UNIVERSITY OF GOTHENBURG
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Master Degree Project in Innovation and Industrial Management

The role of academic inventors in technological innovation and knowledge diffusion in Sweden: The case of nanotech Industry

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"The role of Academic Inventors in technological innovation and knowledge diffusion in Sweden: The case of nanotech industry"

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Abstract

The master thesis project investigates the relationship between academics and the local industry as well as the effect this relationship has to the academic productivity. Nowadays, University-Industry interaction is a common phenomenon in advanced economies. Companies are looking for technological innovation outside the organizational boundaries and universities provide them with the opportunity to acquire and develop new technological innovations.

This paper investigates Swedish academic's involvement in private firms. The paper does not include a cross-sectional analysis for Swedish academics but emphasizes in academics that are involved with nanotechnology. The project examines a dataset of 114 academics in total, 57 authors and 57 authors-inventors. The initial dataset includes data regarding to academics' patents, publications, links and total citations. The dataset was extended including data regarding to academics' participation in private firms and their professional network.

The master thesis project investigates the relationship between academic productivity and academic's participation in companies. Also, the paper examines the degree to which academic inventors develop and commercialize their ideas with the help of private firms. Furthermore, the relationship between professional networking and academic productivity was also examined in the current project. Quantivative methods of analysis are used in order to address the research questions and lead to a valid conclusion.

Key words: Academic Patenting, Academic Entrepreneurship, Open Innovation, University-Industry Interaction, Nanotech Industry

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1. Introduction

1.1) Background of the topic

Nowadays, technological innovation has evolved to one of the most crucial sources of competitive advantage. The vast majority of companies in many industrial sectors, depend on products that have been produced during the last five years (Schilling 2013). As a result, companies invest a lot of financial resources in research and development in order to encourage their innovative activities.

In order to innovate and gain a leading position on the market, companies invest not only in internal but also in external sources of innovation. Many firms establish collaboration networks with universities, NGO's and governmental organizations in order to get engaged in the development of new, innovative projects (Schilling 2013). Universities have been proved to be one of the most valuable source of innovation in the recent years. The scientific output of the academic research project has lasted not only to publications but also to remarkable technological innovations. The vast majority of these innovations are protected by official patent citations (Schilling 2013).

Inventors use to apply for patent protection in most of the developed countries. Patents usually belong to two basic categories, the utility and the design patents. Utility patents include new or significantly improved products or processes while design patents refer to a new design for a product that has already been created (Schilling, 2013). Patent laws and regulations are not the same worldwide. In some cases, there are considerable differences between countries. A representative example is the difference between Sweden and the US. In the US, intellectual property rights for new academic inventions belong to universities. Whatever academic professors produce, it is a property of the university and it is impossible for them to commercialize their idea on their own. Contrary to this regulatory framework, Swedish academics own the property rights for inventions they have produced in the university (Vinnova, 2000).

Swedish regulations would possibly encourage the Swedish academics to increase their scientific output. Also, these regulations could provide Swedish academics with an incentive to participate in entrepreneurial activities.

1.2) Research Question

This master thesis targets to investigate the degree to which academic patenting encourages academics' participation in private firms. Specifically, the paper will investigate the relationship between academic patenting and academics' board membership in private firms. Also, the survey targets to investigate the relationship between academics' board membership and professional networking. Furthermore, this paper will examine the degree to which professional networking and academic's productivity are correlated. More specifically, the current thesis work will try to answer the following questions:

1) How does academic patenting affect academics' participation in companies?
2) Do academic inventors need support from private firms in order to commercialize their ideas?
3) What is the relationship between professional networking and academics' participation in companies?
4) What is the relationship between professional networking and academic's scientific output?

1.3) Purpose of the research

Although the available literature provides us with important information regarding to academic publications and patents, there is not enough information to support the relationship between scientific excellence and academics' participation in companies. This research project targets to fill the gap in the existing literature and provide solid evidence for the degree to which academic authors-inventors are active in the private sector. Specifically, the analysis of the quantitative data will enable us to know the way academic publications and patent citations affect authors' involvement in companies. Furthermore, the results will enlighten the extent to which academic patents increase the engagement of the inventors in private companies. Do authors- inventors participate in more companies than the other authors?

Furthermore, the master thesis project will investigate the role of professional networking in academic's productivity and collaboration with industry. The paper will examine whether the relationship between networking and academic patenting is positive or not. Since scientific output is not only measured by patents but also by academic publications, the relationship between networking and publishing will be examined as well.

The current master thesis project is closely related to open innovation, one of the most important topics for private firms. Nowadays, higher education institutions are considered as a significant source of innovation for the public and the private sector. Companies are trying to collaborate with universities in order to attract scarce talent and find external sources of innovation. As it will be discussed in the theoretical framework, the role of academic inventors in private firms is very important. Especially in the hi-tech sector, private firms are trying to establish relationships with academic inventors, in order to benefit from their patents.

Sweden belongs to countries that allow academics to retain intellectual property rights for their patents. This way, academics are able to develop and commercialize their patents on their own. The Swedish academic patent law has created many possibilities for collaboration between companies and academic inventors. Although academics are able to make a start-up and apply for patent recognition, it is not always possible to do this. Patent applications are associated with high costs that most academics cannot afford that costs. For that reason, the most realistic way to commercialize their ideas is to collaborate with existing large firms. The establishment of University-Industry collaboration strategies leads to knowledge diffusion from universities to companies. The result of this diffusion is the development and commercialization of new patents by private firms. This paper targets to examine the degree to which academics are collaborating with industry as well as the effect of this collaboration to the innovation process.

1.4 Overview

The master thesis project starts with the introduction of the research topic. This part will start by providing information about the theoretical background of the topic. Specifically, this part will introduce us to the concept of innovation and the role of academic patenting in the protection of innovative projects. The introduction part

will continue with the research question that the current thesis targets to answer. Useful information regarding to the purpose of this thesis project will be provided. Also, the motivation for investigating this specific research question will be presented.

The second part of this thesis project will include the theoretical framework in which the whole project is based on. In this part, the available literature about the research topic will be presented. This part will enable the reader to understand how the research question was formed. The information in this part will let us know if the existing literature is sufficient and what is the real contribution of this project.

The third part of this research will include the empirical findings of the research process. This master thesis project will be based on a case analysis about academic patents in the field of nanotechnology in Sweden. The dataset includes a number of academic authors that do not have patent citations and an equal number of authors-inventors. The use of descriptive statistics and applied econometrics will provide us with useful information regarding to the way scientific and technological excellence affect academics' participation in companies. Specifically, we will be able to examine if the academic inventors tend to get involved with the private sector more than the correspondent authors. We will also be able to understand the degree to which academic patenting affects participation in companies. The outcome of the data analysis will make it possible for us to answer the research question as well as to confirm or reject the hypothesis that is connected to this question.

The master thesis project will finish with the conclusion of this research. This part will summarize all the information given in the theoretical framework and the analysis part and will present the final conclusion of this thesis project.

2. Theoretical Framework

2.1) University-Industry interaction

Nowadays, the capitalistic system becomes more and more knowledge intensive, as time passes. In this system, universities have evolved to one of the most important accelerators of the economic progress (Stehr, 1994). Universities are considered to have three basic missions in our time.

The first mission universities have is transferring knowledge to society through the educational process (Salter and Martin, 2001). In a knowledge based society, the role of academics has significantly been upgraded, since they contribute to the transition of knowledge from universities to the private sector (Stehr, 1994). Governments in modern societies have realized the role of knowledge as an accelerator of innovation and economic development. As a result, knowledge diffusion from the academic environment to the industry is a serious aspect for policy makers (Bourelos, 2013). The transfer of knowledge between universities and firms takes place through many different channels. These channels have a big variation based on the type of knowledge that is transferred, the intensity of personal relations as well as the direction to which the knowledge is transferred (Schartinger et al, 2002).

The second mission universities have to complete is to contribute to the technological and economic development throughout academic research. After the academic revolution that happened in the end of the 19th and the 20th century, research has been set as a major long term goal that all universities have to accomplish (Etzkowitz, 1998). In the years that followed the Second World War, governmental funding to universities has rapidly increased. Students are concerned as a connector between universities and companies and academic research as an important source of external knowledge for governments and private firms (Etzkowitz and Leydesdorff, 2000).

The third mission that higher institutions have to accomplish includes interaction with society and the industrial sector as well as commercialization of academic patent. The third mission consists of three channels. These channels are University-Industry interaction (U-I), commercialization of knowledge and interaction with society (Bourelos, 2013). Commercialization of knowledge entails the birth of new firms or academic patents. Although commercialization of knowledge is very important for universities, many of the academic patents are only used to support academic research and thus they are not commercialized (Bourelos, 2013).

Nowadays, there is a shift towards a knowledge intensive economic environment, which has lasted to a strong collaboration between university and industry. Academic research has played a major role in the development of new products and

services, especially for knowledge intensive sectors like the drug industry (Mansfield, 1995). The mutual interaction between industry and higher education institutions has simulated the development of new technological innovations in knowledge intensive sectors like nanotech, biotech and manufacturing industry (Santoro and Chakrabarti, 2002). There are three different types of University-Industry interaction. Specifically, it is possible to have collaboration between universities and existing firms, creation of new firms as well as academic patents that are supported by private firms (Bourelos, 2013).

The strong interaction between universities and companies has lasted in commercialization of academic research. Mansfield made a research about new products and services in the fields of chemicals, oil industry and electrics. His findings suggest that almost 10% of the products and processes commercialized between 1975 and 1985, could not have been developed without the contribution of academic research (Mansfield, 1990). A more recent update on Mansfield's findings investigating the 1986-1994 period, suggests that more than 10% of new products and service could not have been developed without recent academic research findings (Mansfield, 1998).

The adoption of these three missions by universities was followed by a transformation process for all academic institutions. The fact that academic research became a mission, made higher education institutions more productive. Furthermore, the need of interacting with industry and society contributed to the creation of University-Industry links for the accomplishment of the third mission (Bourelos, 2013). In order to strengthen their relationship with the industrial sector, universities introduced the establishment of University research centers. Firms have recognized the value of university research centers, as a source of external innovation. Large companies use to collaborate with research centers in order to encourage research and development within their non-core technologies. For small and medium enterprises like high-tech companies, linkages with universities are more crucial for stimulating innovations related to their core technologies (Santoro and Chakrabarti, 2002).

2.2) Academic patents

The term academic patents refers to patents in which at least one academic is involved as inventor or co-inventor. Academic patents have been widely used as an indicator of measuring innovation, since data related to patents is easy accessible in open-source data bases. The available data about patent citations includes the ownership as well as the inventorship status of each patent (Bourelos, 2013). The fact that modern economies have become knowledge-intensive during the last decades, had a positive effect in academic patents. For instance, university-owned patents in the US, increased from 1% to 2.5% as a percentage of total patents between 1975 and 1990 (Trajtenberg et al., 1997). This upward movement in the number of academic patents, was closely related to the introduction of the Bayh-Dole act (Mowery and Ziedonis, 2002).

The increasing number of university patents does not always entail a high value for these patents. A study of university owned patents in the US between 1965 and 1988, indicates that although the number of academic patents increased over time, the value of patents dropped. This downward movement in patent value, means that a high percentage of university patents did not create significant value for the society and the industrial sector (Henderson et al, 1998).

2.3) The Bayh-Dole Act

Nowadays, higher education institutions are considered a significant source of technological innovation. Most countries try to adapt their policy in order to benefit from academic research results and accelerate economic development. Universities and companies differ in the ways they can utilize their patents. In the US, many researchers have examined the role of the Bayh-Dole act in the innovation process. The Bayh-Dole Act is considered by many researchers as an important driver of innovation and entrepreneurship in our days (Czarnitzki, Doherr, Hussinger, Schliessler, Toole,2016). In the US, the introduction of Bayh-Dole Act in 1980, transferred academic patent ownership from inventors to the academic institutions. More specifically, the Bayh-Dole act provided higher institutions with the

possibility to gain intellectual property rights of the patents they produce, as well as to benefit from commercializing these patents (Shane, 2002).

Universities and companies substantially differ in the ways they can utilize patents and earn revenues from them. Companies are able to increase their revenues either by selling their products on the market or by utilizing these patents in order to produce incremental innovations for the existing products. Higher institutions are not able to produce and sell products directly on the market and thus, they are not able to receive financial returns as private firms do. Consequently, the only way universities can benefit from their patents is through licensing (Shane, 2002).

Licensing has not the same level of effectiveness for all industries. In many cases, sellers are not willing to reveal information regarding to their patents. This disclosure policy makes many potential investors unwilling to invest in new technological innovations. Furthermore, firms withdraw their interest for new technological innovations when the intellectual property rights cannot be obtained at ease (Shane, 2002). In addition, when new knowledge is too complex, companies have to use interpersonal channels in order to transfer knowledge. Since the use of interpersonal channels is associated with high costs, companies prefer to avoid investing in projects that are not based on explicit knowledge (Teece, 1977).

Potential investors always choose to invest in industries where the effectiveness of licensing is easy. The Bayh-Dole act guided the higher institutions to focus their resources in these sectors where licensing is not associated with high bureaucracy. From the introduction of Bayh-Dole and then, universities realized the potential of commercializing their technological innovations and set licensing as one of their major activities (Shane, 2002). Before Bayh-Dole act, only a minority of top universities use to patent and license technological knowledge. The vast majority of higher institutions, started getting involved with patenting and licensing activities during the Bayh-Dole act period (Mowery and Ziedonis, 2002).

2.4) The Swedish Paradox

During the last two decades, the number of academic patents as a percentage of total patent citations has substantially increased in the developed countries. In the European countries, academic patents accounted for 4% in the early 00's instead of

0.5% in 1981. These measurements do not represent the real number of academic patents, since many of the academic patents are represented by private companies (Zeebroeck, Pottelsberghe, Guellec, 2008).

Patent laws and regulations differ at a significant level between different countries and for that reason, it is very difficult to compare the research output between different countries. For example, countries like Sweden and Italy have retained professor's privilege, which allows academic inventors to utilize their own inventions. Specifically, academic inventions are owned by professors and thus, they are not included in the academic patent lists. For that reason, these countries are presented to have a much lower scientific output that they really do (Zeebroeck, Pottelsberghe, Guellec, 2008).

In many cases, differences in regulations have led to research bias, since not all researchers count academic patents in the same way. For instance, most of European countries are presented to have a much lower scientific output in comparison with the USA in previous scientific papers. Most of these papers take into account only university-owned patents .Recent surveys that use inventor-level data, prove that Europe and US have a comparable scientific output (Lissoni, 2008).

In the case of Sweden, only a limited number of patents are owned by universities, while the vast majority of academic patents is a property of academic inventors (Ljungberg and McKelvey, 2012). The fact that universities do not own the intellectual property rights has led to what is called "Swedish Paradox". Although many financial resources are allocated in academic research, Sweden seems to have a relatively low scientific output (Edquist and McKelvey, 1998). Recent surveys that count not only take into account university-owned but also inventor-owned patents, have proved that scientific output in Sweden is much higher that it was considered to be. The total number of academic patents in Sweden is comparable to those of the US and other European countries (Lissoni, 2008).

2.5) Patents and Publications

Strong collaboration between academic institutions could last in more significant academic patents. Furthermore, there is a positive relationship between the value of the academic patents and the scientific publications of the inventors (Pottelsberghe

de la Potterie, 2007). Some surveys suggest that academic patenting makes researchers more reluctant to reveal information about their patents in scientific paper. Apart from that, the vast majority of scientific surveys indicate a positive relationship between academic patents and publications. Italian university professors that have at least one patent citation in the EPO, seem to be more productive than their colleagues, since they have a higher number of publications. Also, Italian patent-authors' articles have a higher quality than those of the non-inventors (Breschi, 2005). In the US, academic professors in the field of biotechnology that are involved with patent citations, seem to have a remarkable scientific output (Zucker and Darby, 1996).

Furthermore, academic surveys suggest that publications have a positive effect on future patents as well. Academic professors with a high rate of publications have a better chance to establish new patents in the future (Breschi, 2005).

In addition, funding from private sector is considered to have a positive effect in academic productivity. Scientific studies in Belgium, Canada and Norway, indicate that academics who receive financial support from the industrial sector use to have more publications in scientific journals (Zeebroeck, Pottelsberghe, Guellec, 2008).

2.6) Academics' collaboration with industry

Academics tend to interact with industry in many different ways. Their interaction with the industrial sector includes birth of physical facilities, consulting and contract research activities, joint research activities, training, as well as meetings and conferences in which academics participate in. In UK, a high percentage of academics use to collaborate with private firms. The percentage is higher for academics that belong to engineering departments (D'Este and Patel, 2007).

Although there is a lot of academic research about the way academic patenting affects the innovation process, there is very limited literature discussing the way patent citations affect academic entrepreneurship and collaboration with firms.

Although Bayh-Dole Act is considered a very crucial driver of entrepreneurship, some contemporary studies indicate that institution ownership has a negative effect in the entrepreneurial activities of the academic inventors (Damsgaard and Thursby,

2013). Some other articles suggest that the role of "star scientists" in firms is very important. Star scientists are those who own the intellectual property rights for their patents and are able to develop a strong collaboration with companies in order to commercialize their patents (Zucker et al., 1998).

In Germany, a recent study investigates academic entrepreneurship rates before and after 2002, when Professors Privilege was abolished and the property of new patents was transferred to the universities. After the implementation of this reform, the relationship between patents and academic startups became stronger, but the number of total patents was decreased. Also, the relationship between academic inventors and industry in the field of patenting was weakened and the technological knowledge transfer from universities to the private sector was decreased (Czarnitzki, Doherr, Hussinger, Schliessler, Toole,2016). The results of the research indicate that academic inventors are more highly motivated to collaborate with industry, when they retain the ownership of their patents.

Academic inventors not only use to be engaged in entrepreneurial activities but also collaborate with large organizations. Meyer investigated a dataset of 243 academic inventors in Finland. He distinguishes academic patents in three categories, according to the utilization context, the type of the invention as well as the technological field to which they belong .Most of the inventions that are included in Meyer's survey, are coming from life sciences, or other related technological fields like the pharmaceutical and the biotech sector. According to his research findings, the vast majority of commercialized academic patents are represented and funded by large organizations. The percentage of new inventions that are supported by academic start-ups is less than 15%. The survey's result indicate that almost 70% of the academic patents have been developed under the supervision of large firms. Academic patents that have been developed exclusively by professor's, without help by any external partner, are represented by start-ups. The study indicates that even in the case of pure academic inventions, most patents are finally commercialized by large companies (Meyer, 2006).

2.7) Academic Networking

The existence of entrepreneurial activities within large organizations has attracted the interest of many researchers in our days, since it leads to organizations to renew their practices and have a better performance. The phenomenon of people behaving like entrepreneurs within a large organization is called Intrapreneurship. Intrapreneurship. Networking has a positive effect in entrepreneurship within an organization, since professionals with a more extended network are more likely to get engaged in entrepreneurial activities (Maritz, 2010).

Previous studies have indicated a positive relationship between networking and innovation. Ruef examined the degree to which an extended professional network is connected with creativity and the birth of new ideas. He concluded that people who have a broad professional network tend to be more creative and produce innovative ideas (Ruef, 2002). Maritz also concluded that networking plays a significant role in leveraging developing innovation within an organization.

2.8) Hypothesis

As a result of the above literature review, we concluded the following hypotheses:

1. Academic patenting has a positive effect in academics' participation in companies.
2. Academic inventors need big firms' support in order to commercialize their patents.
3. Professional networking positively affects academics' participation in companies.
4. Professional networking and academics' scientific output have a positive relationship

3. Methodology

3.1) Quantitative research

The current master thesis project follows quantitative methods of analysis. In a quantitative research, the theoretical framework and the research are supposed to have a deductive relationship, as it happens in natural sciences. Apart from that, qualitative and quantitative research are not completely separated when examining complex social phenomena (Bryman and Bell, 2001). The master thesis project starts with the literature review which leads to the specification of the research question as well as the hypotheses formation. The paper continues with data collection and ends up with the data analysis part, in which the hypothesis testing is implemented.

3.2) Data collection

The current master thesis project is based on the survey "Academic Inventors and Knowledge Technology Transfer in Nanoscience in Sweden (Bourelos, 2013). This survey investigates the level of academic publishing and patenting in nanoscience for Swedish universities. The author made an intensive research through various databases and created a dataset consisting of 114 academics. More specifically, 57 of the academics that participate in this research are academic persons with patent citations in the field of nanoscience. These academic inventors have been matched to 57 professors that have publications in nanoscience but they do not have official patent registrations. The match between academic inventors and their peers happened according to four criteria. These criteria were the year of birth, the department, the faculty and the gender of each professor.

In the first phase of the data collection part, I tried to identify how many academics are board members in private firms. In order to do that, I used the Swedish platform allabolag.se. This database enables us to know the number of companies in which each person participates in. Also, the number of professional connections is provided for all persons that are registered in the database. By typing the full name of each academic, I was able to identify the number of companies he/she participates in, as well as the number of professional connections for each applicant. This procedure was associated with serious obstacles. The most serious issue is that

there are many different people with the same name that are registered in the database. As a result, it was important to identify who is the person we are searching for, otherwise the danger of having variation in the survey would be very high. Since the first six digit of the personal number was available for all persons, I tried to find the exact date of birth for each professor. For some of the professors, the year of birth was available in the previous dataset but for the majority of the professors, I should search in the internet. Specifically, I searched universities' websites for professors' CV's, in order to be able to ensure their date or at least their year of birth and match them with persons I found in the allabolag database.

Furthermore, in order to ensure that we found the right person, I needed to find information regarding to the city of residence, the marriage situation as well as the professional activity of each academic. At this point, the use of social networking sites like Facebook and Linkedin was very useful. For instance, some persons used to run their own family business and were connected to their wife or other family members in allaballag. By looking at the pages that professors retain in social media, I was able to check the name of their family members and ensure that they are the same persons we found in the allabollag database. Even though this procedure was time consuming, it helped a lot in the production of a reliable scientific paper and reduced the probability of having high variation.

In the next stage of the survey, specific information about academic inventors' patents was collected. At this point, the official website of the European Patent Office (EPO) was used for finding more precise data regarding to each one of the patents that the authors-inventors have produced. As it happened in the previous stage of our research, many people from different areas and with different addresses appeared in the search engine's results. First of all, we used information from the previous findings in order to identify the city of each person's permanent residence. Second, I used specific websites that provide information regarding to each person's address, profession, age and personal number. The websites I used more for academics' identification were "hitta" and "merinfo" .For the academics that are board members in companies, it was easier to match the first six digits of the personal number and ensure they were the right persons. Apart from that, since the majority of professors do not participate in any company, I couldn't find them this way.

For the professors that are not board members in private firms, I combined data from EPO, universities' websites and social media in order to ensure that our data is accurate. This procedure was completed under difficult conditions. In Sweden, most of the people do not have a permanent residence and thus, in many patent citations the inventors were registered with their previous addresses. In order to overcome this obstacle, I had to combine all the existing sources of information. First of all, the current addresses of the authors-inventors were detected by combining information regarding to the possible address, the profession and the date of birth. When there was a perfect match for all these characteristics in the available database, I was able to ensure the identity of a particular person. For the patents in which the inventors were registered with an old address, I checked out the city of residence, the kind of the patent, the applicant's and representative's name. When all these elements were matched with the verified patents of the professor, I assumed that it is the same person.

In some cases, there was no enough information in order to verify if the previous address of the inventor was right. Also, the personal number was hidden for some persons for safety reasons. Since we wanted to produce a survey with the lowest possible variation, we eliminated all patents for which we did not have enough information to verify their authors. Although it is not possible to eliminate variation completely, the use of various databases decreases the possibility of mistakes to be made in the current survey.

3.3) Reliability

Reliability refers to the degree to which the results of the research are repeatable. In fact, it indicates the level of consistency of the results in business and management surveys. Reliability is always an important issue for all quantitative researchers, since it helps them define the stability of a quantitative research process. In order to consider a research as reliable, the results of the data analysis should be the same, even if we repeat the process many times (Bryman and Bell, 2001). The level of reliability for the current master thesis project is relatively high. Since the data was not collected by interviews or questionnaires, it is not affected by each author's mood at a particular moment. The data was collected from online

databases and it is going to be the same for any researcher who will try to repeat the research process. Apart from that, if a research takes place many years after this master thesis project, there would be differences in the number of patents for each author-inventor. That is because many academic inventors use to produce new inventions and patent them in the long run.

3.4) Replicability

Replication is a common phenomenon in contemporary scientific research. In many cases, researchers replicate the empirical finders of other scientists. The motivation for replicating others results varies. Some researchers do it in order to support their research question and make further investigation. Some others replicate others findings because they feel that there is a gap in their research. Any study must be replicable, in order to be replicated by other researchers. That means that the researcher should reveal detailed information regarding to his/her research. The concepts replicability and reliability are strongly connected to each other. In order to ensure that a research paper is reliable, we have to repeat the analysis process and to do this, we need information regarding to the data process (Bryman and Bell, 2001). Although it would be technically possible for a researcher to repeat the research process, the replicability of this project is low. In order to replicate this research project, a researcher should have access to sensitive data that is not be published in the current paper.

3.5) Validity

Validity is considered the most important criterion of research. Although there are many types of validity, in quantitative methods of analysis, researchers preferably pay attention to measurement validity. Measurement validity represents the degree to which a survey explains what it is supposed to explain (Bryman and Bell, 2001). In the current master thesis project, relevant literature review was used for the formation of the research questions and the correspondent hypothesis. The data that was gathered, is relevant to topics that are discussed in the theoretical framework and targets to examine if the existing theories apply to this industry-specific study.

For each one of the research questions, I used descriptive and inferential statistics that give a sufficient answer to the question.

3.6) Generalization

Generalization refers to the degree to which the researcher is able to generalize from the results of the data analysis. All research papers target to produce results that are valid not only for a specific sample but can also be applied to individuals that belong to external population. In order to produce generalizable results, we have to choose sample that represents the total population. Before they start statistical analysis, quantitative researchers have to emphasize a lot in the creation of a sample that will be as representative as possible (Bryman and Bell, 2001). The initial dataset that was used for the development of the current project, includes a relatively small sample that has been filtered very well. The final sample of 114 authors and authors-inventors in total, was a result of an intensive filtering process. The results of the initial research in which the current project is based on, have been officially published. As a result, the dataset which was used in the current project has a recognized level of generalization. Furthermore, the data that has been gathered for statistical analysis is coming from credible databases. Thus, the danger of a research bias has been reduced to the lowest possible level. In order to analyze the data, I used descriptive statistics as well as correlation and regression analysis. For the correlation indices and the regression tables, i calculated the correspondent P-Values. The P-Value enables us to know the out of sample probability of the results. In other words, the use of P-Value helps us to understand the extent to which our results can be applied in individuals that do not belong to our sample (Wooldridge, 2003). Consequently, the generalizability of the results in the current project, will be measured by the use of P-Values.

3.7) Variables

1. Dependent variable: NumberofCompanies: This variable represents the number of companies in which academic authors-inventors have a board membership.

2. Independent variables:

   a) Number of Patents: The number of patent registrations each author-inventor has according to the EPO. Patents in which the professors are co-inventors are also included in the total number of patents.

   b) Number of publications: The number of scientific papers that have been officially published in scientific journals.

   c) Total citations: The number of total citations that each author has received for all scientific papers he/she has been published.

   d) Connections: Number of connections that each author or author- inventor has according to allabolag database. It is the professional network of each author.

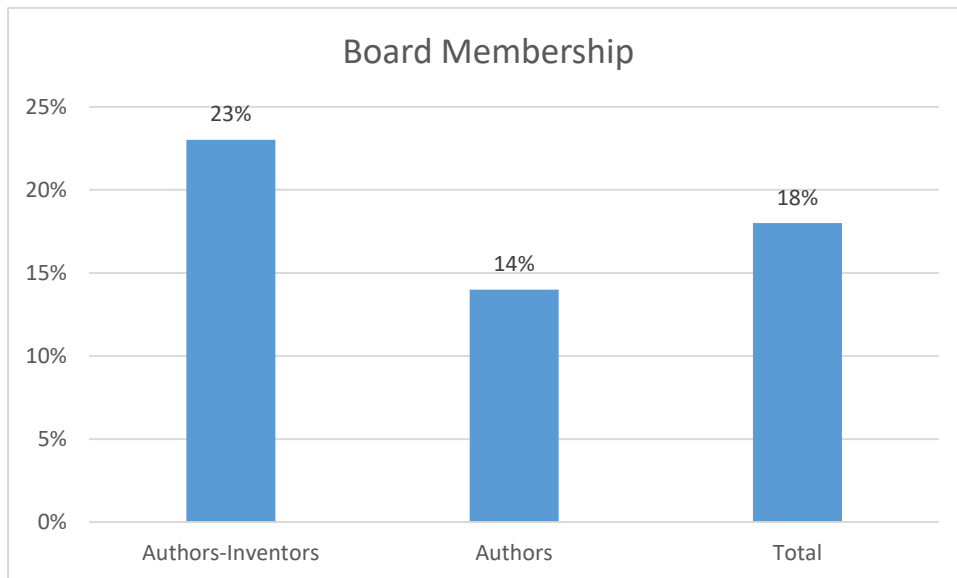# 4. Empirical Findings

4.1) Descriptive Statistics

Figure 1: The percentage of Authors and Authors Inventors that participate in companies as board members.

In order to identify each author's collaboration with industry, I used allabolag's database. Through this database, I was able to identify the companies in which auhors and authors-inventors participate in as board members. In Figure 1, we can see that 18% of the total population of the sample retain a board membership in one or more companies. The percentage for authors-inventors is higher, since 23% of them participate in companies, while just 14% of single authors have a board membership. The information that is coming from figure 1, indicates a strong relationship between inventorship and collaboration with industry. The data in Figure 1, indicates that authors-inventors have a much higher board membership rate than academic authors that do not have any official patent citation. This could be explained by the fact that academic inventors need private firms in order to commercialize their idea. In the next phase of the data analysis part, the role of companies in the commercialization of the academic knowledge will be explored.
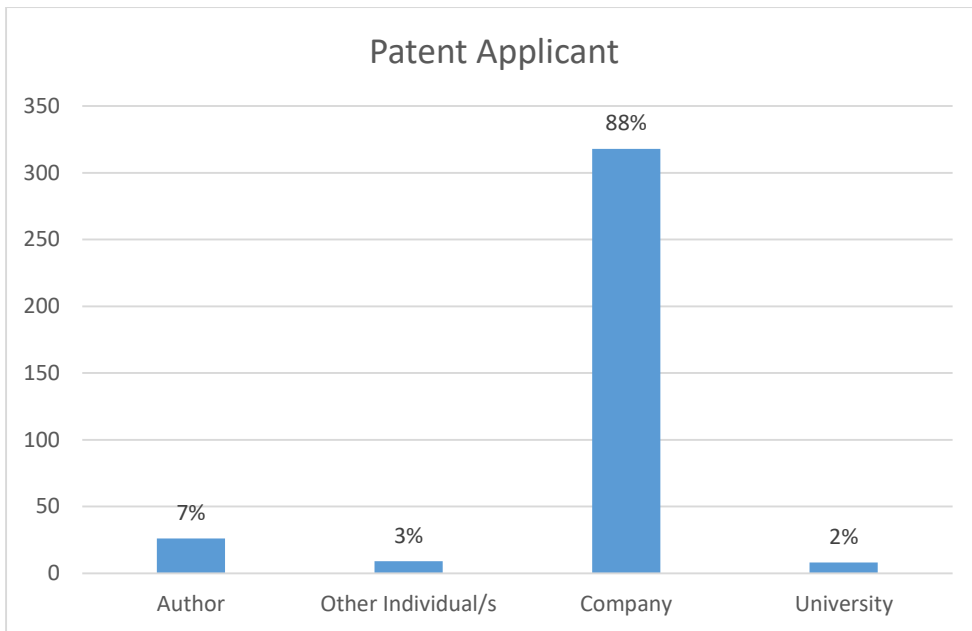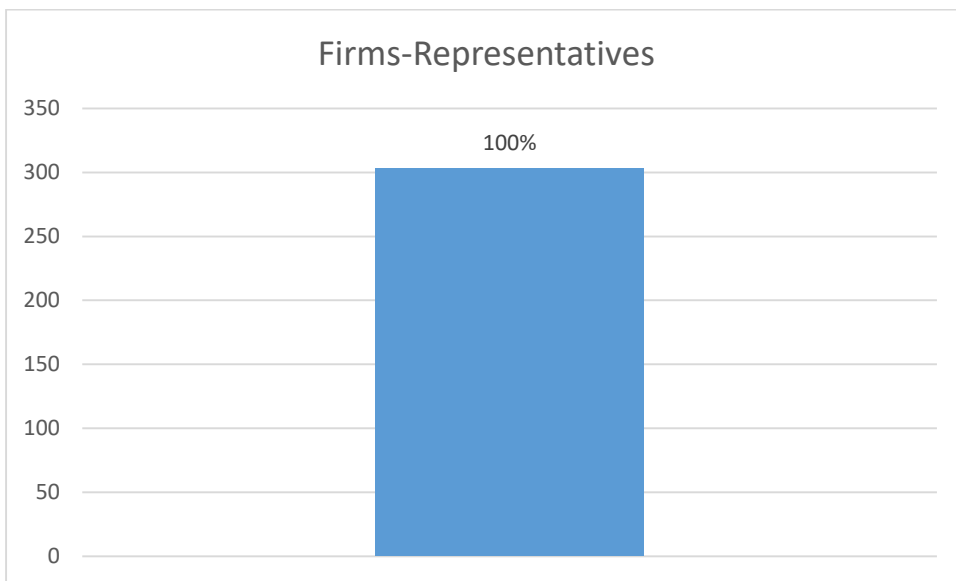
Figure 2: Type of Patent applicants

Figure 3: Percentage of patents that are represented by companies.

The authors-inventors that are included in the initial dataset have 380 patent citations in total. For 19 of these citations, the applicant's name was not available. As a result, the Figure 2 that examines the type of patent applicants, is based on the available data for the rest 361 patents. According to the analysis of the EPO data, 88% of patent applications have been completed by private firms. Only 7% of

authors-inventors apply for patent recognition on their own, while 3% of the applications are made by other individuals. Universities have the smallest share in patent applications, since only 2% of patent applicants are higher institutions.

Figure 3 represents the percentage of academic patents that are represented by private firms. At this point, it should be mentioned that representative's name was available for 303 out of 380 patents. According to the existing data, private firms are the representatives of all academic patents. The vast majority of the firms that represent these patents are large firms that specialize in developing policies for patent protection. These firms are responsible for supervising and supporting the whole innovation process.

The available data coming from the EPO database, supports what is stated in the theoretical framework of this project. As mentioned in the theoretical framework, Sweden belongs to countries that retain "Professor's Privilege". That means that academics own the intellectual property rights of their own patents. Zucker refers to academic inventors that own IP rights for their own patents as "star scientists". He claims that the role of star scientists in private firms is very important. According to Ljungberg and McKelvey, most academic patents in Sweden are a property of large firms. Furthermore, Meyer claims that most of the academic patents are funded and represented by companies.

The analysis of the data that that has been collected for the current master thesis project, supports what has been mentioned in the theoretical framework. Although they retain intellectual property rights for their patents, academic inventors seem to face many difficulties in utilizing and commercializing their own ideas. Most of patent applications have been filled by private firms. Most of these firms are large but some of them are entrepreneurial start-ups. Even in the cases that academics make a patent application on their own or through a small start-up, patents are represented by large companies. Consequently, Meyer's survey results are supported by the empirical findings of the current project. In addition, academic patents seem to be a property of large companies, as mentioned by Ljungberg and Mckelvey.

As mentioned before, the third mission of the university is the interaction with industry as well as the commercialization of academic patents. According to

Bourelos, University-Industry interaction can be associated with strong relationships between universities and firms, the beginning of new start-ups and academic patents that are supported by firms. As applicants and representative diagrams indicate, academics in the field of nanotechnology contribute to the implementation of university's mission. Specifically, academics utilized the so called "professor's privilege", in order to commercialize their patents. As Zucker mentions, authors-inventors are very important for companies, since they are an external source of innovation. In the field of nanotechnology, Zucker's claim seem to be accurate, since companies are very active in supporting, funding and developing academic patents.

4.2) <u>Bivariate Analysis</u>

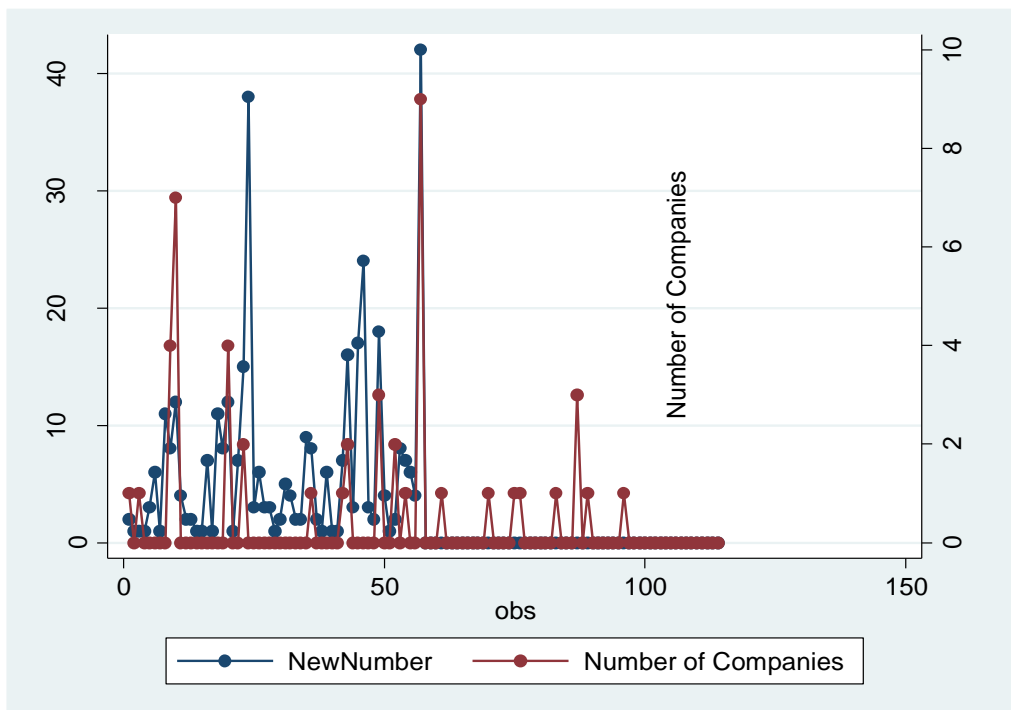## 4.2.1) Academic Patenting and Board Membership

Figure 3: Correlation between academics' Board membership and number of patents they have produced.

R^2: 0.30

	NumbeofPatents	Board Members
NumberofPatents	1	
NumberofCompanies	0.5493	1
P-Value	0	

Table 1: Correlation between academic patenting and academics' board membership.

Figure 3 represents the correlation between academics' participation in companies and the number of patents that academics produce. In order to get a more clear view about the correlation between these variables, I also used Pearson's correlation index and printed a P-Value. The use of P-Value is very important in statistical data analysis, since it indicates the level of significance of the results (Wooldridge, 2003). The reason that Pearson's correlation index was preferred instead of Spearman's index, was that this is that we work with quantitative and not qualitative variables. When the researcher works with qualitative data that is coming from questionnaires, then Spearman's correlation index can be successfully applied. In case the researcher is working with quantitative data, Pearson's correlation index is preferred. In order to interpret results on a better way, I also calculated the coefficient of determination, which is symbolized as R^2. The coefficient of determination enables us to know the degree to which the variation in one variable is because of the other variable. (Bryman and Bell, 2001).

In Figure 3, we can see that there is a positive correlation between the number of patents each author has and the number of companies in which he/she retains a board membership. What enables us to ensure that the correlation between these two variables is positive, is that Pearson's correlation index has a positive value. The coefficient of determination is equal to 0.30. That means that 30% of the variation in the number of patents is because of academics' board membership.

The statistical software returned a negative P-Value for this Pearson's value. Although it is not possible to have a negative P-Value, the statistical software returns this result when the P-Value is smaller than 0.001. That means that the statistical significance of the result is very high and that the result represents what happens in the out of sample population.

As mentioned before, Czarnitzki claims that academic inventors that own the property rights for their patents, are more likely to collaborate with industry. The correlation diagram as well as Pearson's index value, strengthen Czarnitzki's opinion and indicates that there is a positive relationship between academic patenting and academics' participation in companies. Sometimes, a positive relationship between two variables, does not necessarily mean that one variable causes the other. Correlation does not always entail causality between two variables (Bryman and Bell, 2001). Research question 1 is about how does academic's participation in companies affect academic patenting. In the last part of the data analysis chapter, the causal relationship of these two variables will be detected with the use of regression analysis.

4.2.2) Academic publishing and Board Membership

As mentioned before, funding from the industrial sector seems to have positive effect in academic publishing. Zeebroeck et al. concluded that academic inventors that receive financial support from the industrial second tend to produce a higher number of articles that are published in scientific journals. In Figure 4, we can see the correlation between academic publications and participation in companies for all the academics that belong to the sample. Although the relationship between these two variables is not linear, we can see that there is a positive correlation between the variables for the majority of observations.

Pearson's correlation index has a positive value for which indicates a positive relationship between variables. The coefficient of determination is equal to 0.18, which means that 18% of the variation in publications is due to board membership. Furthermore, the P-Value is very close to zero, which means that the results have a high level of significance. Zeebroeck's claims regarding to industrial funding and academic productivity seem to be confirmed, since academics that participate in companies tend to have a higher rate of publications.
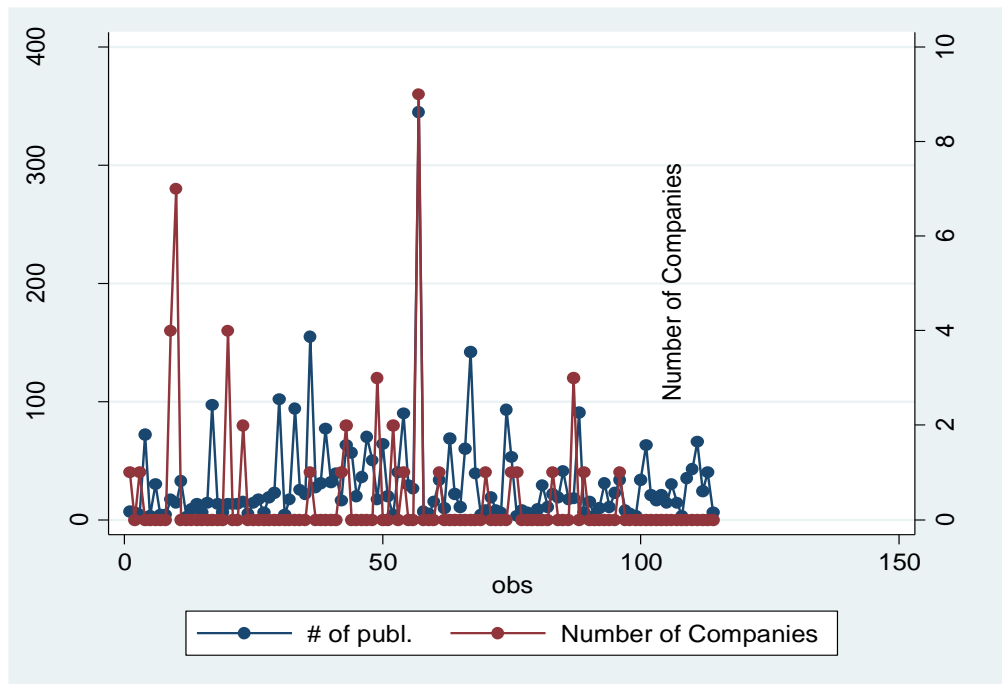
Figure 4: Number of publications that authors have and number of companies they participate in as board members.

R^2: 0.18

	Number of Publications	Number of Companies
Number of Publications	1	
Number of Companies	0.4245	1
P-Value	0	

Table 2: Correlation between Publications and academic's Board membership.

4.2.3) Board Membership and Professional Networking

Figure 5 represents the way academic patent's and academics' board membership are correlated to each other. As we can see in the graph, there is a positive correlation between these two variables for the majority of observations. The price of Pearson's index is positive and relatively high, if we take in to account that some unexpected values of the observation have a negative effect for the index. The fact that the value of the index is close to 1, indicates a very strong correlation between academic networking and the number of companies in which academic inventors participate in. The coefficient of determination indicates that 63% of the variation in board membership is because of professional networking. The statistical software printed a P-Value equal two zero for these two variables, which means that the real P-Value is lower than 0.001. The P-Value indicates that the level of significance is very high, and we are able to generalize from this result.

The fact that academic inventors with a broader professional network tend to collaborate more with the private sector supports Maritz's claims. Maritz says that professionals are more likely to get engaged in entrepreneurial activities when they have a broad professional network. In this case, academics inventors that have a broader professional network tend to collaborate with more companies.

What makes this fact important is that the vast majority of the authors-inventors in the sample collaborate with companies in order to commercialize their patents. A positive relationship between academic networking and academic's participation in companies, indicates that the existence of a broader network is associated with stronger collaboration with companies. As Meyer proved in his survey, collaboration with industry encourages and accelerates commercialization of knowledge. The existence of a more extended professional network, creates better conditions for academic's participation in companies and commercialization of their patents.
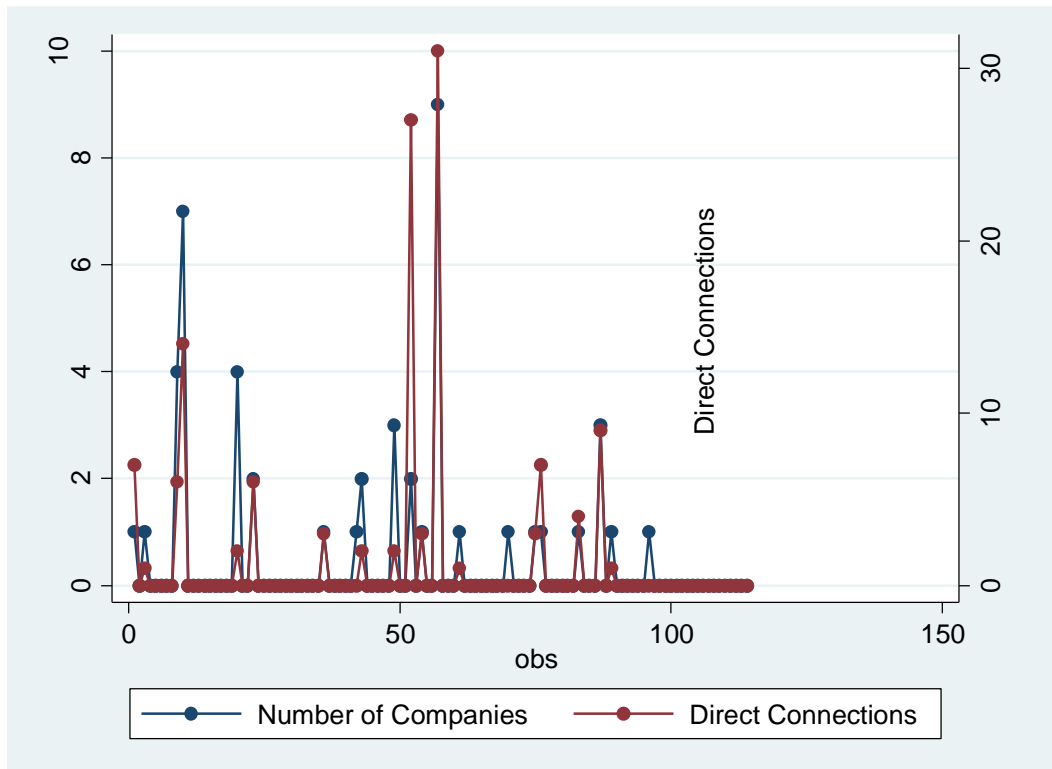
Figure 5: The relationship between academic Networking and academics' board membership in private firms.

R^2: 0.63

	NumberofCompanies	DirectConnections
NumberofCompanies	1	
DirectConnections	0.7947	1
P-value		
	0	

Table 3: Correlation between board membership and academic networking.

4.2.4) Academic Patents and Professional Networking

In the theoretical framework, a positive relationship between professional networking and academic patenting is suggested. More specifically, Ruef contends

that employees with a more extended network are more likely to produce new, innovative ideas. Maritz also considers professional networking as an accelerator of innovation. The analysis of the available data indicates a positive relationship between academic patenting and professional networking. Pearson's correlation index has a positive value and although it is not close to 1, it is strong enough to be taken into consideration.

The coefficient of determination indicates that 19% of the variation in academic patenting is because of professional connections. Ruef's conclusion that the size of networking is connected with the development of innovative ideas seems to be confirmed, since innovation is measured by patents in the vast majority of surveys. Also, Maritz's theory seems to be supported by the results, since networking seems to be a factor that positively affects the birth of new patents.
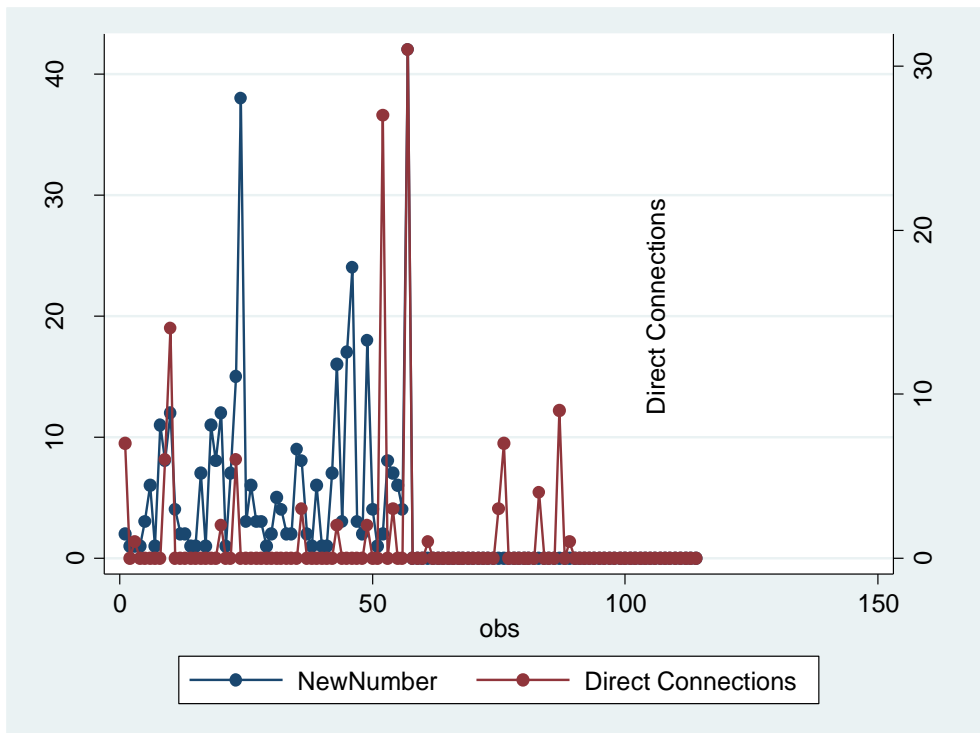

Figure 6: Relationship between academic patents and professional networking

$R^2 : 0.19$

	NumberofPatents	DirectConnections
P-value	0	
NumberofPatents	1	
DirectConnectionss	0.4320	1

Table 4: Correlation between academic patenting and professional networking.

4.3) Regression analysis

Board Membership	Coef.	Std. Err.	z	P>z	[95% Conf.	Interval]
NewNumber	0.074048	0.012691	5.83	0	0.049173	0.098922
ofpubl	0.000136	0.007817	0.02	0.986	-0.01518	0.015457
TotCitations	0.000131	0.000123	1.06	0.288	-0.00011	0.000372
Links2	-0.00281	0.00594	-0.47	0.636	-0.01445	0.008831
_cons	-1.36936	0.251294	-5.45	0	-1.86189	-0.87683

Table 5: Poisson regression model

In we saw in bivariate analysis, academic patenting and board membership have a strong positive relationship. At this stage of the research process, we will try to define the nature of this relationship. The existing literature suggests that collaborating with industry, makes academic inventors more productive and has a positive effect in academic patenting. With the use of multiple regression analysis, I tried to define if this statement is true or not. In order to define the relationship between these variables, I tested four different econometric models. Since academic patenting is not affected only by academic's participation in companies, more variables that affect academic patenting were included in the models. Specifically, the multiple regression models included the number of publications, the number of citations as well as the number of links for all academic inventors.

From all four models that have been tested in the current master thesis project, the poison regression model is the one with the highest level of significance. More specifically, it is the only one that enables us to generalize from the results and make a realistic conclusion. According to the regression table, there is a positive relationship between board membership and the number of patents for each author. The results of the regression process indicated a P value equal to zero. Although it is not possible to have a P value equal to zero, the results are very important, since they entail a P value lower than 0.001. Consequently, probability of the regression results to be valid in individuals that do not belong to the sample is very high. That means that we can follow and inferential process and make a general conclusions based on the poison regression model. Patenting seems to have a positive effect on board membership in general, for all academic inventors within the nanotech sector.

Conclusion

This master thesis project attempted to answer a series of questions regarding to the relationship between academics and industry. First of all, the thesis targeted to define the relationship between academic patenting and academics' participation in companies. The results of the quantitative analysis indicate a positive relationship between these variables. Authors-Inventors have a stronger presence in private firms than single authors. The percentage of academic inventors that retain a board membership in companies is higher than the one of authors. Academic publishing and board membership have also a positive relationship. The results indicate that academics that publish more, are more likely to participate in private firms.

Furthermore, the vast majority of the academic in the field of nanotechnology, use to collaborate with firms in order to commercialize their patents. The vast majority of patent applicants are private firms, while all patents in the sample are officially represented by firms. Even in the case that applicants attempt to utilize patents on their own, the presence of large companies is essential for the commercialization of their patents.

Networking and academic patenting have a very strong positive relationship. For the vast majority of observations, academics that have more official patent citations seem to have a much stronger presence in private firms. The high rates of academics' collaboration with firms, can be explained by the fact that most academic inventors need to collaborate with firms in order to commercialize their ideas. Companies see academic inventors as potential source of innovation and attempt to own and develop academic patents. This collaboration between companies and academic inventors contributes to the accomplishment of the third university mission, which is interaction with society and commercialization of academic knowledge.

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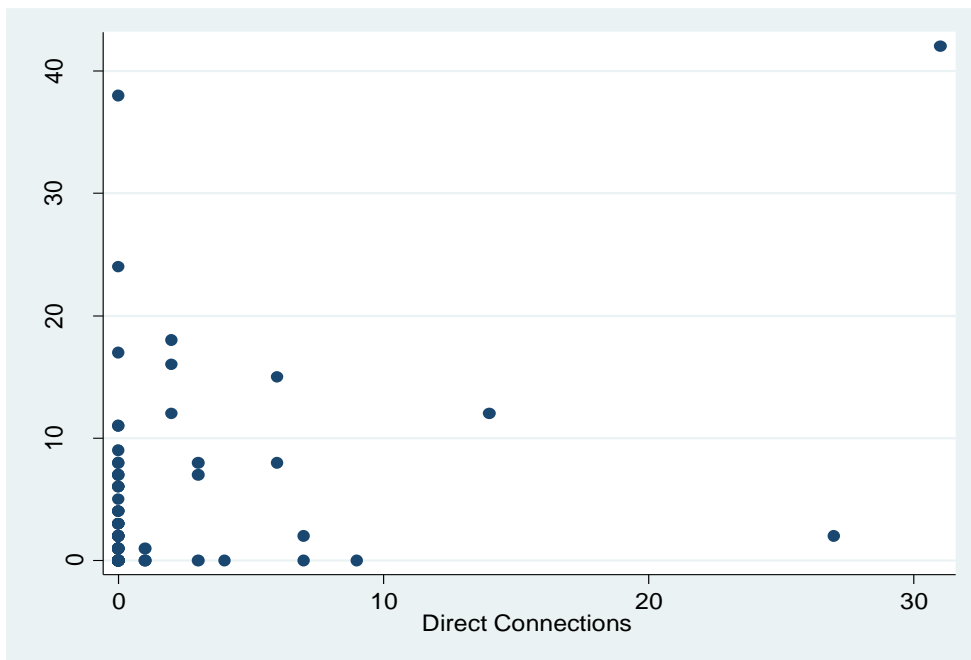http://www.vinnova.se/upload/EPiStorePDF/vf-01-02.pdf

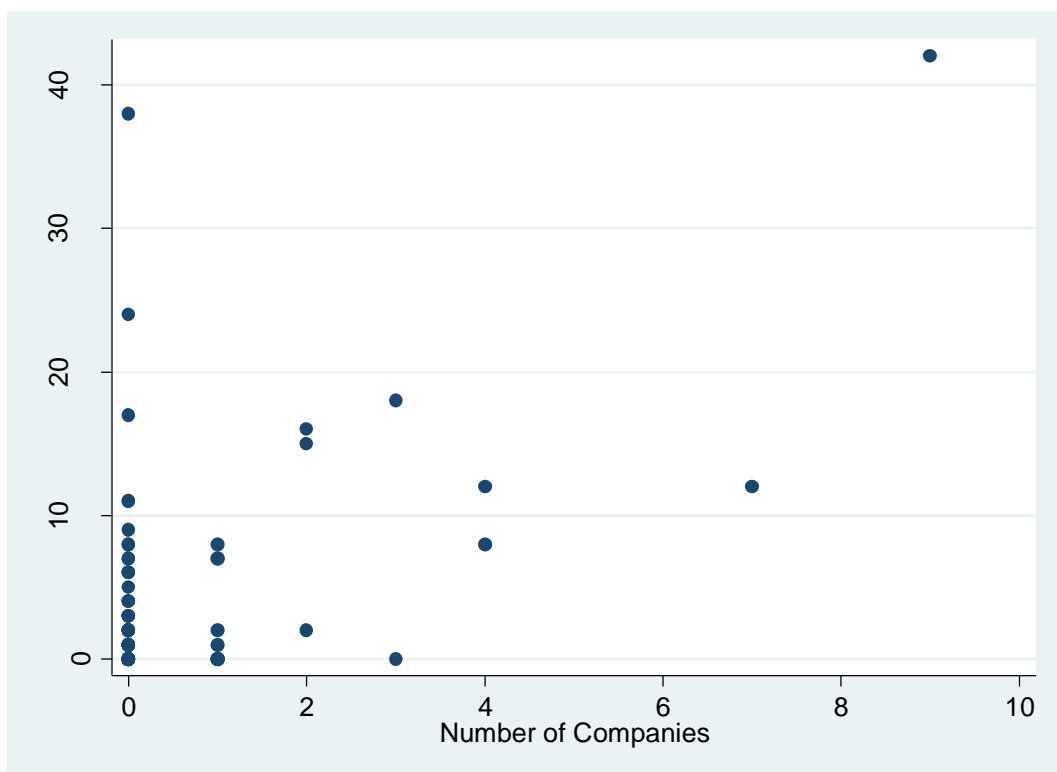Figure 7: Scatter plot for Number of patents and academic networking

Figure 8: Scatterplot for Number of patents and participation in companies.
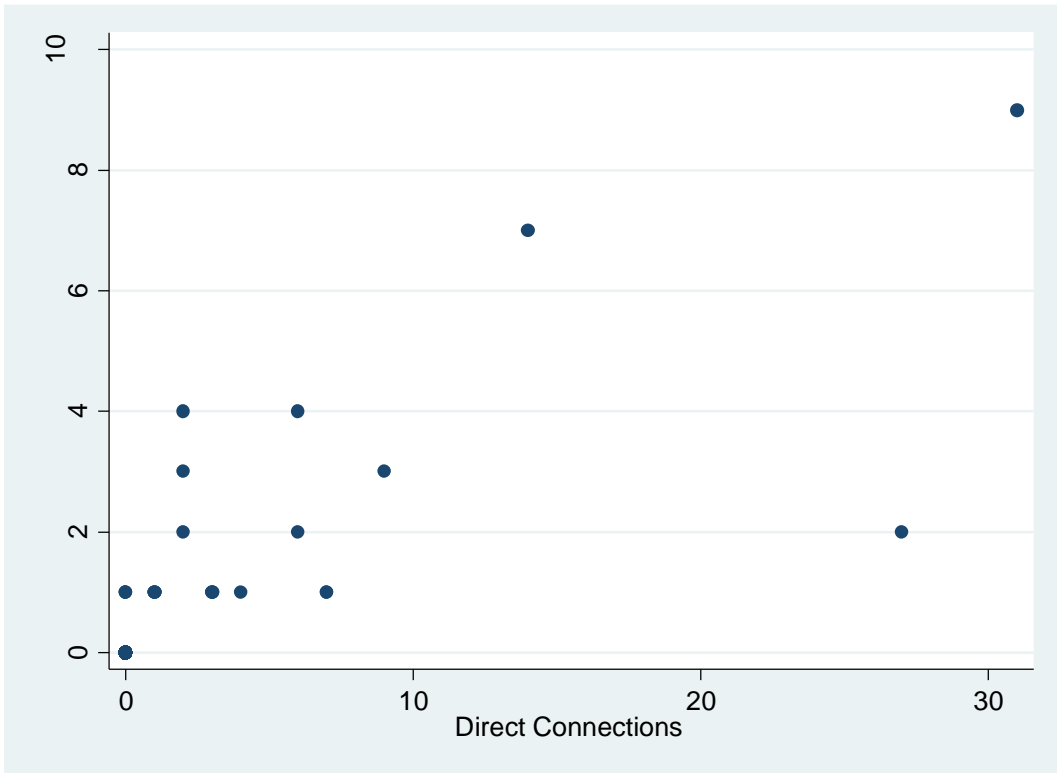
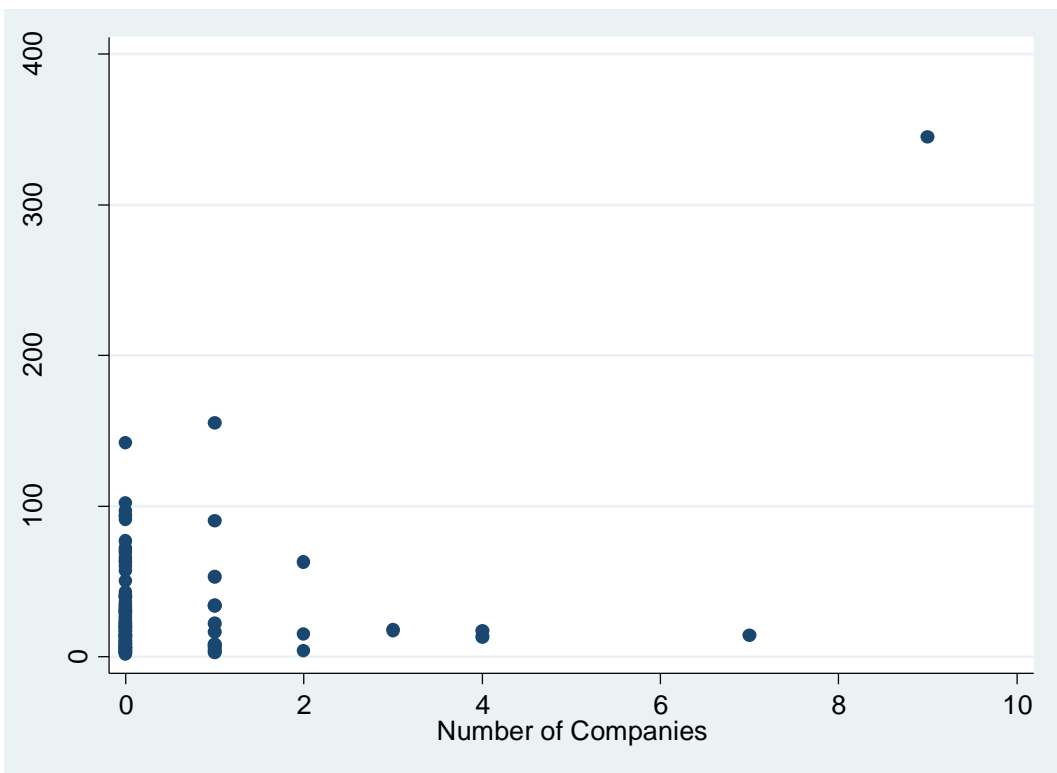Figure 9: Scatterplot for participation in companies and professional network.

Figure 10: Scatterplot for participation in companies and publications.

Logistic Regression

Company	Coef.	Std. Err.	z	P>z	[95% Conf.	Interval]
NewNumber	0.077061	0.037072	2.08	0.038	0.004401	0.149721
ofpubl	-0.01329	0.012899	-1.03	0.303	-0.03857	0.011988
TotCitations	0.00042	0.000273	1.53	0.125	-0.00012	0.000955
_cons	-1.80149	0.341801	-5.27	0	-2.47141	-1.13157

Regression Models

Clogit

Company	Coef.	Std. Err.	z	P>z	[95% Conf.	Interval]
NewNumber	0.106058	0.064707	1.64	0.101	-0.02076	0.232881
ofpubl	-0.02593	0.021026	-1.23	0.218	-0.06714	0.015281
TotCitations	0.000421	0.000403	1.05	0.296	-0.00037	0.001211
Links2	0.002583	0.010155	0.25	0.799	-0.01732	0.022486

Table 5: Clogit regression model

XtPoisson

NumberofCompanies	Coef.	Std. Err.	z	P>z	[95% Conf.	Interval]
NewNumber	0.194819	0.064926	3	0.003	0.067566	0.322072
ofpubl	-0.03799	0.020524	-1.85	0.064	-0.07822	0.002234
TotCitations	0.000554	0.000456	1.22	0.224	-0.00034	0.001447
Links2	0.003857	0.010449	0.37	0.712	-0.01662	0.024337

Table 6: Xt Poisson regression model