order to create comparable patent data sets with the USA system, almost coinciding with this research timeframe, a number of scholars *e.g. Belgium (Saragossi and van Pottelsberghe de la Potterie, 2003), Finland and Flemish Region (Meyer et al., 2003), France (Azagra-Caro et al.,*

2003), Germany, (Schmoch, 2000) Norway, (Iversen et al., 2005) and Italy (Balconi et al., 2003).⁵ Italy, Sweden, France (Lissoni et al. 2006) has recently identified university patenting in Europe by pursuing a different methodological suggestion. These scholars have departed from the argument that lack of the so-called Bayh-Dole system at universities in Europe should require a new methodology in order to find how many university scientists are actually listed as inventors of patents instead of searching for university names or university-TTOs as applicants of patents.⁶ The starting point for this study is similar to the aforementioned studies. Due to different institutional and organizational set-ups of the Swedish universities, who is patenting and the propensity of university patenting should be investigated through the finding the names of the university scientists who are also registered as inventors in the patent databases. (*The methodological and empirical investigation and the construction of the Lund University Patent and Inventor database as a case for Sweden are presented in Section 4*).

The scholars of the previous studies on university patenting for European universities departed from the distinction between inventors and an applicants of patents.

Inventor: The inventor(s) developed the idea (knowledge) represented in the patent. The inventor of a patent can be collective (co-inventorship). Inventors can be affiliated with universities, research institutes, or public and private firms.

Applicant: The patent applicant is normally the individual(s), the firm or another organization responsible for the patent costs, and who/which may assume ownership, if the patent is granted. Applicants can be different from the inventor(s) who developed the idea represented in the patent.⁷

Depending on the ownership of IPRs at universities (i.e. individual ownership or organizational ownership), university inventors can apply for patents by themselves (individually), by university technology transfer offices (hereafter TTOs) or through other actors (e.g. patent attorneys, firms, and technology transfer organizations). The inventor(s) may assign his/her rights to another party to apply for a patent. Therefore, a distinction between inventor and applicant of a patent needs to be highlighted.

The aforementioned scholars (*Saragossi and van Pottelsberghe de la Potterie, 2003; Meyer et al., 2003; Azagra-Caro et al., 2003; Schmoch, 2000; Iversen et al., 2005 Balconi et al., 2003 and Lissoni et al. 2006*). These scholars have distinguished the university-owned patents and university-invented patents from as follows:

University-Owned Patent: University-owned patents are the patents in which universities or their technology transfer offices (TTOs) are listed as applicants, owners (assignees) of these patents.

⁵ In some cases I made personal communications with other researchers, Eric Iversen, Magnus Gulbrandsen, Manuel Trajtenberg, Stefano Breschi and Martin Meyer in order to learn from their methodological experiences. Each scholar has developed their own database management techniques. All comments are highly acknowledged.

⁶ Chapter 5 is mainly based on the methodologies used in these studies, yet the how the name matching techniques are achieved for these studies have not been published. Authors just summarized the whole name matching procedure and university patent database construction in their publicly available publications. I therefore can not give the technical details of their name matching procedure.

⁷ In the United States Patent & Trademark Office (hereafter USPTO), the patent applicant is called the *patent assignee*.

University-Invented Patent: University-invented patents are defined through the affiliation of their inventors with a university rather than university ownership of patents. University-invented patents have a member of a university faculty among the inventors whether or not the university is the patent applicant.

The main principle of the methodology of these different studies is to match two different databases. The database of patent applications (e.g. national patent office, EPO, USPTO) is matched with the so-called University Researcher Personnel Registers which has information on all scientific and administrative personnel at the universities, university colleges, state colleges and research institutes. Most of these studies have used surveys (emails, telephone calls to the inventors) to assure the matching of inventor and faculty member, and sometimes additional interviews as case studies. The main findings of the previous empirical work are presented below and in Table 2.3.

Balconi et al. (2003) found that out of 1,475 university-invented patents in Italy between 1978 and 1999, only 40 EPO patents had universities as applicants, whereas Italian university inventor patents account for 3.8% of EPO patents by Italian inventors. Meyer et al. (2003a) reported that Finnish universities own 36 USPTO patents, but that there were 530 Finnish university inventor patents between 1986 and 2000. In another research, Meyer et al. (2003b) showed that university-invented patents are 379, while the number of university-owned patents is 100 at the Flemish Universities.

In Germany, university assignee patents are relatively rare, but university invented patents have increased continuously from less than 200 in the early 1970s to around 1,800 in 2000 (Meyer-Krahmer and Schmoch, 1998 and Schmoch in Geuna and Nesta, 2004:8). Rapmund et al. (2005) investigated the university patent holders at Norwegian Universities and research institutes between 1998 and 2000. Preliminarily they have concluded that 8-12% of all Norwegian domestic patents are invented by university and PROs researchers.⁸

At an individual university level, Saragossi and van Pottelsberghe de la Potterie's (2003) study points out that the number of university invented EPO patents for Université Libre de Bruxelles (ULB) is more than double the number of university owned patents for the whole period 1985-1999. Azagra-Caro et al. (2003) point out that although French universities are legally entitled to own patents based on faculty research results, in practice the 'university invented, but not university owned' patent has been and remains the most common form of 'university' patent. These authors offer statistical evidence for the University Louis Pasteur (ULP) in Strasbourg, which, in 1993 to 2000 had 463 patents (from the French patent office, the EPO and other patent offices). 62 patents were owned by the university (ULP).

On a more narrow level, Schild (1999) examined the university patent holders at Linköping University who has patents within the Swedish-PCT filings from the East Gothia region. She found that a total of 88 (approximately 14 %) of the East Gothia patents have at least one inventor from Linköping University. She identified 82 inventors affiliated to Linköping University out of 656 inventors in the East Gothia region.

⁸ On the other side, the impacts of institutional changes (i.e. from individual to organizational ownership of IPR) on university patenting in Germany, Norway and Denmark have not been clearly measured yet. (see Valentin and Jensen 2005.)

Table 1: Selected Studies on Patenting versus Publishing

<i>Author /Country</i>	<i>Data</i>		<i>Findings</i>		
	Time Period Database	Type of University investigated	#of University-invented Patents	# of University-owned Patents	Main Technological Category of Patents
Finland (Meyer et al.2003a)	1986-2000 USPTO	All universities except Social Science & Arts etc.	530 patent 285 inventors	36	Telecom Instruments Pharmaceuticals
Flanders (Meyer et al.2003b)	1986-2000 USPTO	Technical Universities	379 x	100 (TTOs)	Organic chem. Life Science
France (Azagra-Cara & Llerena 2003) (Univ.of Strasbourg)	1993-2000 French National Patent Office	Univ.of Strasbourg 82 Research Laboratories	463	62	Genetics Biology Physics
Germany (Schmoch 2000)	1970-2000 EPO	All University Professors. Title of Professor is searched	1800 (2000) and 200 (1970)	NA	Biotech, Medical Engineering, Organic Chemistry
Italy (Balcani et al.2004)	1978-1999 EPO	All Professors registered to Ministry of Education and Research	1,475 919 inventors	40	Biotechnology Drugs, organic chemistry
Norway (Iversen et al. 2005)	1998-200 Norwegian Domestic Patents)	All researchers at universities - colleges	307 (8-12% of all Norwegian Domestic Patents)	NA	Life sciences Instruments
Sweden-Chalmers (Wallmark-Survey)	1943-1994 Swedish Patents or EPO	Chalmers University of Technology	417 68	NA	Chemical Engineering Electrical Engineering
Sweden-East Gothia (Schild Linkoping University (LiU)	1980-1996 (Swedish-PCT filings from East Gothia)	Linköping University Technical Faculties	88 (Swedish-PCT filings from East Gothia) 82 Inventor	NA	Instruments Electricity Health & amusement
Sweden Lund (Goktepe 2005)	1990-2004 EPO	Lund University Except Social Science	458 EPO-patent 250 inventor	1	ICT, biotech, pharmaceuticals

University-invented patents can also be analyzed by looking at the distribution across science and technology areas. Cesaroni and Piccaluga's data point to a clear preponderance of patenting in the broadly defined area of Chemistry and Human Necessities (which includes biotechnology). Studies for Belgium, France, Finland, Germany and Italy show that the technological areas where patenting is most frequent are those relating to biotechnology and pharmaceuticals (in Geuna and Nesta 2004:8).

The strongest technological sectors in each country also tend to be those where university patents are heavily concentrated. For instance, telecommunications in Finland account for 12% of university-invented patents while pharmaceuticals and biotechnology only account for about 9% each (Meyer, 2003). The broadly defined research area of biotechnology and pharmaceuticals tends to be an area of extremely high university patenting activity across many countries.⁹

⁹ These studies have found almost the similar tendencies as in the US. In the US, 41% of academic USPTO patents in 1998 were in three areas of biomedicine indicating a strong focus on developments in the life sciences and biotechnology fields. In terms of revenues, about half of the total royalties were related to life sciences, including biotechnology (NSF, 2002). Whether a corresponding degree of concentration in this

In their three countries study, Lissoni et al. (2006) found that the university professors that are active in 2004 for Sweden and Italy and 2005 for France are responsible for a substantial number of patent applications during 1978-2002. There are 2800 patent applications in France, 2200 in Italy, and 1400 in Sweden. They compared the propensity of patenting in these three countries (for the years between 1994 and 2001) with the U.S. university patent data (for the years between 1993 and 2000) in order to make the U.S.-Europe comparison possible. They found French, Italian and Swedish university-owned patents are less than 1% of total domestic patents, while, in the same countries university-invented patents are respectively around 3%, 4% and over 6%. U.S. estimates for university-invented patents move are 6%. This shows that the gap between the U.S. and Europe in terms of patents, turn out to be a limited gap between U.S. and France and Italy on the one side, and no gap at all between U.S. and Sweden (Lissoni et al. 2006:18)

These empirical investigations support the view that university patenting is not a new phenomenon to the European universities. They show that the more inclusive approach of tracing patents made by academics allows the analysts to identify a much broader impact of and propensity of university patents. They provide clear empirical evidence that the number of university-invented patents is much higher than the number of patents owned by universities. Thus although university-owned patents do not fully show the wealth of contributions university and researchers make to technological development, university-invented patents can be used as a more stronger indicator of the role of universities (Meyer, 2003).

Although the number of university-owned patents are limited, these universities or countries do not necessarily lag behind the U.S. universities. The difference in the numbers can be explained by different institution and organizations. There are no straightforward answers to existence of patenting activities in Europe. However, we still do not know if patenting activities in European universities can be explained because of the individual ownership of patent legislations, entrepreneurial academics or it has been due to the changes in the technology transfer infrastructures or in the academic culture. The previous studies on university patenting have not investigated those issues in a systematic way, except case studies of Gulbrandsen (2005) and Meyer (2005) to date.

4. University Inventors & University Patents in Sweden

The empirical investigation is based on Lund University which was founded in 1666 in the south of Sweden. It is the largest unit for research and higher education in Sweden (and in Scandinavia) with eight faculties and a multitude of research centres and specialized institutes. It has faculties in three cities: Lund, Helsingborg and Malmö. The University has 42,500 students and 6 000 employees. More than 3 000 post-graduates work at LU, 45% of them women. Most doctorates are awarded in medical sciences, followed closely by technology and natural sciences. In 2004 the University had 554 professors, of which 14% were women. 435 new research students were accepted in 2004, half of them were women. 458 doctorates were awarded the same year. Towards the establishment of technology transfer infrastructure LU has taken important steps. For instance, The LU-Innovation unit (former industrial liaison office), LUAB, LU-Development Company, provide business advice to university researchers. Additionally, regional actors (Innovation Bridging Company, Forskarpatent, Teknopol and so forth) have been established in the last decade to guide and help university researchers for commercializing their research results.

area exists for university patents in Europe is less than clear-cut, but the available evidence is not at odds with this assumption (Geuna & Nesta 2004:8)

Lund University Patents (LUP): are defined as the patents for which at least one of the inventors is affiliated with Lund University. In order to be counted as a university person, the inventor has to be included in the official university personnel registers and has to be employed at the time of invention.

This research has used a novel quantitative methodological approach which has now become a standard method to identify university inventors where individual ownership is the common practice (Trajtenberg, 2004; Meyer et al. 2003; Balconi et al. 2004; Iversen et al. 2005). The methodology is based on a procedure which matches names and addresses between two databases i.e. university personnel registers and the patent data.

4.1 Selection of the Databases

The two databases that were used for identifying the university inventors are: European Patent Database (EPO) and Lund University Faculty Registers (LUF).¹⁰ Based on an initial comparison between EPO, PRV and USPTO, EPO database has been chosen. EPO-database provides the most reliable first page information of the patents (i.e. full names and addresses of inventors and applicants, while the other office databases give only the city names but do not have address information for inventors. The EPO database made it possible to find patents and patent applications that have at least one Swedish inventor.

First, EPO-database is selected over Swedish national-PRV database. According to the previous studies, USPTO and EPO patents can be seen as an indicator of commercially more promising inventions than national applications. For instance sometimes national offices (e.g. Italy, France and Norway) may appear to adopt a looser interpretation of the criteria for technical novelty and inventiveness than other patent offices (e.g. EPO, Germany, and USPTO). (Meyer 2004:5).

EPO-database is chosen over USPTO for practical reasons. The USPTO database does not include the full-addresses of inventors, it would have been almost impossible to find whether the inventor and university researcher is the same person. Moreover since most of the Swedish applicants (e.g. firms) work within the European market, they may more likely to care for protection in the European market.

This study counted *patent applications* rather than *granted patents*. This is the standard practice among studies using EPO database (see Balconi et al. 2004; Schild 1999; Breschi, 2004). There are two main reasons: First, a large proportion of patent applications to EPO are eventually granted (80%). Thus the distinction between patent applications and granted patents is relatively insignificant (Schild 1999:38). Second there is a time-lag between the applications and granting. This would preclude an up-to-date database if granted patents were to be used (Schild 1999:39). By the same token, Meyer et al. (2003:33) mentioned that in certain areas such as biotechnology, examination times may take five years. The use of granted patents limits the scope of the research and prevents us from identifying potential inventors. For the sake of simplicity in this research, the term patent is used instead of patent applications.

The EPO-Swedish patent is defined as a patent where at least one of the inventors has a residing address in Sweden, i.e. having SE in the address field. In the EPO- database I found 35,073 patents that have at least one inventor from Sweden from 1978 till February 2005.

Patents that have application dates earlier than 1990 have been excluded because of research objectives. (The choice of time-frame is a trade-off between taking stock of patenting activity

¹⁰ On the other hand, Wallmark (1997) for Chalmers University of Technology-Sweden and Chang et al. (2001) for Taiwan conducted surveys to find out academic patent holders instead of patent searching which was they considered costly and time-consuming.

over longer period of time on the other hand, and lowering the correct matches inventors and university scientists) As a result I have 22,824 patents from 1990 to 2004 that have at least one inventor with a Swedish residence regardless of the nationality of the inventor.

The second database used in this research is Lund University Faculty (LUF) registers. LUF Registers for three main faculties i.e. Lund Institute of Technology (LTH), Faculty of Medicine (MF), and Faculty of Science and Technology (NS) for the years 1999-2004 have been requested from Lund University Personnel Office. This file contains 4214 university employees (LUF).

4.2 Construction of the LU-patent Database

For this research I have developed a new method through the combination of Excel, Access and Visual Basic. The matching of the two databases follows a logical step-by-step procedure, often involving the repetition of the same basic steps.

Step 1: Name-matching between EPO-SE-inv- and LUF

First the procedure is based on matching first two letters in the first name, and full surnames of inventors in the EPO-SE-inv and LUF databases. This type of matching gives all possible combinations (e.g. Anders Andersson--Anders Andersson but also Andrea Andersson, Andrias Andersson etc.).¹¹ All these matches are controlled manually and only exact matches are taken.)

Step1.a: The same matching procedure is repeated for the different combinations of first names, middle names and surnames. (E.g. Anders Andersson → A. Sven Andersson, →Sven Andersson)

However homonyms are controlled by address match. (Homonyms: They have the same names they are not the same person. I do not know if they are the correct match of inventor and university employee). I made a manual address, zip-code and city control and then conclude that university scientist and the inventor is the same person. Moreover some names are abbreviated (e.g. Daniel→Danny) or sometimes mid-names are not registered at all or initials are used (e.g. Anders Sven→ A.Sven, or only Sven). All these different name combinations are checked. Moreover I thoroughly went through every match and checked each name one-by-one) due to possible spelling mistakes such as use of double *ss* or single *s* (e.g. *Andersson might be spelled as Anderson or the other way round*).

Step 2: Name, Address and zip-code matching ¹²

The second stage of matching is based on name, zip-code and address and name matching. This matching provides the perfect matches since it confirms both names and the addresses of inventors.

Step-3: Address and zip-code matching

In this step, only the addresses and zip-codes are matched. As a result of the address matching some of the names that are missed are found. (E.g. some names were misspelled, changed, abbreviated names, use of middle names, divorced, married, different transliteration of foreign names- Chinese, Russian etc., different uses of Å, Ö, Ä etc.)

¹¹ All names used for methodological explanations are arbitrary and created by the author. They do not reflect the real inventor-researchers.

¹² This kind of methodology has not been used or suggested by the other researchers in the field. This method is especially important to find the misspelled names. The address-matching confirms also our choice of EPO database, but the others (USPTO, PRV etc.)

The same procedure is repeated for all the inventors from INAD1 to INAD27, and zip-code matching for INzip1 to INzip-27. All possible abbreviations of addresses e.g. Gatan-G, Vägen-V, Södra, Östra, Västra, Norra, abbreviations etc., different spellings of ä-å-ö are checked manually. As a result name and address matching and subsequent manual controls, two sets-of name matches were found.

Perfect matches: The first-name, mid-names and surnames, address, zip-code and city of the inventors in EPO-SE-inv and researchers in the LUF registers are matching).

Name-matches: The first-name, mid-names and surnames of the inventors in EPO-SE-inv and researchers in the LUF registers are matching but their addresses can not be controlled due to lack of information.

Step 4: Controlling Scientific field of the Inventor-researcher Pairs and Patent Area

For further assurances, the possible relevance between the scientific fields of the researchers and the patents are manually controlled.

Step 5: Co-inventors and Colleagues

I manually checked the co-inventors. I have checked the LU Publications, and research projects list, staff homepages and CVs of inventors to find out if any of the co-inventors is also from LU. 10 more inventor-researcher pair is identified. Their names are different and who could not be identified due to missing address (e.g. inventors who have different name orders e.g. Arabic and Chinese names and who did not have the same addresses in databases. They were mostly foreign PhD students.).

Step 6: Identification of Academic title and Age at the time of Patent Application

The date of patent application is used as proxy to identify the link between the inventor and LU. In order to identify the academic title of the inventor, I consider the academic title and age which is the closest to the application date of the patent.

Step 7: Identification of Academic Affiliation at the time of Patent Application:

The identification of academic affiliation has been complicated due to the ongoing changes (re-organization) at LU, especially at the Medical Faculty. Another problem is the miscoding of academic affiliations in the LUF database. Moreover, some of the employees have been affiliated with several divisions and it was very difficult to determine which division should be the inventors' milieu. I consider the academic affiliation which is closest to the application date of the patent.

Step 8: Identification of Patent Applicants

In order to get the most accurate information about the size, sector, location, type and linkages of applicants to the inventors, the applicants of each patent are identified in the EPO-SE-Inv database. These features of all applicants & proprietors are investigated by using search engines, homepages and business websites. Use of different names for applicants (e.g. Astra or Astra Zeneca, Ericsson or Telekombolaget Ericsson, etc.) are controlled manually

To sum-up, name and address matching is more accurate than the methods used in previous researches which have mainly relied on name-matching and surveying the name-matches. This research has on the other hand decreased the risks of including non-patent holders due to same names. As a result of matching and manual controls I found around 273 inventors, 23 of which had only name matches, but they do not have address information. These 23 inventor-researcher pairs are put into a gray zone for further controls.

Step 9: Validation of the names in the gray zone

This thorough methodology has decreased the number of researcher-inventor pairs into 23, which needed to be further re-checked personally (by phone and emails for confirmation). 10 inventors confirmed that they were the inventors and employed at LU. 3 inventors stated that they were inventors but they patented at another organization, and eventually asked not to be included in the LUP-database. 10 inventors could not be reached due to missing addresses. These inventors were not included in the final database. I checked their EPO-addresses in Eniro Swedish (online yellow pages) in order to contact them. However this effort did not lead to any conclusion. This step-by-step, quite tedious and manual procedure has provided a methodological efficiency by eliminating the risks of excluding or including wrong inventor-researcher pair. Finally 260 inventor-researchers from LU are identified.

4.3 Limitations

First, the use of EPO limits the scope of the analysis. By doing so, I might have excluded inventors who have patents registered only in other offices (e.g. USPTO, Japan Patent Office, and Swedish Patent & Registry Office-PRV, etc.). Second, the university researchers are covering Lund University employees. A broader researcher register (covering all Swedish universities) could have been used. However given the time and resources allocated, it is far beyond the scope of this research. Yet Lund University can be taken as an exemplary of other research and industrial activity intensive universities in Europe. Third, names (of inventors and researchers) were matched across the periods. Although it is found to be a perfectly legitimate choice; it has certain limitations whether the inventor was employed at the university at the time of invention. This is especially important for pre-1999 patent applications in this study. This problematic side is encountered when the inventors' survey was sent to 260 inventors. Approximately 10 inventors responded to the survey and claimed that they were not employed at Lund University at the time of patenting. They are excluded from the LUP-database and the surveyed sample.

5. Empirical Findings

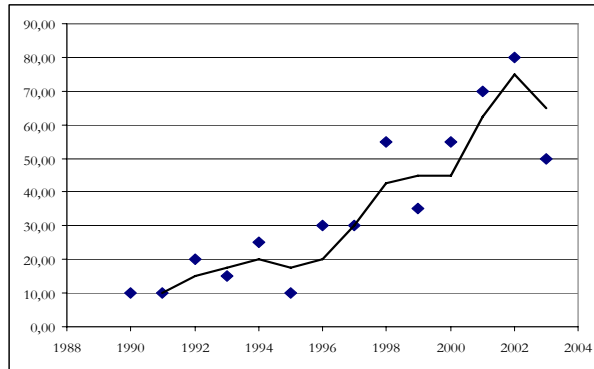
As a result of these matching and validation processes with a survey and telephone calls, a total of 458 patents with 250 university-researchers as inventors were identified at Lund University. This means that Lund University-related patents (LU-patents) account for at least 2% of the total amount of national patents (1990-2004). The following section describes these findings in detail. Empirical findings are analyzed in the lights of the three research questions that are posed in the introduction. First, it reflects on the patterns of LU-patents over time. Second, it presents the basic information about inventors and sets the background for further in-depth studies on inventors. Third, it presents the findings related to applicants, and proposes tentative insights where university patents are utilized.

5.1 Basic Characteristics of Patenting Activity at LU

Distribution of the patents at LU yearly and over 5-years periods

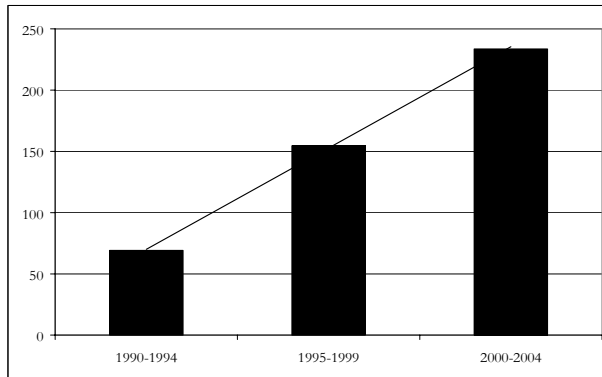
The extents of patenting at LU yearly and over selected periods are examined. As shown in Fig. 2, there has been a positive trend in the number of patents over the years 1990-2004. Although it is difficult at this point, to conclude the reasons behind this positive trend, the literature suggest several factors such as the development of new, high-opportunity technology platforms e.g. computer science, molecular biology, and material science; the more general growing scientific and technical content of all types of industrial production; the need for new sources of academic research funding created, and the so-called "third mission activities".

Fig. 2 Distribution of Patents Yearly (1990-2004)



Even though many scholars have argued that university patenting has not been exceptional before 1990s, patenting has become much more common within the last 2 decades. Fig.3 shows this positive trend in a more definite way by grouping the patents into 5-years periods. Between 1990 and 1994; the total number of patents was 69, between 1995 and 1999. The number of patents increased to 155, more than double of the previous period. Finally, the number of patents reached around 250 between 2000 till 2004.

Fig. 3 Distribution of Patents on 5-Year Basis (1990-2004)



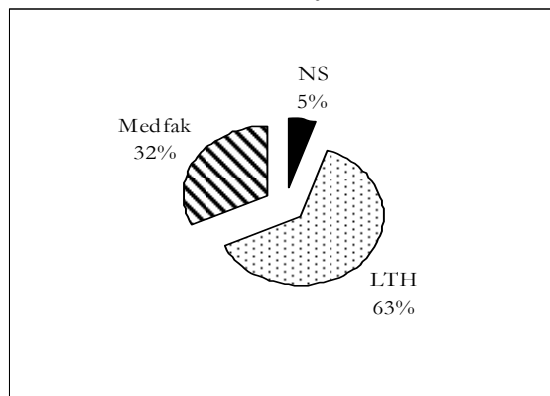
It has been argued that the relations with industry have intensified in the recent years. Stylized facts behind this intensification are: (i) the development of new, high-opportunity technology platforms e.g. computer science, molecular biology, and material science; (ii) the more general growing scientific and technical content of all types of industrial production; (iii) the need for new sources of academic research funding created by budgetary stringency; (Bercovitz and Feldman, 2005:175) (iv) and the prominence of government policies aimed at raising the economic returns of publicly funded research by stimulating university industry technology transfer (Geuna, 2001:10), (v) institutionalization of university patenting e.g. the Bayh-Dole Act of the USA and active roles of TTO. Although these factors are not exhaustive and conclusive, it is not feasible yet within the scope of this paper to go further in depth to find further explanations behind this positive trend.

Distribution of Patents by Scientific Fields

Patenting activities can also be related to the field of scientific specialization. Fig.4 shows the more patent intensive research milieus at LU. 63% of the patents have emerged from LTH-based scientific fields e.g. electronics, chemistry etc. 32% of the patents are related to Medical Faculty, and 5% of the patents have originated from Natural Sciences.

The basic explanation behind the scientific distribution could be that, in certain fields (basic-theoretical physics, geology etc.) patenting is not the preferred route for the protection and utilization of research results (Stephan, 2005). On the other hand, it has become more common to patent in fields like biotechnology, chemistry or engineering fields in general. The NS has 36 patents (out of 458). The lower rates of patenting at NS, can partly be explained by the nature of the research at NS, which is more theory oriented, compared to engineering fields at LTH or Medical Faculty. Second, LTH and MF have more connections with the surrounding industry. Third, due to the relatively higher research funds and research staff at LTH and MF, these faculties have produced more patents.

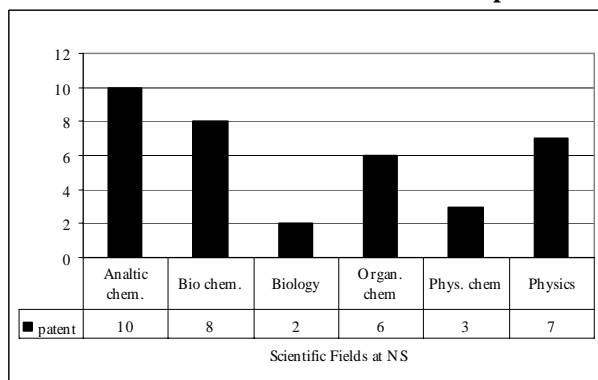
Fig. 4 Distribution of Patents by Faculties of (1990-2004)



The intensity of patenting activities differs not only among these three faculties, but to a considerable extent, the departments within the same faculty differ in their patenting activities as well. Each university patent in this study was allocated to a university department by the identification of the departmental affiliation of the inventor.¹³ The differences within the same faculty can not be explained by the “stylized facts behind the university patenting” or “reasons behind differences of the patenting intensity of different faculties”.

The following three figures show the distribution of patents at departments within the same faculty. Fig.5 shows that the most patent intensive department is the Analytical Chemistry at the Faculty of Natural Sciences (NS). It is followed by bio-chemistry, physics and organic chemistry.

Fig. 5 Distribution of Patents at the Natural Science Departments (1990-2004)



¹³ In cases where a single patent is invented with several inventors from LU, the patent was allocated to each of the relevant inventor’s department. This resulted in a small amount of double-counting. Yet, as shown in Fig.1.2 this also implies the intensity of patenting among LU. The single counting of patents is 458.

According to the Table.2 the Departments of Chemical Engineering (79), Information Communication Technologies (45), Physics (44) and Mathematics (41) Biotechnology (27), Industrial Electronic and Automation (28), have the highest numbers of patents at the LTH.

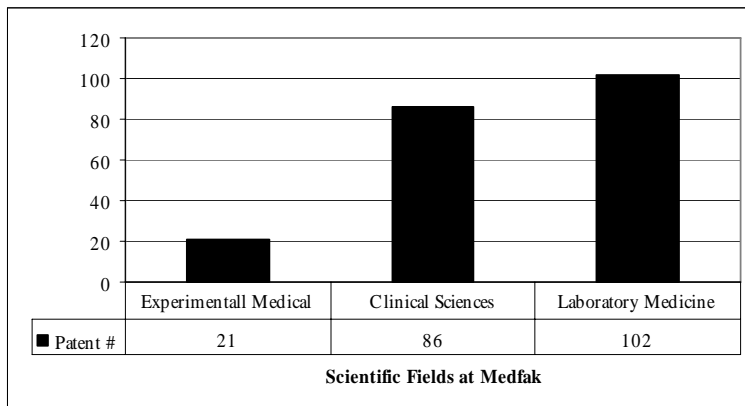
Table:2 Distribution of Patents at LTH Departments (1990-2004)

Automatic Control	17
Biotechnology	27
Chemical Engineering	79
Communication	10
Computer Science	5
Electrical Measurements	30
Electro-science	26
Food Engineering	19
Industrial Electronics	28
Information Technology	45
Mathematics	41
Energy-Building Sciences	20
Mechanics-Design	10
Physics eng.	44
other	9

The possible explanations behind difference among department within the LTH; can be “difference in the size and resources of departments, role and motivations of chairperson, the inherent culture of the department, external funding and so on.” Participation of departments in projects with industrial partners or in Vinnova Competence Centres, such as Nanotechnology Forum, Electro-science Forum, Bio-separation Centre and so on are expected to be important reasons for the intensity of patenting in these fields.

Fig.6 shows the distribution of patenting at the departments of Medical Faculty.¹⁴ The patenting activities in the Medical Faculty are concentrated to three departments: Laboratory Medicine (102) and Clinical Sciences (86), and Experimental Medical Sciences have (21) patents.

Fig. 1 Distribution of Patents at Medical Faculty Departments (1990-2004)



At the Medical Faculty, inventive activity is concentrated to the divisions of cell and molecular biology, Medical Sciences and clinical chemistry, cardiology and orthopaedics. Differences

¹⁴ From 01.01.2005, Medical Faculty has been re-organized under 6 main departments (located either at University Hospital Lund, or Malmo General Hospital-MAS).

within the Medical Faculty can also be explained by the culture of the department, closer relations to industry and participation in competence centre such as Swegene Center for Integrative Biology, Biocatalysis (BIOCAT), and Vinn excellence centre for Drug Development (VIDD).

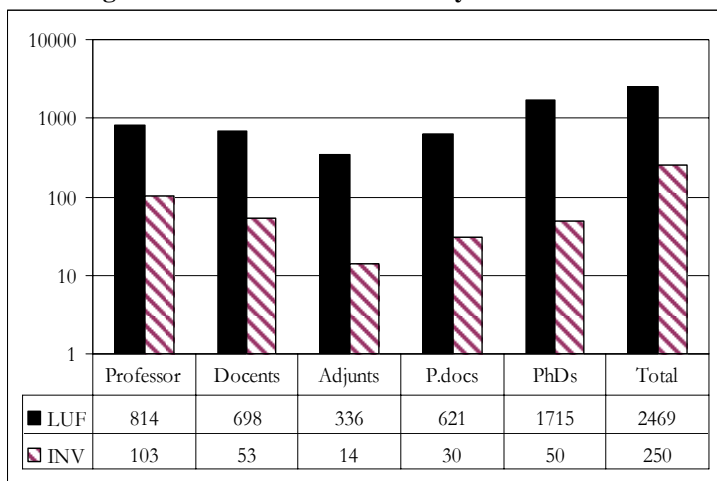
However, when comparing departments & faculties in terms of patenting, it should be noted that departments and faculties vary in size (number of faculty, research expenditure, types of research etc.). The different budgets and research personnel allocated to different departments may affect the research profile and capacity of the departments. For instance, the number of faculty at LTH is 1802, at the Medical Faculty 1610, and at the Natural Sciences 802. The industrial funding that LTH-faculty receives and the industrial networks they have may be higher than has the NS-faculty.

5.2 Basic Characteristics of Inventors

“Academic rank, scientific field, employment status, gender, age and even residence of inventors” are investigated. The basic descriptions of the inventors by these aforementioned features would imply what sort of faculty members are involved in patenting. This analysis may help us to distinguish what might be the main the motivations and incentives of each group of inventors. This analysis would also indicate if there is any specific group of faculty who was not involved in patenting.

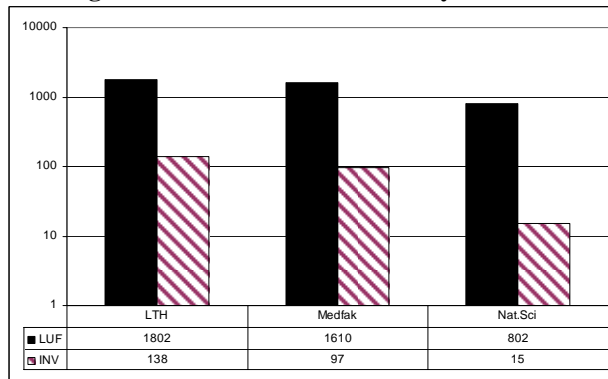
Fig.7 shows the distribution of inventors by academic ranks. Most of the patenting activity is concentrated among professors (103), it is followed by associate professors (Docents, 53), PhD students (50), and Post-doctoral fellows (including assistant professors). A special group is the university employees who are adjuncts (working part-time at LU). Out of 366 adjunct-employees, 14 of them are inventors. The reasons behind the higher number of professors can be explained by life-cycle theories. Scientists start patenting when they are established in their careers. It is also expected that professors can identify the patentability of research results and they are in most cases the principal investigators of projects. They hence become listed as inventors in most cases. Third, they may have more contacts and networks with industry or TTOs which can help them to patent more.

Fig. 2 Distribution of Inventors by Academic Rank



Classification of inventors according to their scientific fields are reflects which faculties are patent intensive. Accordingly the inventors are classified by their scientific fields at the time of the patent application.

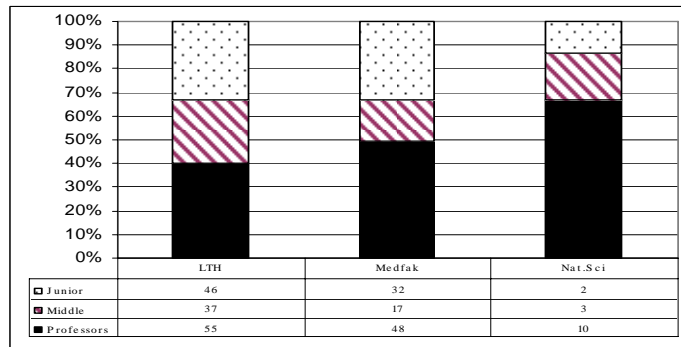
Fig. 3 Distribution of Inventors by Faculties



According to Fig.8 LTH has the highest number of inventors (138 out of 250), it is followed by the Medical Faculty and finally there are 15 inventor-researchers affiliated with Faculty of Natural Sciences.

One step further, the inventors are grouped into three main levels: seniors (full professors, professor adjuncts), middle-level (associate professors), and juniors (post-docs, assistant professors and PhD students). After this classification, the inventors are distributed by their scientific fields. Fig.9 shows the distribution of inventors by academic ranks and scientific fields.

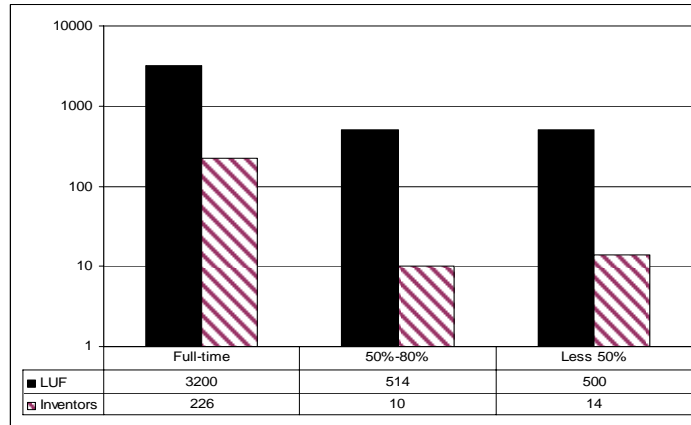
Fig. 4 Distribution of Inventors by Academic Ranks & Scientific Fields



At the Natural Sciences, 10 of the inventors are full professors as compared to 5 inventors who are either at their middle or early levels of their careers. At the Medical Faculty, the number of professor-inventors is 48, and the number of inventors from other ranks is 49. At LTH out of 142 inventors, professor-inventors are 55, while the total of other groups is 83.

Fig.10 shows the distribution of inventors by employment status. Most of the LU-inventors are employed full time. The inventors who have less than half-time employment are mostly adjunct professors. Their patents need further identification if those patents were the direct results of their activities at their industrial jobs, or a result of interaction with their university colleagues. However even these patents are mainly resulting from their activities at their industrial jobs, it is most likely that their tasks in both places are mostly overlapping and complementing each other.

Fig. 5 Distribution of Inventors by Employment Status



Another implication is on the ownership of such patents. Should the patents resulting from the collaborative works with industry belong to the firm directly or it should be co-ownership with university or with the inventor? It is expected that a legal involvement of university, e.g. in the form of a TTO, would most likely yield to tensions between the inventor and the firm.

Fig.11 shows the distribution of inventors by gender. The number of women inventors is quite low, compared to their total employment at LU.

Fig. 6 Inventors by Gender

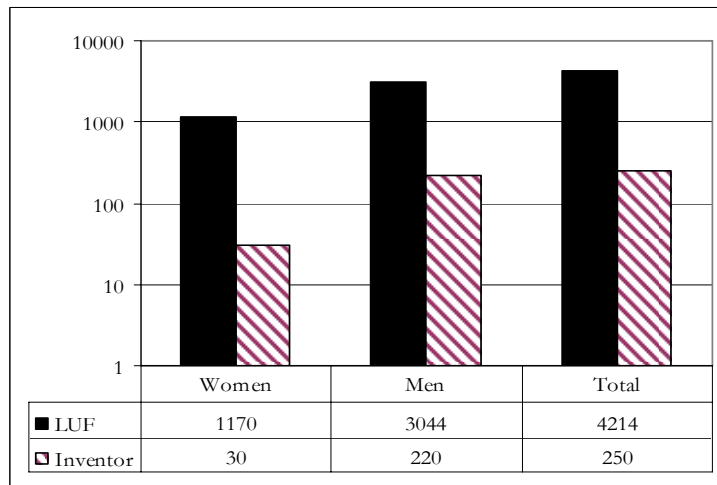


Fig.12 shows the distribution of inventors by gender & age. Similar to the academic ranking discussions, it is problematic to determine the impact of age on the productivity of the scientists.

Fig. 7 Distribution of Women Inventors by Age

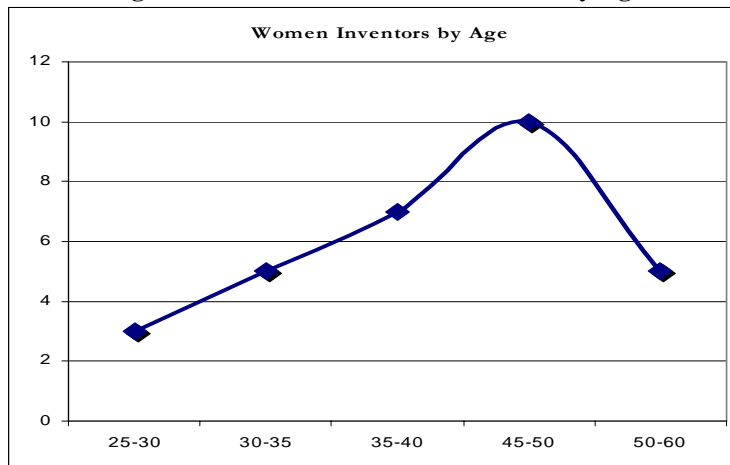
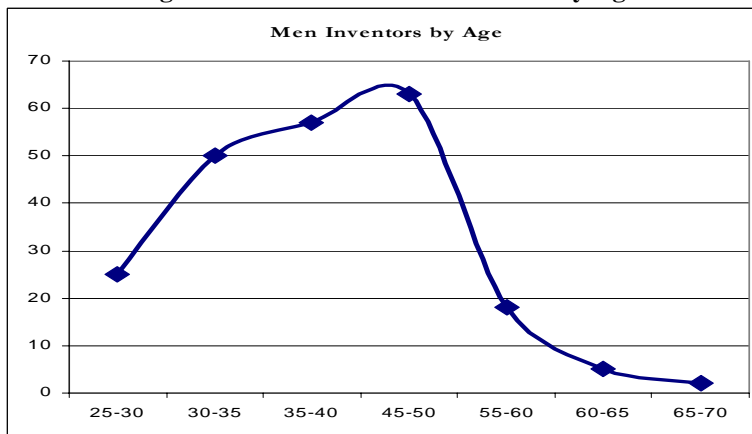


Fig. 8 Distribution of Men-Inventors by Age

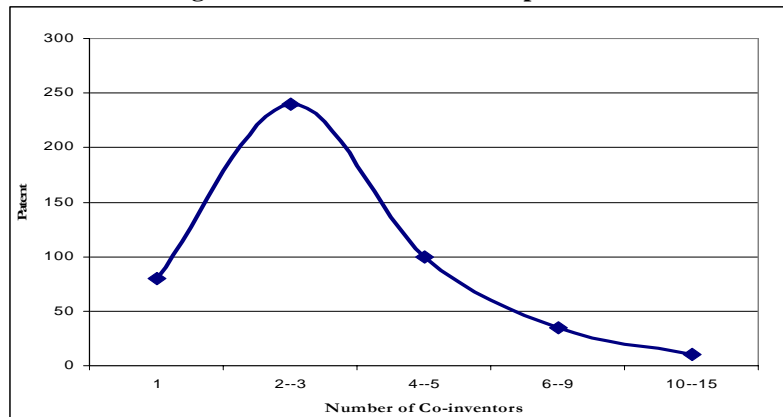


The findings show that the numbers of men and women inventors are highest between the ages 45-50. The oldest man inventor at LU is around 60, while it is 50 for woman. The age of the youngest inventor for both men and women is around 26 to 30 which may be during their doctoral education. Yet women inventors have started to do patenting later than the men.

Number of inventors per patent

Fig.14 shows the number of co-inventors per patent. Around 80 patents have single inventors, while patents invented by groups of two to three inventors reach a peak of around 200 patents out of 458. The number of patents decreases to 100 as the number of inventors increased to four to five. The number falls below 50 for patents with more than six inventors.

Fig. 9 Number of Co-inventors per Patent



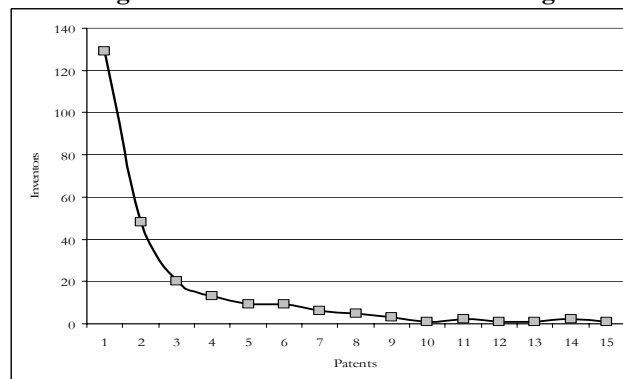
The breaking-down of the number of co-inventing over time (year by year, and over three and five years) do not yield any noteworthy differences. In different time periods, patents with two to three inventors are found the most common.

With regard to clustering based on technological fields, while chemistry related patents slightly higher co-inventors, traditional engineering sectors (machine tools, controls) have lesser co-inventors. However differences are not very significant. (The number of the co-inventors and the size of research groups (e.g. co-authorship, role or researchers who were not listed as inventors) are investigated further in Göktepe, 2007.

Skewed distribution of patenting activities

It was found that out of 250 inventors, 130 of them only have one patent. After the fifth patent, the number of inventors is decreasing sharply. The Fig.15 shows a skewed distribution of patenting activity. Five times of patenting could be considered as a threshold level for becoming a more patent productive inventor. The number of inventors who have five or more patents is 40. These 40 inventors are named serial inventors. This implies that university patents are concentrated on some serial inventors.

Fig. 10 Skewed Distribution of Patenting



Basic explanations behind this skewed distribution of patenting goes back to Lotka's Law. I assume ability to recognize the patentability of research result, having resources to apply for patent, learning to patent are some of the factors that may enable and motivate scientists to patent further. The more they do patenting, the more they learn what is patentable and how to apply for a patent, and even they might have established their networks to get their research results patented.

Hence the process becomes less burdensome. The details of the skewed distribution of patenting, role of serial inventors and their research group (members) are analyzed in Goktepe, 2007.

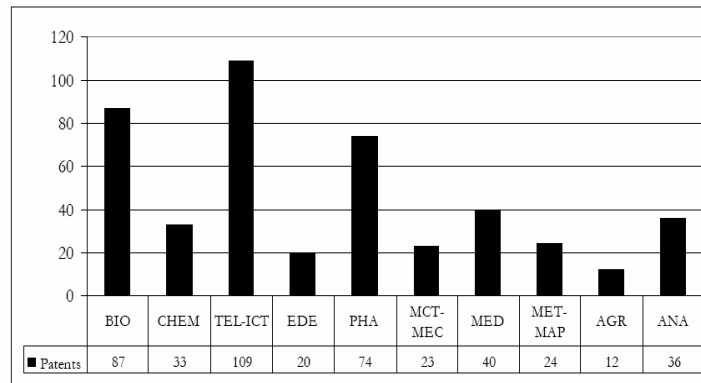
5.3 Basic Characteristics of the Applicants of LU-Patents

This part focuses on the applicants of the LU-patents. There is a burgeoning amount of literature examining when, why, how and which types of firms that collaborate with university and faculty (e.g. Community Innovation Survey etc.). This Section investigates the applicants of patents as a proxy to investigate the nature of relations between LU and industrial partners according to type, sector and location of firms.

Distribution of patents by technological classification

LU-patents are classified according to technological and industrial sectors.¹⁵ According to Fig.16 Pharmaceuticals, biotech, and ICT (including telecom) are the largest sectors. The number of patents in Telecom-ICT is 109. It is followed by biotechnology (87) and pharmaceutical sectors, 74. Most of the Telecom-ICT patents are reflecting the dominance of telecommunications sector in the Swedish Economy and presence of Ericsson close to Lund University. Dominance of biotechnology and pharmaceutical patents are closely related to the strong Medical Faculty, Department of Chemistry, university-industry consortia, e.g. Swegene, Bio-separation etc. Importance of strong patent protection as well as recognition of this field as an important sector and thus availability of investors and industrial demand for these fields triggered higher number of patents.

Fig. 11 Distribution of Patents by Technological Field (1990-2004)



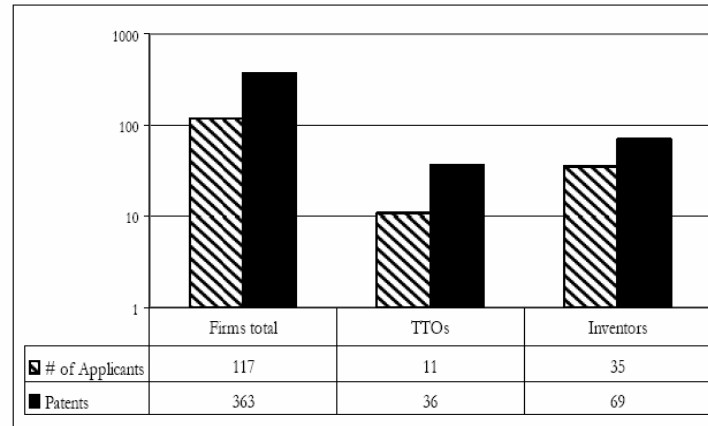
The region Skåne is traditionally strong in agriculture sector in Sweden; however there are relatively less patents in the agriculture field. This is partly due to the lower needs for patent protection in agriculture and lack of connections between agriculture sector and university researchers. This has changed recently, due to needs for functional foods, alternative production methods, better preservations, etc. A number patents in agriculture have been taken. They are resulting from the Divisions of Food Engineering and Food Technologies at the Departments of Chemistry at Lund University together with industrial participants from Food Innovation Network.

¹⁵ The classification scheme was originally developed by the Fraunhofer Institute in collaboration with the French Science and Technology Observatory-OST and IP agency INPI (Meyer et al., 2003). The scheme is based on the International Patent Classification and provides a more aggregated view of patenting by distinguishing thirty technological sectors. Full list and the abbreviations can be found the in the Appendix.

Applicants of LU-patents

Fig.17 shows how LU-Patents are distributed by different types of applicants. Firms are the main applicants of patents; in total (116) firms applied for 353 patents. 69 patents were applied for by the inventors themselves. Those 69 patents are unassigned to any company at the time of application. Inventors most probably assign (license-sell or give) the patents to firms after the application.

Fig. 12 Distribution of Patents by type of applicants (1990-2004)

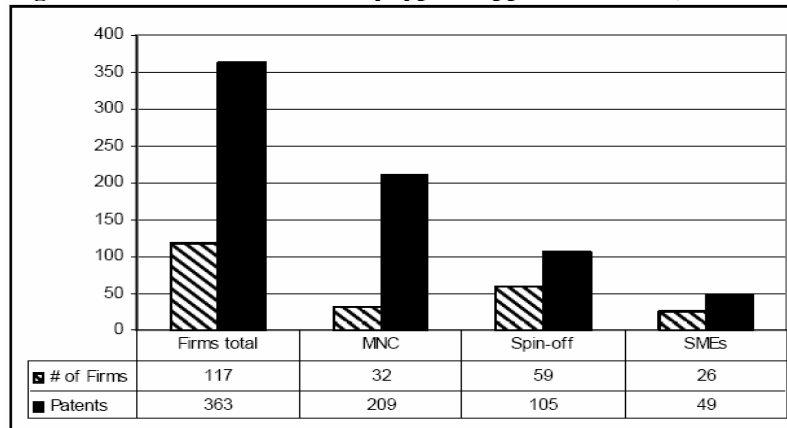


In total 11 technology transfer organizations (3rd agents e.g. Forskarpatent i Syd AB, BTG international) or public research institutes (e.g. Lund University and several other research centres) applied for 36 patents.

Types of industrial firms

Fig.18 shows the distribution of patents by type of applicant firms. The number of large firms (32) is less than the number of spin-offs (58) as applicants of LU-patents. However, the number of patents applied for by large firms (209) is higher than the total number of patents applied for by SMEs (48) and Spin-offs (95). This reflects the dominance of large firms in the Swedish economy and in access to university knowledge.

Fig. 13 Distribution of Patents by type of applicants firms (1990-2004)



These findings have different implications to understand whether university research results are absorbed by the existing companies (incumbents). On the other hand, despite dominance of big companies, e.g. Ericsson, there has been substantial amount of spin-off companies. There is no

evidence that Swedish universities are not generating spin-offs at all or all of their research results are taken by existing (incumbent) firms.

Distribution of the applicant firms by technological field and size

Table 3 shows the distribution of different types of applicants (i.e. firms, inventors and TTOs) by technological fields of patents. In Pharmaceuticals and Chemistry individual applications are the most common. Higher levels of individual applications could be explained by the fact that inventors aim to show the value of their research results by applying for patents to the firms. Especially these sectors are dominated by traditional large firms and some of these firms may be reluctant to undertake the “newer university research results”, yet an existing patent application may increase the interest of the firms while it increases the bargaining power of university inventors vis-à-vis firms.

Particularly after changes in the firms’ structure (loss of the contact person at the firms, closure of relevant programs, or closure of firms e.g. Pharmacia, Kabi AB etc.); inventors may find it difficult to convince the industrial firms to apply for a patent. Therefore they may be inclined to patent themselves and then to find a company to sell or license the patent.

Table:3 Distribution of Applicants by Technological Fields (1990-2004)

Distribution of Patents by T.F. and Types of Applicants			
T.F.	Firm Applicants	Inv- Applicants	TTOs- Applicants
BIO	78	5	4
CHEM	17	13	3
TEL-ICT	105	2	2
EDE	8	6	6
PHA	50	20	4
MCT-MEC	19	0	4
MED	31	4	5
MET-MAP	17	5	2
AGR	4	4	4
ANA	34	0	2
Total Patents by different applicants	363	59	36

On the other hand, firms may take the advantage of inventors when they actually disclose their research results to the firms. For instance due to the weaknesses of non-disclosure agreements and the possibilities of being cheated by the firms; inventors could again be motivated to patent in advance as to protect themselves against firms.

Distribution of applicant firms by technological field and types

Table 4 shows the distribution of the applicant firms by the technological field and types. There are 105 patents in ICT sector, but there are only 8 companies, in which 80 of the patents are applied for by one large company (i.e. Ericsson). To some extent the majority of large firms are in the pharmaceuticals, chemistry and electronics. In mechanics and biotech, there are more SMEs and spin-off firms.

Table:4 Distribution of Applicant Firms by Technological Field and Types (1990-2004)

T.F.	Total Patents applied for by Firms	Total Firms	MNC		Spin-offs		SMEs	
			# MNCs	Patents By MNCs	#of Spin-offs	Patents by Spin-offs	#of SMEs	Patents by SMEs
BIO	78	38	5	15	19	39	14	24
CHEM	17	10	7	12	2	2	1	3
TEL-ICT	105	8	3	95	3	4	2	6
EDE	8	7	0	0	5	6	2	2
PHA	50	16	8	35	4	5	4	10
MCT-MEC	17	15	1	1	13	14	1	2
MED	31	10	3	18	5	10	2	3
MET-MAP	19	6	1	1	4	17	1	1
AGR	4	3	1	1	2	3	0	0
ANA	34	4	3	31	1	3	0	0
	363	117	32	209	58	103	27	51

Mapping of LU-patents' Applicants

Distribution of Applicants firms by Location		Distribution of Patents by Types of Applicants			Distribution of Patents by T.F. and Types of Applicants				Distribution of Applicants Country				
Location	Patents	Type	# of applicant	Patents	T.F.	Firm App.	Inv. App	TTOs App	SE	EU	US/overseas	Total Firms/Patents	
Lund	201	MNC	32	209	BIO	78	5	4	28	5	5	38	78
Skåne	28	Spin-off	58	103	CHEM	17	13	3	6	4	0	10	17
Sweden	72	SMEs	27	51	TEL-ICT	105	2	2	4	4	0	8	105
Outside	52	TTOs	11	36	EDE	8	6	6	7	0	0	7	8
		Inventors	35	59	PHA	50	20	4	10	4	2	16	50
				458	MCT-MEC	19	0	4	13	3	0	16	19
					MED	31	4	5	8	0	2	10	31
					MET-MAP	17	5	2	3	2	0	5	17
					AGR	4	4	4	3	0	0	3	4
					ANA	34	0	2	4	0	0	4	34
						363	59	36	86	22	9	117	363

Distribution of applicant firms by technological field & geographic location

Table 5 shows that university patents are mostly utilized by firms located in Lund (53). Around 30 of them are located in the Ideon Science Park, which also implies the importance of science parks around universities. After Lund Malmö, Stockholm, Uppsala, Gothenburg and Västerås are the main cities where companies that applied for LU-Patents are located. Few (32) companies that applied for LU-patents are located outside Sweden.

Table:5 Distribution of Applicant Firms by Technological Field & Geographic Location (1990-2004)

T.F.	Total Patents	Lund	Skåne	Other SE	Non SE	Total
BIO	78	15	5	7	11	38
CHEM	17	1	3	1	5	10
TEL-ICT	105	2	1	1	4	8
EDE	8	6	1	0	0	7
PHA	50	5	2	3	6	16
MCT-MEC	19	1	3	9	3	16
MED	17	1	0	3	1	5
MET-MAP	31	6	1	1	2	10
AGR	4	0	2	1	0	3
ANA	34	3	0	1	0	4
Total	363	40	18	27	32	117

Distribution of applicant firms by countries

Table 6 shows that the applicant firms' countries. Sweden is the main country of the applicants. This implies that most of the LU-Patents are applied for by firms located in Sweden. These findings underline the fact that there is not strong evidence that Swedish research result are flowing out of Sweden and causing lower levels of the utilization of research results.

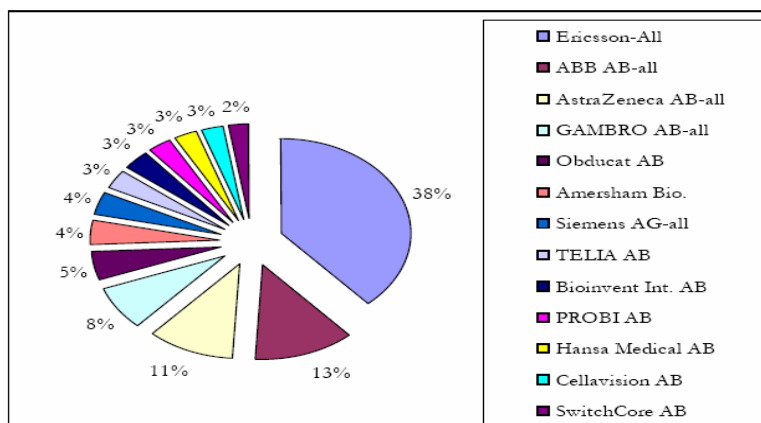
Table:6 Distribution of Applicant Firms by Technological Field and Country (1990-2004)

T.F.	SE	EU	US/	Total Firms
BIO	27	6	5	38
CHEM	6	4	0	10
TEL-ICT	4	4	0	8
EDE	7	0	0	7
PHA	10	4	2	16
MCT-MEC	13	3	0	16
MED	8	0	2	10
MET-MAP	3	2	0	5
AGR	3	0	0	3
ANA	4	0	0	4
	85	23	9	117

Distribution of patents by key applicants

Fig.19 shows that LU-Patents are concentrated to small number of key applicants. Ericsson, Astra-Zeneca, ABB, and Gambro are the key applicants of the LU-patents. Obducat AB, Amersham AB, Bioinvent and Probi AB are small sized firms that spun-off from Lund University and they still have links with the respective researchers at Lund University.

Fig. 14 Distribution of Patents Key Applicant Firms (1990-2004)



6. Concluding Remarks

This study has acknowledged the main findings of the previous studies. I pursued that that in countries where individual ownership is the common practice, the share of contributions of universities to technology transfer in terms of patenting can be best determined by tracking university patents by the names of university inventors, rather than by the names of universities or TTOs. This approach gives a more appropriate picture of the role of universities in technology transfer, especially for a European context (e.g. Sweden, where university technology transfer infrastructure-TTOs- are not only inexperienced, but also quite uncommon to the scientists). The tracking of university inventors illustrates a more inclusive notion of university-related or academic patents and it captures more comprehensively the contributions of academic science to a technological base. Naturally, also academic patents are only one of several indicators of useful research. Due to the individual ownership practices in Sweden, the number of Lund University-owned patents is only 1 out of 458 patents which have at least one inventor affiliated with LU. While they seem to capture the inventive activity of researchers more comprehensively, they still remain a partial measure of scientific contributions to technological change Meyer (2003).

Even though this research has departed from the similar point as the studies for *the identification of university patents and inventors* it aims to go well beyond these studies. The common conclusion of the studies on university patenting in Europe is that European Universities are actually patenting and they are as entrepreneurial as their American counter-partners even without the Bayh-Dole Act. This conclusion has few implications. Different technology transfer infrastructure and patent legislations at European universities require a different methodological approach. Finding the names of university scientists by matching with the inventors of patents rather than cursory investigation of the names of universities or TTOs as applicants for patents gives a better picture of the propensity of university patenting. In countries where universities don't own the patents researchers still make a substantial contribution to technological development. European universities do not necessarily need to emulate the Bayh-Dole Act in order to increase university patenting. European university scientists may be as inventive and /or entrepreneurial as their U.S. counterparts.

I found that researchers are not islands and research (patenting) is a collective, interactive process which involves more than one actor. Involvement of an industrial researcher or a researcher with some industrial background has become quite common. University scientists who were involved in competence centres, like Bioseparation, Swegene, Functional Food Centre, or in joint centres of different faculties were listed as inventors more often than non-participating scientists. These platforms also provide a substantial number of patents and spin-off companies. Triple Helix dynamics seemed to be achieved through top-down initiations of the governmental actors. On the

other hand since a substantial amount of the patents resulted from the individually initiated relations with industry, I found bottom-up motivations. This model of triple helix relations is resulting from the synthesis of bottom-up (individual) and top-down (government) initiations, instead of following a single mode. Thus e.g. abolishment of university teachers' privilege law, and adoption of Bayh-Dole model will not increase relations between these actors.

In this study, a total of 458 patents with 250 university-researchers as inventors were identified at Lund University. This means that Lund University-related patents (LU-patents) account for at least 2% of the total amount of national patents (1990-2004). One must bear in mind that this is a conservative measure since only four /five years of personnel register were available for the analysis, compared to 15 years of EPO database. As there are long examination times, especially for life science related applications, not all inventive activity in these areas could be investigated here.

Inventive activity is shown to be concentrated in terms of both inventors and faculties. I have identified 40 serial inventors who are quite prolific in patenting. This study showed that some departments (i.e. electronics, telecommunications, physics, mathematics, chemistry, biotechnology, laboratory medicine) account for the highest number of LU-patents.

Similarly to the inventor concentrations, there is also a concentration on key assignees. Mostly large firms are applicants (e.g. Ericsson or Astra Zeneca) of LU-patents. In total 11 technology transfer organizations applied for a 36 patents. The chief technological contributions of Lund University-based inventors are in biotechnology, pharmaceuticals and telecommunications sectors. Foreign-owned LU-patents invented in Sweden but owned by overseas organizations are limited. Although most of the patents are owned by big companies (i.e. Ericsson, AstraZeneca Gambro etc.); there are around 40 spin-off companies, and several SMEs which are related to LU employees or had been started by former LU-employees. Finally, only a limited number of foreign companies are applicants of LU-patents.

This Chapter argues that the relation between knowledge, invention, innovation and patents is not linear. It suggests that it is unrealistic to expect that all investments to R&D (universities) will lead to knowledge that is patentable and/or commercialized. Only a sub-set of knowledge can be commercialized. Second, by adopting an extensive research strategy, this Chapter constructs the university patent and inventor data base to analyze the extent of patenting at a Swedish University for further qualitative and quantitative studies on the factors that motivate, enable scientists to patent or factors that influence the scientists' decision to patent.

References

- Acs Z, Audretsch D, Feldman M (1992) Real effects of academic research: a comment. *American Economic Review* 82: 363–367
- Agrawal, A., Henderson. R. 2002 Putting patents in context: Exploring knowledge transfer from MIT. *Management Science* 48 (1) 44–60
- Anselin, L., Varga, A. and Acs, Z.J. 1997 Local geographic spillovers between university research and high technology innovations *Journal of Urban Economics* 42, 422-448.
- Anselin, L., Varga, A. and Acs, Z.J. 2000 Geographic and Sectoral characteristics of academic knowledge externalities, *Papers of Regional Science* 79, 435-443.

- Archibugi, D. 1992 Patenting as indicator of technological innovation: a review, *Science and Public Policy* 19 (6), 357-368.
- Azoulay, P.; Ding, W. and Stuart, T. 2004 The Impact of Academic Patenting in Public Research Output, working paper in www2.gsb.columbia.edu/divisions/finance/seminars/io/
- Balconi, M., Breschi, S., and Lissoni, F. 2004 Networks of inventors and the role of academia: An exploration of Italian patent data, *Research Policy* 33 (2004) 127–145
- Basberg, B.L. 1987 Patents and the measurement of technological change: a survey of the literature, *Research Policy* 16, 131-141.
- Boitani, A. and Ciciotti, E. (1990) Patents as indicators of innovative performances at the regional level, in: Capellin, R. and Nijkamp, P. (eds), *Spatial Context of Technological Development*, Aldershot: Avebury, pp. 139-165.
- Baldini, N., Grimaldi, R. Sobrero, M. 2004 Institutional Changes and the Commercialization of Academic Knowledge: A study of Italian Universities' patenting activities between 1965 & 2002 working paper no. 11
- Bercovitz, J., M. Feldman, I. Feller and R. Burton, 2001, "Organizational structure as determinants of academic patent and licensing behavior: An exploratory study of Duke, John Hopkins, and Penn State Universities," *The Journal of Technology Transfer*, Vol. 26: 21-35.
- Blumenthal, D., Gluck, M., Lewis, K.S., Stoto, M.A and Wise.D 1986 University-industry relations in biotechnology: Implications for the university, *Science*, 232: 1361-1366,
- Breschi, S.; Lissoni, F. and Montobbio, F. 2004 The scientific productivity of academic inventors: new evidence from Italian data 2004 *Economics of Innovation and New Technology*, 2006 (forthcoming)
- Caracostas, P. and Muldur, U. 1998 *Society, the endless frontier – A European vision of research and innovation policies for the 21st century*, Luxembourg/Brussels (Office for Official Publications of the European Communities) (EUR 17655)
- Cesaroni, F. and A. Piccaluga, (2002) Patenting activity of European universities Relevant? Growing? Useful? Paper presented at the conference 'Rethinking Science Policy: Analytical Frameworks for Evidence-Based Policy' 21-23 March, SPRU-University of Sussex. in <http://www.sussex.ac.uk/Units/spru/publications/imprint/sewps/sewp99/sewp99.pdf>
- Clark, B.1998 *Creating Entrepreneurial Universities*, Pergamon/IUA Press
- David, P. 2003 The Economic Logic of "Open Science" and the Balance between Private Property Rights and the Public Domain in Scientific Data and Information: A Primer, SIEPR Discussion Paper no. 02-30
- Di Gregorio, D., and Shane, S. 2003 Why do some universities generate more start-ups than others? *Research Policy*, 32(2): 209-227.
- European Commission, 1995 *Promoting innovation through Patent, Green paper on the Community Patent and Patent System in Europe*
- Edquist, C. and McKelvey, M. 1996 High R&D Intensity, Without High Tech Products: A Swedish Paradox? Working Paper 161, Department of Technology and Social Change, 23
- Etzkowitz, H. 1983 Entrepreneurial Scientists and Entrepreneurial Universities in American Academic Science. *Minerva* 21:198-233.
- Etzkowitz, H. 1989 Entrepreneurial Science in the Academy - a Case of the Transformation of Norms *Social Problems* 36:14-29.

- Etzkowitz, H. 2001 The Second Academic Revolution and the Rise of Entrepreneurial Science *IEEE Technology and Society*, 22 (2): 18-29.
- Etzkowitz, H., Webster, A., Gebhardt, C. and Terra B. R. C. 2000 The future of the university and the university of the future: evolution of ivory tower to entrepreneurial paradigm *Research Policy* 29:313-330.
- Freeman, C. & Soete L 1997 *The Economics of Industrial Innovation*, London & Washington Pinter
- Geuna, A. 2001 The Changing Rationale for European University Research Funding: Are there Negative Unintended Consequences, *Journal of Economic Issues*, Vol. 35, pp.607-632
- Geuna, A. and Nesta L. 2004 University Patenting and its Effects on Academic Research: The Emerging European Evidence SPRU working paper no.90
- Goktepe, D. & Etzkowitz, H. 2005 Towards an Assisted Linear Model of Innovation: an exploratory study of Technology Transfer Offices in Bos-Wash Corridor, Triple Helix-5 Conference Proceedings
- Griliches, Z. (1990) Patent statistics as economic indicators: a survey, *Journal of Economic Literature* 28, 1661-1707.
- Grupp, H. and Schmoch, U. 1999 Patent statistics in the age of globalisation: new legal procedures, new analytical methods, new economic interpretation, *Research Policy* 28, 377-396.
- Grupp, H. 1998 *Foundations of the Economics of Innovation: Theory, Measurement and Practice*, Cheltenham: E.Elgar.
- Henderson, R., Jaffe, A.B. and Trajtenberg, M. 1998 Universities as a source of commercial technology: a detailed analysis of university patenting, 1965-1988, *The Review of Economics and Statistics* 80 (1), 119-128.
- Jaffe, A.B. 1989 Real Effects of Academic Research *American Economic Review*, 79, pp. 957-70.
- Jaffe, A.B. and Lerner, J. 2001 Reinventing Public R&D: Patent Policy and the Commercialization of National Laboratory Technologies, *Rand Journal of Economics*, 32:1, pp. 167-98.
- Jaffe, A. 1998 Patents, Patent Citations and the Dynamics of Technological Change NBER Publications in http://www.nber.org/reporter/summer98/jaffe_summer98.html
- Jaffe, A. and Trajtenberg, M. 1996 Flows of knowledge from Universities and Federal Labs: modelling the flow of patent citations over time and across institutional and geographic boundaries, NBER working paper 5712.
- Krimsky, S. 2003 *Science in the Private Interest: Has the Lure of Profits Corrupted Biomedical Research* Lanham, MD: Rowman & Littlefield (cited in Auzolay et al. 2004)
- Lucas, R. 1988 On the mechanics of economic development, *Journal of Monetary Economics* 22, 3-42.
- Langinier, C. and Moschini, G.C. 2002 *The Economics of Patents: An Overview Working Paper 02-WP 293*
- Mansfield, E. 1998 Academic research and industrial innovation: an update of empirical findings, *Research Policy* 26, 773-776.
- Mansfield, E. and Lee, J.Y. 1996 The modern university: contributor to industrial innovation and recipient of industrial R&D support, *Research Policy* 25, 1047-1058

- Mansfield, E. 1995 *Innovation, Technology, and the Economy: the Selected Essays of Edwin Mansfield*. Aldershot, UK: Brookfield. (Cited in Auzolay et al. 2004)
- Meyer-Krahmer, F. and Schmoch, U. 1998 Science-based technologies: university-industry interactions in four fields, *Research Policy* 27, 835-851.
- Merton, R.K. 1957 *Social Theory and Social Structure* revised and enlarged edition. New York: Free Press of Glencoe
- Meyer-Krahmer, F. and Schmoch, U. 1998 Science-based technologies: university-industry interactions in four fields. In: *Research Policy* 27, S. 835-851
- Meyer, M. 2000 Does science push technology? Patents citing scientific literature, *Research Policy* 29, 409-434
- Meyer, M., 2003a Academic entrepreneurs or entrepreneurial academics? Research-based ventures and public support mechanisms, *R&D Management* 33 (2) 107-115
- Meyer, M., 2003b Academic patents as an indicator of useful research? A new approach to measure academic inventiveness? *Research Evaluation* 12 (1) 17-27.
- Meyer, M., Goloubeva, T. and Utecht, J.T. 2003a Free Patent Information as a Resource for Policy Analysis *World Patent Information* 25 (3) 223-231.
- Meyer, M., Siniläinen, T. and Utecht, J.T. 2003b Towards hybrid Triple Helix indicators a study of university-related patents and a survey of inventors, *Scientometrics* 58 (2) 321-350.
- Miyata, Y. 2000 An empirical analysis of innovative activity of universities in the United States, *Technovation* 20, 413-425.
- Mowery, D.C., Nelson, R.R., Sampat, B.N. and Ziedonis A.A. 2004 *Tower and Industrial Innovation: University-Industry Technology Transfer Before and After the Bayh-Dole Act*, Palo Alto: Stanford Business Books
- Mowery, D.C., Nelson, R.R., Sampat, B.N. and Ziedonis, A. 2001 The growth of patenting and licensing by US universities: An assessment of the effects of the Bayh-Dole Act of 1980, *Research Policy* 30, 99-119.
- Narin, F., Hamilton, K.S. and Olivastro, D. 1997 The increasing linkage between US technology and public science, *Research Policy* 26, 317-330.
- Nelson, R.R., 2001 Observations on the Post Bayh-Dole Rise of Patenting at American Universities In *Journal of Technology Transfer*, 26, 1-2, pp.13-19
- OECD 1994 *The Measurement of Scientific & Technological Activities Using Patent data as Science and Technological Indicators*, Patent Manual 1994, Paris OECD, OECD/GD (94) 114
- Owen-Smith, J. and Walter W. P. 2001 Careers and Contradictions: Faculty Responses to the Transformation of Knowledge and its Uses in the Life Sciences *Research in the Sociology of Work*, 10, pp. 109-40.
- Owen-Smith, J. and Powell, W. 2003 The expanding role of university patenting in the life sciences: assessing the importance of experience and connectivity, *Research Policy* 32 (9), 1695-1711.
- Pavitt, K. 1998 Do patents reflect the useful research output of universities? *Research Evaluation*, 7 (2) 105-112.

- Pavitt, K. 1988 Uses and abuses of patent statistics, in: Raan, A.F.J.Y. (ed), *Handbook of Quantitative Studies of Science and Technology*, Amsterdam: Elsevier, pp. 509-536.
- Rapmund, A.; Gulbrandsen, M, & Iversen, E.J. 2005 Light in the Empirical Shadow: Base-lining the Impact of academic patenting in Norway, EPIP Conference Proceedings
- Romer, P. 1990 Endogenous technological change, *Journal of Political Economy* 98 (5), S71-S102.
- Romer, P. 1994 The origins of endogenous growth, *Journal of Economic Perspectives* 8 (1), 3-22.
- Saragossi, S. and van Pottelsberghe de la Potterie, B. 2003 What patent data reveal about universities: The case of Belgium, *Journal of Technology Transfer*, 18, 47-51.
- Schild, I. 2004 Patent or perish. On the nature and role of patenting amongst Linköping University researchers, Working paper, Umea University, Dept of Sociology.
- Shane, S. 2004 Encouraging University Entrepreneurship? The Effect of the Bayh-Dole Act on University Patenting in the United States, *J. of Business Venturing*, 19 (2004) 127-151
- Siegel, D., Waldman, D. and Link. A. 2003 Assessing the Impact of Organizational Practices on the Relative Productivity of University Technology Transfer Offices: An Exploratory Study, *Research Policy*, 32(1), 27-48.
- Stuart, T.E. and Waverly W. D. 2003 The Social Structural Determinants of Academic Entrepreneurship: An Analysis of University Scientists Participation in Commercial Ventures in Academy of Management Conference. Seattle.
- Thursby, J., Jensen, R. and Thursby, M. 2001 Objectives, Characteristics and Outcomes of University Licensing: A Survey of Major U.S. Universities, *Journal of Technology Transfer* 26, 59-72.
- Thursby, J. and Thursby, M. 2003 Industry/University Licensing: Characteristics, Concerns and Issues from the Perspective of the Buyer, *Journal of Technological Transfer* 28, 207-213.
- Thursby, J.G. and Thursby, M.C. 2002 Who is selling the Ivory Tower? Sources of Growth in University Licensing *Management Science*, 48:1, pp. 90-104.
- Trajtenberg, M., 2004 The Names Game: Using Inventors Patent Data in Economic Research Tel Aviv University, NBER and CEPR June 2004 in www.eco.uc3m.es/IEEF/trajtenberg.pdf
- Wallmark, T. 1999 Inventions and Patents at Universities: The Case of Chalmers University of Technology, *Technovation*-17.3
- Verbeek, A., Debackere, K., Luwel, M., Andres, P., Zimmermann, E. and Deleus, F. 2002 Linking science to technology: using bibliographic reference in patents to build linkage schemes, *Scientometrics* 54 (3), 339-420.
- Zucker, L.G., Darby, M.R. and Brewer. M.B. 1998 Intellectual Human Capital and the Birth of U.S. Biotechnology Enterprises *American Economic Review*, 88:1, pp. 290-306. 28