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by

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WHY AND HOW DO SCIENTISTS COMMERCIALIZE THEIR RESEARCH? TOWARDS A TYPOLOGY OF INVENTORS

September 2008

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Abstract

Incentives and assistance provided by TTOs, university policies, patent legislation and scientific disciplines are certainly part of the explanations for academic entrepreneurship. But they are only one facet of the story. Another facet is related to the scientists' motives, expectations and perceptions about the importance and necessity of such activities. There are no comprehensive studies to date that cover both internal and external factors. This is an important, complex and relatively under-researched theme. Our findings suggest that scientists are rarely engage in patenting activities for economic profit reasons or due to institutional and organizational support. Individual relations and networks with firms and other actors found to be important factors for scientists' entrepreneurial activities. Serial inventors act as role models to other scientists and crucial in the creation of an entrepreneurial milieu at the universities, as others would be affected by these behaviours and tend to follow them. However, the fact that university policies and TTOs have provided little incentives for scientists to get involved in entrepreneurship should not be considered to rule out institutional effects.

JEL-classification: O31; O34; O38; B31

Keywords: university patenting, incentives, individual inventors, inventors' typology

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1. Introduction

The focus on the organizational and institutional aspects and outcomes of patenting in the literature on university-industry relations has hitherto largely overlooked the identification of factors that may explain why university researchers patent. Inventors are among the principal actors in the university patenting process. Despite their importance, however, they constitute a much neglected unit of analysis compared to organizations and institutions in university-industry technology transfer (UITT) studies. Little systematic information exists about university inventors. For instance, since the initial discovery of the basic technique for recombinant DNA at Stanford University and the University of California, an increasing amount of research has been conducted on academic entrepreneurship. However, scholars have rarely tried to investigate the inventors of these discoveries (Stanley Cohen and Herbert Boyer), their motivations to patent, how they managed to patent and the problems that they faced. Except for a few studies on individual scientists, inventors have generally, not received the same amount of attention and interest in UITT studies as TTOs, spin-offs and universities. In the light of the analytical framework on external and internal factors behind university patenting this paper investigates in-depth *why and how do university researchers commercialize their research results?*

This paper aims to provide both qualitative and quantitative insights about university inventors and to address factors that may possibly explain the patenting activities of inventors at a large public research intensive university in Sweden. Sweden is particularly interesting to study university inventors and university patenting, because of the country's increasingly unique institutional and organizational set-ups for university patenting. Unlike many other EU member states, Sweden has kept the law on the *university teacher's exception*,¹ a law which allows university researchers to retain the intellectual property rights to their research results. At the same time, Sweden has also created many new TTOs, including university holding companies and other regional technology transfer agents (e.g. Innovationsbron AB, incubators etc.). Sweden has also enshrined in legislation the third task of universities to initiate and contribute to commercial activities, although this mandate has been expressed in more general terms that refer to general interaction with, and communication of research results to the broader society (Jacob et al., 2003). Moreover, many large Swedish firms have for long time had strong connections with leading universities in Sweden (Stankiewicz, 1997; Etzkowitz et al., 2005). Current Swedish policies for the formation of university-industry competence centres or projects with industrial partners have strengthened such relations. Consequently, Sweden's present system provides different routes to university inventors such as patenting individually, patenting through TTOs, choosing among different TTOs to patent through, or patenting through industrial firms.

The discussion thus far has indicated that there is a scientific need (i.e. lack of studies on university inventors) as well as a policy need (e.g. current debates in Sweden and abroad) that motivate further research on university researchers' patenting activities. In order to understand the internal and external factors regarding entrepreneurial activities of scientists, we focused on the population of scientists who have applied for a patent and/or established their own firms or have actively participated in such.

After a brief introduction in Section 1, Section 2 presents the framework used to understand the commercial activities of scientists. Section 3 presents the methodology and the university inventors who responded to the survey. Section 4 discusses the factors that may

¹ Hereafter, for the sake of brevity, I use the term *teacher's exception* in referring to the individual ownership of patents at universities (in Swedish, *Lärarundantaget*). It is also common to use professor's privilege, teacher's exemption, etc. in referring to this law.

influence researchers' patenting activities. In Section 5, a typology of inventors is proposed Section 6 summarizes the main findings and directs the future work.

2. External & Internal Factors behind University Patenting

Universities have been and remain crucial generators of new knowledge, although other kinds of organizations such as firms and research institutes are also increasingly engaged in knowledge production. Universities are not only acknowledged as important organizations for teaching and research; they are also expected to contribute to the development of industrially relevant technologies in modern knowledge-based economies. These developments, among others, have attracted the increasing attention of researchers and policy-makers around the world, especially in the US and Europe, for their capacity to pave the way for the third task activities such as the inclusion of an economic development mandate for universities in addition to their traditional missions of education and research (Etzkowitz and Leydesdorff, 1997; Rasmussen et al., 2006). For instance, university researchers and universities have been encouraged to embark upon collaborations with private companies in the UK (Geuna, 2001). Universities have also been urged to become involved in technology transfer as a way of controlling their own destiny, i.e. in order to continue their other missions and to retain their autonomy (Clark, 1998).

Extensive literature reviews (Rothaermel, 2007; Goktepe, 2008) show that most of the research to date has focused on universities, firms, science parks and TTOs as the most common units of analysis. This stream of studies has mainly pointed to financial, institutional and organizational factors to explain the propensity, outcomes and nature of academic entrepreneurship at different universities. Most of these studies are based on data (number of patents, spin-offs, licensing revenues, etc.) available from TTOs or e.g. the Association of University Technology Managers. These official registers may fail to reflect the actual number of scientists who are involved in commercialization and the actual amount of commercial activities since many scientists may avoid disclosing their inventions to TTOs officially (Markman et al., 2005; Thursby et al., 2006). As a result, official data take into account only university-owned patents and may therefore underestimate the actual patenting activity of scientists. Thursby et al. (2006) have shown that this phenomenon (firms owning patents to university research) also occurs even in the post Bayh-Dole US, although at a relatively lower frequency than in the European cases as shown by Meyer et al., 2003 and other similar subsequent studies.

There are only a few studies that have focused on individual academics. The lack of studies on the role of academic entrepreneurs is significant given the fact that possible negative consequences of commercial activities on traditional tasks (basic research and teaching) of scientists have received a great deal of attention (Gray, 2000). This stream of studies discussed the importance of individual factors such as entrepreneurial traits, age, experience, scientific background for scientists to commercialize their research results. Except for a small number of recent studies on university inventors (Owen-Smith and Powell, 2001; Thursby et al., 2001; Gulbrandsen, 2005; Meyer, 2005; Giuri et al. 2006; Baldini et al., 2007; Bercovitz and Feldman, 2008), most UITT studies have focused on the roles of technology transfer institutions and organizations or on academic entrepreneurs, new venture creation and the consequences of university-industry relations. However, these studies on university inventors have not addressed the phenomenon of university inventors per se, and their relations within their research milieu. They have discussed a few factors to explain why scientists patent. We therefore focus specifically on the literature on university patenting and on university inventors. Several studies have focused on individual scientists and entrepreneurs in the context of university technology transfer, but few have examined the influence of both internal and external factors on the patenting activities of university researchers. The discussion in this paper attempted to integrate internal and external factors. Through an in-depth literature review, several different kinds of explanatory factors were derived deductively from the above mentioned three streams of studies

on university industry relations, particularly previous studies that had proposed explanations for university patenting discussed in Section 4 in the light of the empirical findings.

External and internal factors that have been discussed in the literature are classified in Table 1 in order to show how these factors are grouped. The first category focuses on *internal factors* such as individual skills, characteristics, scientists' age and career, scientific human capital, industrial experience and diversity of career, as well as motivations and values of scientists such as an interest in solving the research question, job satisfaction, social and personal rewards. Some internal factors such as scientists' age and academic position, scientific human capital, industrial experience and diversity of career, image and confidence, social capital and networks may enable scientists to patent by providing the skills and resources needed to do so. On the other hand, some internal factors such as values and expectations regarding academic entrepreneurship, solving the research question, job satisfaction, social and personal rewards, reputation and promotion may trigger scientists' commercial activities.

Table 1 Classification of Factors behind University Patenting

Internal Factors		External Factors	
Triggers	Enablers	Triggers	Enablers
Solving the research question	Scientists' career life cycle	New academic culture	Patent legislation
Job satisfaction	Scientific human capital	Social imprinting	(ownership of patents)
Social and personal rewards	Industrial experience & diversity of career	Scientific discipline & industrial relevance	TTOs
Reputation		Industrial funding and resources	Third task
Promotion	Image & confidence	Society, culture and location	University strategy & policy
Personal income, benefits			
Job security & alternative career options	Social capital & networks		

The second category is *external factors*, which focuses primarily on institutions and organizations such as patent legislation (e.g. the teacher's exception in Sweden), the third task mandate, TTOs, university structure and culture, as well as increasing relations with industry, new academic culture (e.g. social imprinting). Factors such as patent legislation, TTOs, the third task or strategies and policies of university administration enable scientists to patent. These factors may facilitate scientists' patenting activities by providing scientists with the necessary resources, skills and infrastructure. Factors such as the new academic culture, role models, research areas, scientific fields, industrial funding and getting access to external resources may, on the other hand, trigger scientists towards patenting.

3. Data & Methods: Survey of Inventors

The empirical material on which this paper is based was generated by a survey of inventors and entrepreneurs who were identified as a part of larger project on university industry technology transfer in Sweden.² Previous studies, questionnaires as well as the questions and

² The detailed description of the method and data can be found in Goktepe, 2008 and Goktepe-Hulten, 2008.

comments raised by the pilot survey respondents were taken into consideration in the design of the final questionnaire.

Questionnaires were sent to 250 inventors by e-mail on the 25th of April 2006, together with a cover letter. Two e-mail follow-ups and telephone reminders were carried out in May and June 2006. By the end of September 2006, the number of responses totalled 75 inventors out of 250. The overall response rate to the survey was thus around 30 per cent. The relatively low response rate to the survey had several explanations. First, out of 250 inventors, although a lot of effort has been exhausted to find the right contact addresses of all inventors, 40 inventors could not be reached because their e-mail addresses were not correct and they had not been updated. Some inventors were deceased. Second, approximately 10 inventors responded by e-mail or telephone that their patenting activities were no longer current and they had forgotten the details of the patent application process. Another 10 inventors stated that their patents and the research on which these patents were based were not related to their activities at the university. Third, around 10 inventors recommended contacting their co-inventors (e.g. supervisors, project leaders, or industrial partners) since they had not had any active role in the patent application and it was their colleagues or industrial partners who had taken care of the patent application. Finally, a few inventors mentioned that they had already participated previously in other similar studies and they had no time for another one.

3.1. Who Were the Inventors?

The survey results were reported to describe all inventors who responded to the survey in relation to all inventors who were identified in the patent database. However, it should be underlined that because of the relatively limited number of respondents and the low response rate to the survey, we are not generalizing the findings at the scale of university employees as a whole. It should be also noted that some of the responses may suffer from ex-post rationalization, whereby inventors may interpret and respond in an overly positive way or give more reasonable and acceptable answers.³ However, their responses may still provide important information about the inventors' perception of different factors in relation to their patenting activity.

This survey aims to provide more information on characteristics of individual university inventors and their motivations to patent. Table 2 shows the basic distribution of respondents in relation to the whole population of university researchers between September 1999 and September 2004 and that of inventors in the patent database, covering the years between September 1990 and September 2004. We also checked the response rate by each group (i.e. gender, academic ranking and faculty).

Insert Table 2 here

Table 2 Proportion of Inventors Who Responded in Relation to Total University Inventors

Table 2 presents the university researchers, university inventors, number of responses and response rates per each group. Overall response rates were quite similar, although junior inventors and inventors from the Engineering Faculty responded slightly below the average 30 per cent. Based on similar response rates from different groups, it is accepted that sample (responses) was not biased towards any group.

Employment status of the inventors is also relevant to understand further if the patent is closely related to the research at the university or not. Almost all inventors were employed full-

³ When people find themselves in unexpected situations, they may modify their preferences and beliefs in order to justify the current situation and avoid appearing irrational. This is a process of ex-post rationalization, namely a form of rationality that allows agents to organize (and reinterpret) past experiences and actions by relating them to their current situation in a positive way (see Doyle 1992).

time (86.7 per cent) at the time when their research was conducted and their patent applications were made. Except for 10 inventors who responded to the survey, 65 inventors were employed full-time during the patent application. There were 5 inventors (6.7 per cent) who were employed partly by another university during the period under investigation, and another 5 inventors (6.7 per cent) who were employed partly by industry. This result ensures that most of the patents reported in the survey were related to the inventors' university research.

Senior scientists (i.e. professors, associate professors, or docents) accounted for 72 per cent of the inventors, while the rest (28 per cent) were junior scientists (i.e. assistant professors, post-doctoral fellows, or Ph.D. students). Further, 16 per cent of the inventors were also heads of departments or divisions. More than half of the inventors (55 per cent) were also project leaders (principal investigators) of the research that led to their most recent patents. Most research groups were composed of a principal investigator, senior and junior researchers as well as, in some groups, technicians. The academic position of the inventors at the time of the research behind the patent and patent application implies that it is more common that senior researchers and researchers with higher ranks have patented more than junior researchers.

4. Why and How Do Inventors Patent?

Table 3 reports on the main factors influencing the patenting activities of the inventors. We report the descriptive statistics (mean and standard deviation). These factors were divided into two main categories. As summarized in Section 2, we grouped the factors that may influence scientists' patenting activities into *internal* and *external* factors. Inventors were asked to rate the given factors from 1 (not important) to 5 (very important). The aim here is to investigate the extent to which these different factors are important motivations for university researchers to patent. The averages are given in parentheses.

Internal factors

Among different factors behind university researchers' patenting activities, inventors noted an interest in solving research questions (4.31), getting access to materials and funds from industry (4.15), and job satisfaction, i.e. doing something professionally interesting and enjoyable (4.11) as important. These findings indicate that even if university researchers are involved in patenting, their main motivation to patent is highly related to their aims in doing research. As emphasized also in previous studies, doing something professionally interesting and enjoyable and increasing job satisfaction were also deemed to be important factors for inventors to patent (Gulbrandsen, 2005; Giuri et al., 2006; Stephan et al., 2007).

In addition to curiosity-driven research, researchers are motivated to achieve reputation and recognition among their peers (Merton, 1957). Patenting can enhance scientists' prestige and increase their productivity by reaffirming the novelty and usefulness of their research (Owen-Smith and Powell, 2001). The findings of this study also underlined the importance of increasing recognition and reputation (3.04) by showing that the quality and novelty of the research were deemed to be another factor that strongly motivates scientists to patent. Inventors considered academic promotion possibilities (2.43) and publication possibilities (2.46) to be relatively less important factors for patenting than the factor of increasing reputation and recognition.

Slaughter and Leslie (1997), Etzkowitz (1998) and Stephan et al. (2007) questioned the impact of financial rewards and the profit motive in their analyses of the rise of academic entrepreneurship. The findings of this study indicate that even though patents may generate some financial benefits (such as equity shares or royalty fees), increasing personal income (2.37) was not found to be an important factor for researchers to patent. Shinn and Lamy (2006) found

scientists commercial activities is not reducible to the profit motive but entails a more extensive transformation of preferences and representations. That is, the findings showed that any material and monetary gains which scientists sought through patenting mainly involved obtaining materials, research equipment, funding and resources from industry for their research groups and projects (see below).

Inventors were also asked if intentions to have job options in industry or to change from an academic to an industrial career were important reasons for them to patent. Inventors regarded having job options in industry or changing from an academic to an industrial career (2.43) as less important factors influencing their patenting behaviours. This explains why university inventors preferred to remain at the university. One factor stood out as particularly important among a series of different personal traits such as previous experience in patenting, industrial networks and reputation, credibility to attract money and financial and business skills. Having the credibility to attract enough money to be able to finance patenting activities was deemed a relatively important factor (3.63) affecting the patenting activity of the inventors.

Insert Table 3

Table 3 Factors behind Researchers' Patenting Activities

External Factors

University research is often performed collectively. Bercovitz and Feldman (2008) and Louis et al. (1989) have argued the importance of local group norms and culture, training effects, and leadership effects for patenting. We found that researchers adopt the behaviours of other researchers in their research environments. Local colleagues, e.g. peers or supervisors (chairperson), act as role models and influence the patenting activities of researchers (3.90). Industrial partners or collaborators (3.79) and the decisions taken within the research group (3.75) are also important factors for researchers to patent their research results. Inspiration from foreign colleagues (2.45), e.g. through educational or work experience in the US, exposure to the US model, was rated as a relatively less important factor influencing researchers' decision to patent compared to the roles of local colleagues and actors (e.g. senior colleagues, supervisors).

Consistent with previous studies (Lee, 2000), this study showed that scientists were motivated to patent in order to supplement their own academic research. Researchers mainly patented to secure funds for graduate students, gaining access to lab equipment, seeking insights into their own research, and acquiring access to industrial funds and materials either free or at a reduced cost (4.15). Similarly, keeping industrial links that provide access to data, research problems and industrial research expertise (3.18) is also found to be an important factor. Patents can be used to attract industrial funds and may provide a basis for industrial networks and connections.

Although a substantial amount of research underlines the importance of TTOs and university culture and strategies, the survey found external factors such as TTOs and patent legislation not to be critical for the patenting activities of the inventors. The third task mandate is an effort to signal the beginning of a concerted policy effort to change the academic culture of universities towards an entrepreneurship or enterprise culture. However, inventors in this study did not consider such external factors to be important influences on their patenting activities. TTO support (2.36), patent legislation (ownership of patents) (2.46), political support and interest, e.g. the third task (2.63) are considered to be relatively less important factors. Previous studies have found university tradition, encouragement of entrepreneurship and a university strategy and culture for entrepreneurship to be influential in researchers' commercial activities (Roberts, 1991; Franklin et al., 2001; Etzkowitz, 2004). In this survey the university

administration's interest and support (2.61) are found to be relatively less important factors for university researchers to patent.

5. Typology of Inventors

Researchers have hitherto focused on differentiating inventors and entrepreneurs from the rest of the population, while implicitly assuming that almost all inventors and entrepreneurs constitute a very homogenous group. Even though the studies on socio-demographic characteristics of inventors have revealed consistent results, inventors do not necessarily have the same levels of patenting activities and do not necessarily apply for a patent or commercialize in the same way. An analysis that considers university inventors as homogenous actors would have some limitations. We therefore try to distinguish differences and commonalities among inventors instead of simply distinguishing inventors from non-inventors. Inspired by earlier studies on different typologies, or classification of scientists' technology transfer or entrepreneurial activities, in this section we investigate whether, and if so, to what extent, there were any differences among inventors regarding the importance of different factors for their patenting activities.

Etzkowitz (1998: 830; 2002: 134) identified four technology transfer styles among researchers. Meyer (2003) distinguished between academic entrepreneurs and entrepreneurial academics. Gulbrandsen (2005: 55-56) also suggested two types of university scientists: the basic researchers, or researchers who have a clear academic orientation, versus the liminal scientists, who generally have a certain detachment from academic science as well as from the commercial world. Shinn and Lamy (2006) defined three paths of commercial knowledge associated with three profiles. Each profile exhibits a specific academia-enterprise coordination mode. The group labelled "Academics" exhibits a "strategic" mode (formation of an enterprise for scientific objectives). Another category labelled "Pioneers" develops an "imitation-based" mode of coordination (the adaptation of scientist to entrepreneurial objectives). A third group named "Janus" demonstrates a "sequential" coordination mode (an alternating passage between academia and the firm). Each of these modes of coordination accompanies different forms of university-enterprise synergy, and is characterised by different levels of university-enterprise "tension".

In line with these previous studies, we aim to contribute and broaden our understanding of differences among individual inventors. The discussion in this section specifies the main differences among inventors. On that basis, we propose a typology of inventors which is derived inductively from the empirical data and on the basis of the previous literature. The theoretical grounds for the selection of the two dimensions are derived from two sets of studies. (i) Productivity of inventors: the level of patenting activity by inventors (Narin and Breitzman, 1995; Ernst et al., 2000; Lotka, 1926). (ii) Paths for the commercialization of patents: formation of a spin-off firm to apply for and commercially exploit the patent, or patent application and commercialisation by a third party to whom the inventors sell (license, give or transfer) the rights to the patents (Amesse et al., 1991; Jensen and Thursby, 2001; Zucker et al., 2002; Shane, 2003; Lockett et al., 2005). This typology was developed inductively by grouping the respondents along these two dimensions.

Empirically, the typology is thus based on two axes of comparison. With regard to the typology's first dimension patenting activities have been concentrated to a small number of inventors. 135 inventors out of 250 have only one patent, 55 inventors have two patents, and 60 inventors have three or more patents. Inventors who have three or more patents are named serial while those who have less than three named occasional inventors. In the survey, 44 inventors out of 75 have three or more patents. The typology's second dimension concerns the mode of

commercializing patents.⁴ Out of the 75 inventors who responded to the survey, 51 applied for a patent through a *third party* (firms, TTOs) to whom the inventors transfer (license or give) the knowledge. We labelled them as passive inventors. The other 24 inventors applied for and commercialized their patents either by forming a spin-off firm or through spin-off firms they had previously established.

Figure 1 indicates how the 75 inventors are distributed along the two dimensions of the typology of inventors. The distribution is as follows: 17 serial-active inventors; 7 occasional-active inventors; 27 serial-passive inventors; and 24 occasional-passive inventors. In what follows, we describe these four different types of inventors. This description provides insights about the main internal factors that may influence university researchers' decisions to patent. Table 5 summarizes the basic socio-demographic characteristics and backgrounds of the inventors. The aim here is to describe the inventors but rather to complement the discussion about why and how scientists patent their research results.

SA-inventors: These inventors are mainly seniors by age and rank. They are also mainly men. They have commercialized their research results by forming spin-off firms. They have high scientific status, credibility and reputation. This makes it easier for them to be involved in risky activities such as spin-off firm formation. Their credibility and reputation have also lent credibility to their projects and enabled them to attract funding. They have been actively involved in the formation of their companies and have maintained their roles in these companies, even though it is very unlikely that they will change their careers from university to industry. University inventors of this type correspond roughly to the earlier classifications of 'knowledgeable partners' (Etzkowitz, 1998) or 'academic entrepreneurs' (Meyer, 2003). Serial-active inventors almost push their science and research group into industry by initiating spin-off firms.

SP-inventors: These inventors are seniors by age and rank. They are also mainly men. Relations with large Swedish firms are an important basis for patenting for inventors of this type. These inventors have high scientific status, credibility and reputation. They have strong industrial networks, and most of them participate in industry-university research collaboration projects. The external relations of this group implicitly reflect the influences of competence centres and other types of collaborations between researchers and firms. At that time, universities were expected to conduct industrially relevant research and respond to the problems and needs of industry. To some extent, the Serial-Passive inventors are similar to the categories of Etzkowitz's (1998) 'seamless web' or Meyer's (2003) 'entrepreneurial academics'. Their commercialization activities can be seen as more technology or industry driven. They connect their research group with an existing corporate research group and solve the industrial problems. Much of the funding comes from these existing firms in return for the ownership of any intellectual property resulting from the project.

⁴ Some of the patents have not been turned into products or processes or have not led to any commercial success. This typology is a snapshot of patenting activities of inventors as described by the inventors. Therefore, possible changes, if any, in the inventors' mode and number of patenting activities cannot be captured. Patents which might be utilized to create a spin-off firm may later be sold and licensed to existing companies, or vice versa.

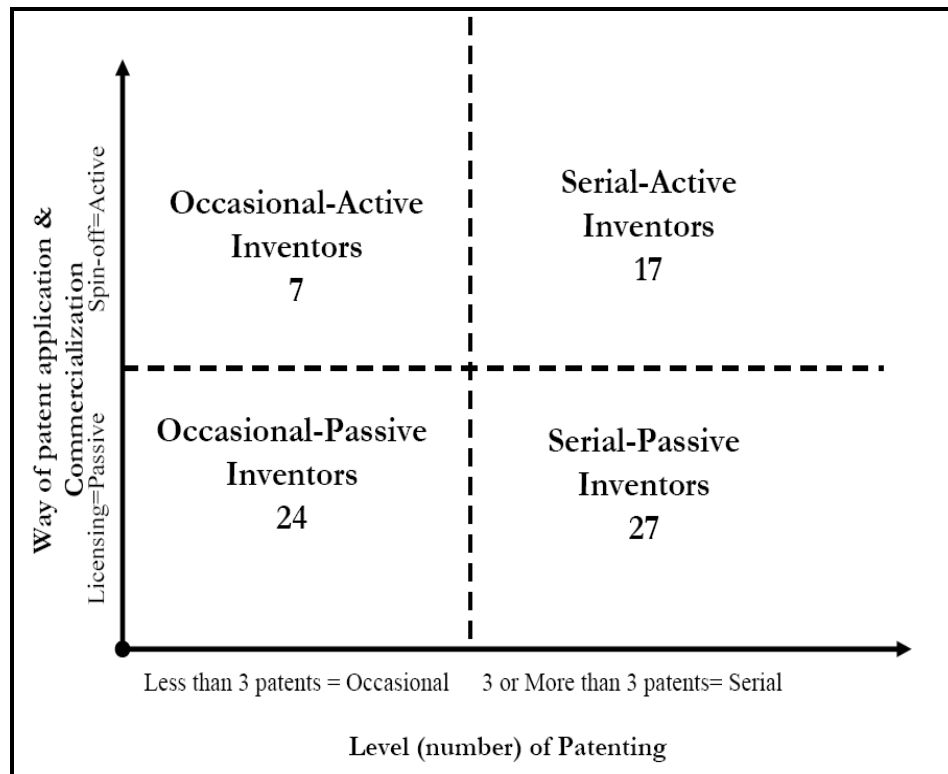


Figure 1 Typology of Inventors

(Source: Author's compilation)

OA-inventors: Occasional inventors are distinguished from serial inventors by a relatively lower level of patenting activities. The occasional-active inventors are relatively the youngest group. There are more inventors with foreign background in this type than in the others. They are junior researchers such as former Ph.D. students and post-doctoral fellows who were mainly men from LTH. Some of them have stated that they have had minor roles in the legal and financial aspects of the formation of their spin-off firms. Some have been employed by these spin-offs. Inventors in this group have a higher possibility of changing career to industry and are more flexible in their plans than inventors belonging to the other types. As some of them consider themselves to have average skills for identifying commercial opportunities, as well as lack of social networks, reputation, credibility and financial means, they have patented with their senior colleagues (i.e. SA-inventors). For their future commercialization activities they need guidance and help to patent. In the past, they have required and received some kind of assistance from TTOs or other actors such as colleagues or industrial partners.

OP-inventors: These inventors also have lower levels of patenting activity. They have utilized their patents through licensing agreements with firms or TTOs. They have become involved in patenting activities recently, but they are senior or mid-level researchers and have a scientific visibility almost as high as that of SP-inventors. There are more women among OP-inventors than in the other types. OP-inventors are one-time inventors and members of large research groups. They have either patented with others in the group who are more experienced (e.g. SP-inventors) or with the help of TTOs. They have a strong academic career focus and minimal ownership and responsibility when it comes to commercialization. They have difficulties in identifying commercial opportunities and have not yet become competent in patent applications. They have patented with TTOs and have preferred to license rather than to form a spin-off firm. Their relations towards patenting and commercialization are the most 'hands-off' of

the four types. In the past, they have required and received some kind of assistance from TTOs or other actors such as colleagues or industrial partners.

5.2. T-test Analysis: Differences among Inventors

In order to assess whether there are differences among the factors behind the patenting activities of inventors as grouped in the typology of inventors, we have conducted two-sided tests examining whether the means of the responses regarding internal and external factors were statistically different.⁵ We performed this analysis in order to assess whether there were differences between (i) active versus passive inventors and (ii) serial versus occasional inventors. The analyses of differences in the means of internal and external factors between active and passive inventors are reported in Table 4.

The results of the t-test analysis show that active and passive inventors differ significantly (at the 0.01 level) with regard to the importance of different factors behind their patenting activities such as: job creation, spin-off formation, the role of foreign colleagues and the role of TTOs. For passive inventors, job creation/spin-off formation is less important than for active inventors. It should be noted that even though the t-test analysis shows a difference between active and passive inventors regarding the factor job creation/spin-off formation, in the typology these groups were actually defined on the basis of the way they utilized their patents. This factor therefore should be interpreted carefully meaning that it rather confirms the relevance of using ‘spin-off versus licensing’ in the categorization of inventors as showing to some extent the differences in the motivations of active and passive inventors.

Passive inventors on the other hand found the TTOs’ support relatively more important than the active inventors did. This could be taken to suggest that while active inventors may not need TTOs in their patenting activities, passive inventors, especially those who may not have industrial networks patented with TTOs. This prompts questioning the roles of TTOs. As discussed later differences among inventors concerning the role of TTOs suggest that while some inventors may prefer or need TTOs, some inventors do not need TTOs at all. Active inventors on the other hand found foreign colleagues relatively more important in influencing their patenting activities than the passive inventors did.

(Insert Table 4 here)

Table 4 T-tests of Differences in Means of Factors to Patent between Active and Passive Inventors

According to Table 4, at the 0.05 level, active and passive inventors differ with regard to earlier experiences in patenting, industrial partner’s decision, keeping industrial links up to date, and university administration support and interest. Individual characteristics (skills and background) and networks are also relatively more important factors for active inventors to patent than for the passive inventors. Finally, active and passive inventors differ (at the 0.10 level) with regard to group decision. This factor reflects the influence of research teams or the collective nature of university research on the individual activities of scientists.

There are no significant differences in the means of inventors’ perception of factors such as solving research problems, job satisfaction, promotion, reputation, publication possibilities, increasing income, local colleagues, the third task, ownership of patents, having industrial networks, having the credibility to attract money, having financial and business skills, and getting access to materials, data and funds. This finding underlines the common factors that motivate all types of inventors towards patenting activities.

⁵The t-test was conducted assuming that the variances in each respective group were not equal.

Table 5 reports the tests of differences in means between serial and occasional inventors. The results of the t-test analysis show that serial and occasional inventors differ significantly (at the 0.01 level) with regard to the importance of different factors on their patenting activities such as: job satisfaction, having industrial networks and reputation, having financial and business skills, getting access to materials and data and funds from industry, and keeping industrial links/collaboration up to date. Serial inventors found 'job satisfaction' to be relatively more important than occasional inventors did. Since occasional inventors have not yet achieved high-levels of patenting activities they might have realized more difficulties in the procedure. Interestingly, occasional inventors have lower expectations of attracting industrial funds and materials through their patenting activities.

(Insert Table 5 here)

Table 5 T-tests of Differences in Means of Factors to Patent between Serial and Occasional Inventors

Serial inventors have also rated internal factors, such as having industrial networks and reputation, having financial and business skills as relatively more important factors for them to patent than occasional inventors did. It is more likely that most occasional inventors have lesser financial and business skills. Serial and occasional inventors differ (at the 0.05 level) with regard to factors like job creation/spin-off formation, previous experience in commercial/industrial work and industrial partner's decision. Serial inventors rated job creation/spin-off formation as more important than occasional inventors did. It can be interpreted that due to the lower activity levels, the latter group has not identified the possibilities of initiating a new business based on a single patent. Since only a small portion of their research has led to a patent, occasional inventors may think it is not enough to start a company around a single patent.

Serial inventors rated their previous experience in commercial and industrial sectors as relatively more important for them to patent than occasional inventors did, who may lack such experiences. Industrial partner's decision also played a more important role in the patenting activities of serial inventors. It is more likely that most occasional inventors have fewer industrial contacts or that they are less known or recognized by the industrial partners.

There are no significant differences in the means of inventors' perception of factors such as solving research problems, promotion, recognition and reputation, publication possibilities, personal income, having credibility to attract money, research group decision, local colleagues, foreign colleagues, TTO support, ownership of patent), political support and interest (e.g. third task), having industrial networks, university administration's interest and support.

5.3. Roles of TTOs

In order to understand further the roles of TTOs on the patenting activities of inventors, inventors were asked in the survey why they had – or had not – used the services of TTOs. The following analysis, which is partly based on the interviews, is important for understanding the extent to which TTOs played a role in motivating scientists to patent. 24 inventors out of 75 have used TTOs, while 51 inventors have not used TTO services. A reflection on the differences among how the inventors perceived the roles of TTOs can nonetheless be summarized as follows.

Six SA-inventors out of seventeen utilized some of the services of TTOs. These services were sought not in relation to patenting, with which they did not need help due to previous experience or links with industry or investors, but principally for the purpose of getting financial help for the formation of spin-offs. Two SP-inventors out of twenty-seven used the services of TTOs. Since they had patented with the help of existing firms, these SP-inventors used TTOs not to apply for the patent but to get help finding an industrial partner. Three OA-inventors out of

seven, and thirteen OP-inventors out of twenty-four used the services of TTOs to patent. Their main reasons for doing so were lack of patenting experience, no time, and no desire to get involved in the legal and administrative aspects of patenting. They also used TTOs to obtain financial help and guidance in finding licensee firms.

The analysis of the fifty-one inventors who applied for patents individually or with the help of existing firms – that is, without using TTOs – can be summarized as follows. Eleven SA-inventors found TTOs not very helpful and ineffective. Several SA-inventors stated that no TTOs existed at the time they had patented. Seventeen SP-inventors did not use TTOs because they patented through their industrial contacts and most of them had already patenting experience. Six OA-inventors identified less bureaucracy and direct relations with investors or industrial partners as their most important reasons for not using TTOs. Seventeen OP-inventors specified existing relations with firms or the existence of an interested industrial partner as their most important reasons for not patenting with a TTO.

Inventors were asked to assess the reasons behind their successful patent applications. Almost all inventors confirmed that the patent's potential commercial value based on industrial interest in, and need for, the patented idea – implying the willingness of firms and/or investors to pay for the patent – were the most important factors that led them to apply for a patent rather than support and incentives provided by any of the TTOs.

SA-inventors deemed patenting experience and knowledge about patenting to be important factors that enabled them to apply successfully for patents. Some SP-inventors found that previous relations with the applicant or licensee firms and achieving consensus with the firms about further payments and royalty fees were important factors that enabled them to apply successfully for patents. They also stated that previous experiences such as education and/or work experience in a university where patenting was common were important factors that led them to make successful patent applications.

OA-inventors stated that agreement within the research group and obtaining support from colleagues and heads of department were important factors behind their successful patent applications. Most of the OP-inventors, on the other hand, considered support from the university administration or the use of services offered by TTOs to be important factors for their successful patent applications. They received assistance from TTOs in such areas as covering the costs of patent applications and help in writing the patent application.

6. Concluding Remarks

Commercialization of university research results is of increasing importance due to the beliefs that new knowledge can play in industrial development and economic growth. Despite the increasing scholarly and policy interest on academic entrepreneurship, the paucity of studies on university inventors motivated us to explore the nature of university patenting further. By reviewing the current studies internal and external factors behind university patenting were identified. In the light of this framework we investigated why and how university inventors' patent. However, since this study is limited to one university and most results are interpreted qualitatively we refrain doing general conclusions. We may still inform some hypothesis that can be investigated with larger samples and cross-university examples. Finally the policy-makers and university administrators may benefit from the implications of this study.

Based on the research findings, university inventors were stratified into four types as a manifestation of the two main dimensions of the patenting activities. First, inventors have been divided into two groups: Serial versus Occasional based on the number of patents they have had. Second, inventors have also been divided into two groups: Active versus Passive based on the way they applied for their patents.

These four types of inventors (*serial-active, serial-passive, occasional-active and occasional-passive*) have different but also similar characteristics and backgrounds. Factors influencing their patenting activities and their patenting process differ to some extent. Inventors have generally considered the ‘personal satisfaction involved in showing that something is technically possible and in solving industrial or societal problems’ as more important than money or career advancement. External factors (such as TTOs, patent legislation, university support) have generally not been the most important factors motivating inventors. However, the roles of TTOs and patent legislation merit further research beyond their sole function of facilitating patenting activities. We therefore investigate such factors in the interviews with different types of inventors in order to capture whether there are any differences among inventors’ perceptions of the impact of external factors.

Although several institutional and organizational attempts have been taken by the Swedish government to promote technology transfer at the universities most scientists got involved in entrepreneurial activities with a personal interest and motivation. Irrespective of the type of inventor, our findings suggest that scientists are modestly engage in patenting activities for economic profit reasons or due to institutional and organizational support. Interestingly, individual relations and networks with firms and other external actors found to be important factors for scientists’ entrepreneurial endeavours. Such scientists (e.g. serial inventors) should therefore be invited to be part of such initiations and act as role models to other scientists. They may be crucial in the creation of an entrepreneurial milieu at the universities, as others would be affected by these behaviours and tend to follow them. However, the fact that university policies and TTOs have provided little incentives for scientists to get involved in entrepreneurship should not be considered to rule out institutional effects. While experience and existing networks of serial inventors may tone down the roles of TTOs, such organizations may still be helpful for inexperienced scientists. The existing classification of scientists can be complemented by the proposed typology of inventors developed as a result of this study.

The overall aim of this exploratory research on university inventors is to better understand the incentives and motivations of scientists in one university setting. We investigated a little-understood actor, i.e. university inventors. This is an increasingly important unit of analysis for Swedish policy makers and university administration due to the law teacher’s exception which gives ownership of intellectual property to the university scientists. The single case limits the applicability of the findings to other organizations. However, the framework and the typology proposed here provide important insights concerning differences among inventors. As such, we contribute to an emerging research interest on university scientists and entrepreneurs in addition to the studies on institutions and organizations. It is also our hope to stimulate a discussion about the fact that inventors are not necessarily alike. Inventors differ not only in terms of their patenting outputs, but also in the sense that their patenting activities may depend on different enabling and/or motivating factors. The results presented above are a snapshot of the activities and views of a number of inventors. To complement and strengthen the arguments put forward in relation to the framework and the inventors’ typology further studies are worth pursuing.

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Appendix

Table 2 Proportion of Inventors Who Responded in Relation to Total University Inventors

	<i>3 Faculties (on average during 1999-2004)</i>	<i>Inventors (EPO: 1990-2004)</i>	<i>Number of responses</i>	<i>Response rate (per cent)</i>
Population	4,214	250	75	30%
Gender				
Women	1,170	30	11	37%
Men	3,044	220	64	30%
Academic Ranking				
Seniors (Professors, Assoc. Profs.)	1,878	170	54	32%
Juniors (Asst. Profs., Post-Docs, Ph.D.s)	2,336	80	21	26%
Faculty				
Medical Faculty	1,610	97	32	33%
Engineering Faculty	1,802	138	38	28%
Natural Sciences Faculty	802	15	5	33%

Table 3 Factors behind Researchers' Patenting Activities

<i>Variable</i>	<i>Responses</i>	<i>Mean</i>	<i>Std. Dev.</i>
To solve research questions	75	4.31	0.59
Materials & data and funds	73	4.15	1.24
For job satisfaction	73	4.11	1.20
Local colleagues	72	3.90	1.23
Industrial partners decision	72	3.79	1.39
Research group decision	69	3.75	1.06
Credibility to attract money	75	3.63	1.15
Financial & Business skills	75	3.37	1.19
Keep industrial links/collaboration	44	3.18	1.72
Having industrial networks & reputation	75	3.17	1.22
For Recognition & Reputation	68	3.04	1.41
Experience in commercial /industrial works	71	2.75	1.09
Political support & interest e.g. third task	63	2.63	1.50
Univ. Administration's interest & support-	61	2.61	1.15
Ownership of patents	47	2.46	1.66
For Publication possibilities	71	2.46	1.10
Foreign colleagues	55	2.45	1.30

Job creation/spin-off	60	2.43	1.29
For Promotion	67	2.43	1.22
Personal income	60	2.37	1.20
TTO support	44	2.36	1.57

* Factors are shown in descending order of importance as rated by the inventors.

Table 4 T-tests of Differences in Means of Factors to Patent between Active and Passive Inventors

Variable /Type of inventor	Active			Passive			t-test H ₀ : X=Y H ₁ : X≠Y
	Obs	Mean X	Std. Dev.	Obs	Mean Y	Std. Dev.	
To solve research questions	24	4.33	0.13	51	4.29	0.80	-0.2659
For job satisfaction	24	4.29	1.23	49	4.02	1.26	-0.8911
For promotion	23	2.57	1.30	44	2.36	1.18	-0.6185
For recognition & reputation	23	3.22	1.44	45	2.96	1.39	-0.7149
For publication possibilities	24	2.54	1.14	47	2.43	1.09	-0.4108
Personal income	22	2.45	1.29	38	2.32	1.16	-0.4138
Job creation/Spin-off	23	3.00	1.50	37	2.08	1.01	-2.5846 ***
Experience in commercial/industrial work	24	3.17	1.12	47	2.53	1.01	-2.3146 **
Having industrial networks and reputation	24	3.42	1.13	51	3.06	1.25	-1.1277
Credibility to attract money	24	3.83	1.37	51	3.52	1.04	-0.9613
Financial and business skills	24	3.58	1.05	51	3.27	1.25	-1.1097
Research group decision	24	4.00	0.97	45	3.62	1.09	-1.4660 *
Local colleagues	24	3.96	1.42	48	3.87	1.14	-0.2488
Foreign colleagues	22	3.00	1.41	33	2.09	1.10	-2.5451 ***
Industrial partner's decision	24	4.21	1.28	48	3.58	1.41	-1.8820 **
Materials, data and funds	24	4.42	1.28	49	4.02	1.21	-1.2612
Keep industrial links/collaboration	22	3.73	1.57	22	2.63	1.73	-2.1822 **
TTO support	19	1.56	0.96	25	3.00	1.65	3.6965 ***

Ownership of patents	19	2.53	1.80	28	2.42	1.59	-0.1907
Political support and interest, e.g. third task	23	2.57	1.37	40	2.67	1.59	0.2877
University administration's interest and support	22	2.27	0.88	39	2.79	1.26	1.8922 **

(* significant at p<0.10 level, ** significant at p<0.05 level, *** significant at p<0.01 level)

Table 5 T-tests of Differences in Means of Factors to Patent between Serial and Occasional Inventors

Variable /Type of inventor	Serial			Occasional			t-test Ho: x=y H ₁ : x≠y
	Obs	Mean x	Std. Dev.	Obs	Mean y	Std. Dev.	
To solve research questions	44	4.36	0.92	31	4.22	0.10	-1.0084
For job satisfaction	42	4.43	1.01	31	3.61	1.40	-2.6344 ***
For promotion	40	2.38	1.21	27	2.52	1.25	0.4690
For recognition & reputation	41	3.00	1.28	27	3.11	1.60	0.3022
For publication possibilities	41	2.49	1.09	30	2.43	1.13	-0.2025
Personal income	36	2.47	1.20	24	2.21	1.21	-0.8264
Job-creation/Spin-off	34	2.71	1.31	26	2.08	1.19	-1.9328 **
Experience in commercial/industrial work	42	2.90	1.10	29	2.52	1.05	-1.4939 **
Having industrial networks and reputation	44	3.50	1.17	31	2.71	1.16	-2.8934 ***
Credibility to attract money	44	3.75	1.16	31	3.45	1.15	-1.1010
Financial and business skills	44	3.70	0.95	31	2.90	1.35	-2.8415 ***
Research group decision	43	3.86	1.60	26	3.57	0.90	-1.1401
Local colleagues	41	4.00	1.32	31	3.77	1.11	-0.7842
Foreign colleagues	34	2.56	1.30	21	2.28	1.30	-0.7520
Industrial partner's decision	41	4.12	1.24	31	3.35	1.47	-2.3338 **
Materials, data and funds	42	4.50	0.91	31	3.68	1.46	-2.7468 ***
To keep industrial links/collaboration	24	3.83	1.55	20	2.40	1.63	-2.9635 ***

TTO support	26	2.15	1.54	18	2.67	1.60	1.0575
Ownership of patents	30	2.40	1.67	17	2.59	1.69	0.3671
Political support and interest, e.g. third task	38	2.55	1.48	25	2.76	1.56	0.5259
University administration's interest and support	36	2.58	1.07	25	2.64	1.28	0.1805

(* significant at $p < 0.10$ level, ** significant at $p < 0.05$ level, *** significant at $p < 0.01$ level)

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