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Academic Inventors and Knowledge Technology Transfer in nanoscience in Sweden

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Abstract

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Abstract
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of nanotechnology in terms of scientists and their scientific output. We present the nanotechnology spread across the scientific disciplines, the departments and Swedish universities. We identify and analyze all the authors and inventors within nanotechnology in Sweden. The second purpose is to scrutinize at a micro-level the university industry interaction dynamics in terms of patents and publications. The hypothesis derived by the literature which supports that science and technology are complementary in academia is supported by the results which show that academic inventors have on average 24% more publications.

Keywords: Nanoscience, academic patents, University, publications, Sweden
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Academic Inventors and Knowledge Technology Transfer in nanoscience in Sweden

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Abstract

This paper has two purposes. The first is to present an overview of nanoscience in Swedish academia. Combining bibliometric data from Web of Science, patent data from EPO and data from the Swedish academia we compile a map of nanotechnology in terms of scientists and their scientific output. We present the nanotechnology spread across the scientific disciplines, the departments and Swedish universities. We identify and analyze all the authors and inventors within nanotechnology in Sweden. The second purpose is to scrutinize at a micro-level the university industry interaction dynamics in terms of patents and publications. The hypothesis derived by the literature which supports that science and technology are complementary in academia is supported by the results which show that academic author-inventors have on average 24% more publications. Nanoscience is an innovation intensive interdisciplinary field and in high interest especially in Sweden where a significant fraction of academic patents and publications can be classified in Nanoscience.

Keywords: Nanoscience, academic patents, University, publications, Sweden

1. Introduction

The specific role of the university in the knowledge economy has attracted the focus of innovation studies during the last years. Researchers and policy makers are focused on how universities are learning to compete and how they try to act strategically (Deiaco, Hughes et al. 2012). University-Industry interaction, the so called third mission, is the main challenge for universities in order to achieve a key position within the regional and national innovation. The transfer of knowledge takes place through different channels such as university spin-offs, academic patents, publications and different types of collaboration between companies and universities. In this paper we focus in the development of emerging technologies, which are impacted by developments in knowledge for science and technology through academic patents and publications in nanoscience in Sweden.

The interactions between university and industry are particularly relevant for emerging technologies like nanotechnologies, because universities may play an important role in stimulating radical technological changes. Some insights from the modern emerging technologies like biotechnology and life sciences are useful. They more generally seem to be particularly stimulated to develop faster when there are interactions between science and technology and between universities and industry (McKelvey 1996). At the same time, biotechnology has been heavily dependent upon networks, because they require the interactions among heterogeneous actors and disciplines (Powell, Koput et al. 1996). This has been called 'Mode 2 science' and is characterized by being hitch, is context-driven, problem-focused and interdisciplinary(Scott, Gibbons et al. 1994). Nanotechnology seems to correspond to several of these characteristics, and therefore it is particularly interesting to study in relation to how, when and why academic scientists choose to engage in publications and patents. This suggests that we may expect increasing returns to both patenting and publishing, instead of the substitution effects that are sometimes found in other technological fields.

Indeed, many studies emphasize on the expected revolutionary and transformative impacts of nanotechnology on scientific fields, industries and current products / processes, or the promising impact of breakthrough nanotechnology innovations on economic development (Andersen 2011; Genet, Errabi et al. 2011; Mangematin, Errabi et al. 2011; Shapira and Youtie 2011; Mangematin and Walsh 2012). As a general purpose technology (Youtie, Iacopetta et al. 2008), nanotechnology enables new products, devices or systems across various industries and works as an engine of economic growth (Bresnahan and Trajtenberg 1995). The U.S. National Nanotechnology Initiative (NNI) defines nanotechnology as "the understanding and control of matter at dimensions between approximately 1 and 100 nanometers, where unique phenomena enable novel applications". A world market for products of nanotechnology of 1 trillion USD and a need of a workforce of two million and about three times as many jobs in supporting activities for 2015 is estimated (Roco 2001; Roco 2005).

One special feature that needs to be emphasized about nanotechnology patents is the strong impact of scientific literature which is measured by citations made to academic articles in patent documents. Meyer (2000; 2000) and Hu (2007) are among the studies investigating the relationship between science and technology using patent citations. Hu (2007) analyzes nanotechnology-related patents from 1976 to 2004 at USPTO and finds that the number of patents and article citations in patent documents has increased faster in this interval for nanotechnology field as compared to other technology fields. The results of this study show that about 60 percent of nanotechnology related patents have on average approximately 18 academic citations. Moreover, authors identify two major technology fields in nanotechnology based on citation patterns: (i) chemical/pharmaceutical fields with an average patent citing about 40 articles; and (ii) the materials/semiconductor fields with an average patent citing about 10 articles. Thus, nanotechnology is an interesting emerging technology to study, because the interactions between scientific activities in the form of publications and the industrial and technological activities in the form of patents seem to be particularly strong. This suggests that nanotechnology provides a special case to further understand the relative productivity of university scientists that engage in only writing articles, as opposed to those who engage in both articles and patenting. This matters to understand the knowledge dynamics of the emerging field as a whole.

The majority of academic patents in Sweden are owned by large firms(Ljungberg, Johansson et al. 2009). Nevertheless, in Sweden, in the grounds of the professor's privilege, academics own the right to inventions. The fact that universities owned only a small fraction of patents in Sweden had led to the misconception that Swedish academia lacks in terms of patents as an argument within the discussion of the "Swedish paradox", that in Sweden there is low innovation output despite of high R&D input(Edquist and McKelvey 1998). But the new evidence which came out from the KEINS database in 2005 showed that the number of academic patents in Sweden is comparable to the corresponding ratios in other countries in Europe and in USA(Lissoni, Llerena et al. 2008). Thus, Sweden forms an interesting national context to study nanoscience, because academic patents are primarily owned by firms, and they therefore provide a good measure of the university-industry interactions as a counterweight to the academic publications or as compared to academic patents only owned by universities (e.g. without obvious and immediate industrial value).

In line with previous literature, which has revealed the significant role of academic inventors in Europe (Lissoni, Llerena et al. 2008), we define academic patents as those which have at least one inventor affiliated to university. Studies on academic patenting have revealed the relation between academic excellence (publications) and innovation performance (patents) (Larsen 2011).

This paper's aim is to contribute in the above research by exploring the academic and innovative performance. We are interested in the specific characteristics of academic author-inventors, as compared to academic authors, at the individual level in terms of productivity.

The data are a combination of two different databases created by the authors: First, the database of Swedish academic employees in Swedish universities in 2011. By matching this database with the European patent data from KEINS database we identified the Swedish academic inventors, as part of an ongoing project (APE-INV) in different European countries using the same methodology (Lissoni, Sanditov et al. 2006). Second, we created a database with all the academic authors within nanoscience from existing publications in Web of Science. Matching the two datasets resulted in a match of 60 scientists who are at the same time scientific authors and inventors. Next, from the list of academics in Sweden we identify 58 scientists who are "twins" with the aforementioned author-inventors but they are not inventors but just authors. The selection took place through a combination of exact and nearest neighbor matching based on the attributes of the academics: university, discipline, position and age. Next, we compare the productivity scores of the two groups and the population in terms of publications and citations.

The rest of the paper is organized as follows. Section 2 presents the literature review relative to the university industry interaction which leads to our hypotheses. Section 3 contains the data and methodology. Section 4 presents the overview of nanotechnology in Sweden and the descriptive statistics and section 5 the results in the hypothesis testing analysis. Section 6 concludes the paper by providing suggestions for further research and extensions.

2. Literature Review and hypotheses

University-Industry interaction has become a main focus by policy makers strongly based on the assumption that knowledge diffusion has a key role on innovation and growth. The so called third mission was adapted as a complementary strategy implemented by the universities that is to co-operate with society and communicate the results(Högskoleverket 2000). University-Industry interaction can take place through various mechanisms. Perkmann, Tartari et al.(2012) distinguish these mechanisms into formal mechanisms of commercialization on the one hand and informal mechanisms of academic engagement with the industry. Patenting, licensing and start-ups are examples of formal mechanisms while consulting, contract research and informal relationships are examples of academic engagement. The main focus of research has been put into commercialization mechanisms where patenting constitutes a big part. The latent contradiction between the generally presumed public nature of science and the strictly protected nature of inventorship, through patents creates a trend to believe that patenting and other similar commercialization activities (licensing) could be an antagonist factor in doing science. There is evidence that academics who consider science as a public good will less likely commercialize (Krabel and Mueller 2009). We will present later on the other stream of literature which shows the complementary process of science and commercialization but we should already mention here that nanotechnology, as a heavily science-based field, is expected to present a higher positive effect of academic performance on commercialization.

Global Nanoscience and Nanotechnology (NST) research literature has grown exponentially in the last two decades. The number of records regarding nanotechnology publications in the SCI / SSCI was 11265 in 1991 however it reached 64737 records in 2005 with an almost six fold increase (Kostoff, Koytcheff et al. 2007). However, recent studies show that more than 2 million scientific articles were published worldwide and over one million applications in nanotechnologies were made to patent offices (Mangematin and Walsh 2012). Many studies (Huang, Chen et al. 2003; Huang, Chen et al. 2004; Alencar, Porter et al. 2007; Li, Chen et al. 2007; Li, Lin et al. 2007; Meyer 2007; Dang, Zhang et al. 2010) confirm that the number of nanotechnology patents and patent applications has been continuously growing. The worldwide annual growth rate of the number of nanotechnology patent applications in the period from 2000 to 2008 is nearly 34.5% and it is higher than the rate of increase in the number of Science Citation Index nanotechnology articles which is around 25% (Dang, Zhang et al. 2010). Furthermore, USPTO patent data indicates that the share of universities as assignee institutes has recently grown. Wang (2007) points out that the average annual growth rate between 1990 and 2005 was 12 percent for industry patents and 30 percent for university patents. While the share of industry patents decreased from 88 percent in 1990 to 68 percent in 2005 the share of university patents among USPTO nanotechnology patents reached 22 percent in 2005 from 6 percent in 1990.

Nanotechnologies are breakthrough inventions of a new method of inventing (Darby and Zucker 2003; Thursby and Thursby 2011). Breakthrough inventions are defined as the fundamental inventions which are the basis of many subsequent technological innovations(Trajtenberg 1990; Ahuja and Morris Lampert 2001). Nanotechnologies are science-based inventions and developed in a context where technology bridging and strong ties between academia and industry are playing pivotal roles (Rothaermel and Thursby 2007; Zucker, Darby et al. 2007; Genet, Errabi et al. 2011). However what we know about the commercialization of nanotechnologies is very limited and needs further investigation (Genet, Errabi et al. 2011; Shapira, Youtie et al. 2011). Some recent studies (Rothaermel and Thursby 2007; Palmberg 2008; Fiedler and Welpe 2010; Nikulainen and Palmberg 2010; Andersen 2011; Genet, Errabi et al. 2011; Mangematin, Errabi et al. 2011; Shapira, Youtie et al. 2011) open up the black box of the university-industry interactions and commercialization of scientific knowledge in nanotechnologies.

The scholarly attention to the commercialization of nanotechnologies from universities and public labs has considerably grown in the last few years. All of these studies improve our perspective to understand the specialties of university-industry interactions and commercialization of scientific knowledge in the nanotechnology field. Conclusions from these recent studies suggest that researchers performing research in the field of nanotechnology in the academia have intensive collaboration with firms(Nikulainen and Palmberg 2010; Thursby and Thursby 2011) in comparison to those in other fields. Direct links between university researchers and large firms exhibit greater importance in nanotechnologies(Genet, Errabi et al. 2011). Shared technology platforms (i.e. nanotechnology research centers) might ignite the direct collaboration between universities and large firms(Robinson, Rip et al. 2006; Merz and Biniok 2010; Mangematin, Errabi et al. 2011).

Turning now again on the impact of patenting, the literature suggests that academic author-inventors publish more and better papers than their non-patenting colleagues(Perkmann, Tartari et al. 2012). Agrawal and Henderson (2002) study MIT patents and publications and although they find that patent volume does not predict publication volume, patent volume is positively correlated with paper citations. On the other hand, in a study of academic life scientists, Azoulay, Ding et al.(2007) find that patenting has a positive effect on the rate of publications but a weaker effect on the quality of these publications. Breschi, Lissoni et al.(2007) in a study of Italian academic inventors reveal a positive correlation between patenting and publishing but interestingly the effect is significant when the patents are owned by business partners instead of university or the inventor. As already said, the vast majority in academic patents in Sweden is owned by firms. Fabrizio and Minin (2008) in US data, find a complementary effect between publishing and patenting but the average citations for repeated patenters decreases over time.

Thus, taking into account the literature and the Swedish academic map we conclude to the following hypotheses.

Hypothesis 1. Academic Author-Inventors have a higher number of publications than the non-patenting academic authors within nanotechnology.

Hypothesis 2. Being an academic author-inventor in nanoscience increases the quality of scientific publications in terms of citations.

3. Data and Methodology

3.1 Framing nanotechnology

Given that nanotechnology is an emerging technology, there are methodological difficulties in defining the field, but also many academics are involved in other disciplines or fields and only occasionally publish in nanotechnology. Therefore, to capture the dynamics of this knowledge base, particular methodological techniques have been developed that are followed in this paper. An important problem in the bibliometric studies focusing on the emerging field of nanotechnology is the delineation of the field. This is not only because nanotechnology is an emerging technology field but also it is interdisciplinary. Many efforts have been spent for analyzing academic efforts and also patents in nanotechnology since the mid-1990s. Braun, Schubert et al.(1997) was an early attempt to analyze nanotechnology using bibliometric techniques; authors built a database of articles on the frequency of usage of the prefix-nano in the title of science and technology journal papers during the period 1986-1995. Tolles (2001) followed a similar way and searched the SCI database using "nano*" to analyze the international scientific standing of USA in nanotechnology. However, due to the fast growing and interdisciplinary nature of the field, there occurred a need to consider some terms and phrases which do not contain any nano-prefix but should be included in nanotechnology field.

The first attempt using a list of keywords and phrases instead of nano-prefix was held in a project prepared for the EU Commission. In this research, the final list of the phrases for the delineation nanotechnology field was decided through the opinions and suggestions of a wider group of experts doing nano-related research Noyons (2003). In the second half of 2000s, the number of studies aiming at the delineation of the field of nanotechnology using text mining and bibliometric methods has increased. Among those Zitt and Bassecoulard (2006), Porter, Youtie et al.(2008) and Kostoff, Koytcheff et al.(2007) have come into prominence more than the others.

This research follows the methodology proposed by Porter, Youtie et al.(2008) for the delineation of the nanotechnology field in Sweden. For the aim of the identification of authors and institutes engaged in nanotechnology research in Sweden we use ISI Web of Science-Science Citation Index (expanded) database for publications. For almost 12 years period from 2000 to April 2012, the bibliometric data including the full contents of the articles including the keywords provided by Porter, Youtie et al.(2008) in their title or abstracts, and having at least one author affiliated to Swedish institutes were retrieved from the ISI Web of Science databases on 12 April 2012. We found 14 317 papers published in this period. Full bibliometric records of these articles were exported as a text file from ISI WoS. These records were reformatted into a Microsoft Access 2003 database using a Visual Basic script. Each of these articles was given a unique number from 1 to 14317 and all variables included in bibliometric content (i.e. authors. institutes. addresses. titles and keywords) were linked to each other through this unique identifier. Data processing was performed through created tables and queries in this database. Most of these tables and queries were recreated from bibliometric software tool Sitkis (Schildt 2005) which is also based on Microsoft Access. These new data tables are used for the identification of author names, their number of publications and for the descriptive analysis of nanotechnology research in Sweden. We will refer to this database as NANO_AUTHOR database.

3.2 Identifying the group of academic inventors in nanotechnology

In this paper we present an overview of nanotechnology in Swedish academia. The ground data for the Swedish academia come from the database SWEDISH ACADEMICS 2011, a database created by the authors. We have to mention here that in Sweden there is no centralized database with the academic employees but each university has administrative autonomy and therefore different structure in their databases. We had collected the lists of employees from each university separately and then unified into one database containing the following information about all the employees in Swedish universities: Name, Surname, Birthday, Address, Position, University, Discipline, Faculty, Department, and Division. The database includes all the employees, 48 237, in 27 Universities, all the universities which according to the Swedish National Agency for Higher Education (högskoleverket) have the right to do research. We should also mention that for the variables Position, Faculty and Department, there is a high degree of heterogeneity across the different universities as it does not exist a unique national system of taxonomy used. On the other hand, we have manually normalized the variable Discipline across all universities according to the "Standard for Swedish classification of research areas 2011", see "Standard för svensk indelning av forskningsämnen" (Högskoleverket 2011), a normalized classification's guide published by the Swedish National Agency for Higher Education.

In order to identify the academic inventors who belong to the interdisciplinary field of nanotechnology, as we framed in the above subsection, we combine the following two databases.

The NANO_AUTHOR database we already described and the 2011 version of the KEINS/APE-INV database for Sweden.

The KEINS/APE-INV database contains data about the academics that are registered as patent inventors in the European Patent Office's (EPO) register[1]. This database was expanded by the authors, in the APE-INV project, by matching the SWEDISH ACADEMICS 2011 to EPO applications. The methodology used largely corresponds to the one employed for constructing the KEINS database. This resulted to a dataset of 889 academic inventors employed by a Swedish University (KEINS/APE-INV 2011-SWEDEN).

Matching the NANO_AUTHOR database and the KEINS/APE-INV 2011-SWEDEN database identified which academic inventors have been publishing within nanotechnology. The initial match on names-surnames resulted in 95 people but because of the large homonymy problem in Sweden, as well as duplicated matches, we proceeded with a manual check and cleaning of the data which resulted into 60 academic author-inventors in nanotechnology. This group will be our treatment group on the econometric model in the following section.

3.3 The Model

The dependent variables in our sample are: productivity in terms of publications and citations. The independent variable of main interest is: having a patent. Given the dynamic and interdisciplinary nature that we want to capture, we have to be very careful regarding the control variables in our model. In the SWEDISH ACADEMICS 2011 database, there is a high heterogeneity in the data across universities regarding position, faculty and department. For example there are different titles for the position according to the university's policy of employing (guest professor, professor employed as lector, professor employed as chief physician, research assistant, researcher, etc.). A solution would be to normalize these variables across the

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[1] For a detailed account of the KEINS database, constructed in 2004, see Lissoni, F., B. Sanditov, et al. (2006). The Keins Database on Academic Inventors: Methodology and Contents, KITeS, Centre for Knowledge, Internationalization and Technology Studies, Universita' Bocconi, Milano, Italy.

whole database as for the discipline variable. In a traditional econometric model the use of these categorical variables would be still limited, for example in the case of discipline, the disciplines are expanded in different levels according to the level of specialization we could identify and we end up with a high variation in 3 different levels, while nanotechnology is highly interdisciplinary as mentioned. The problem of missing values is also present as we did not manage to get all the required information from all universities. In order to overcome the above difficulties we chose a semi parametric technique and more specifically an alteration of the treatment effect analysis. This matching technique will allow exploiting our database as much as possible in terms of the use of control variables, while at the same time we avoid the potential bias of a traditional regression model. For example, the high variation in the variable discipline will not affect the outcome as each "twin" we will compare will belong into the same discipline category. Thus, we think that the treatment effect analysis, which follows, is the best fitted model for our data.

Having the 60 identified nano authors-inventors as a treatment group; we then identify a control group of twins which are as "similar" as possible. The method used is a combination of exact and nearest neighbor match. The criteria for the exact matching were: University, Discipline and Position(Rank). The research quality of the affiliate university increases the likelihood of researchers participating in commercialization (Owen-Smith and Powell 2001; Di Gregorio and Shane 2003; Sine, Shane et al. 2003; O'shea, Allen et al. 2005). Research has also found local peer effects imply that academics are more likely to be entrepreneurial if departmental colleagues of the same rank are entrepreneurial (Stuart and Ding 2006; Bercovitz and Feldman 2008).

After identifying the academics fulfilling the above criteria, we created a pool of potential matches for each one of the 60 individuals of the treatment group. Then we selected the best possible match, nearest neighbor according to the following criteria: Year of birth, department, faculty, gender. We ended up with 58 good matches while we dropped two individuals that we were not able to parse with a good match which could fulfill at least the exact matching's criteria. Thus we ended with a sample of 116 academic authors in nano science. 58 are the academic author-inventor and 58 the control group of academic authors. Figure 1 below the databases' creation and methodology.

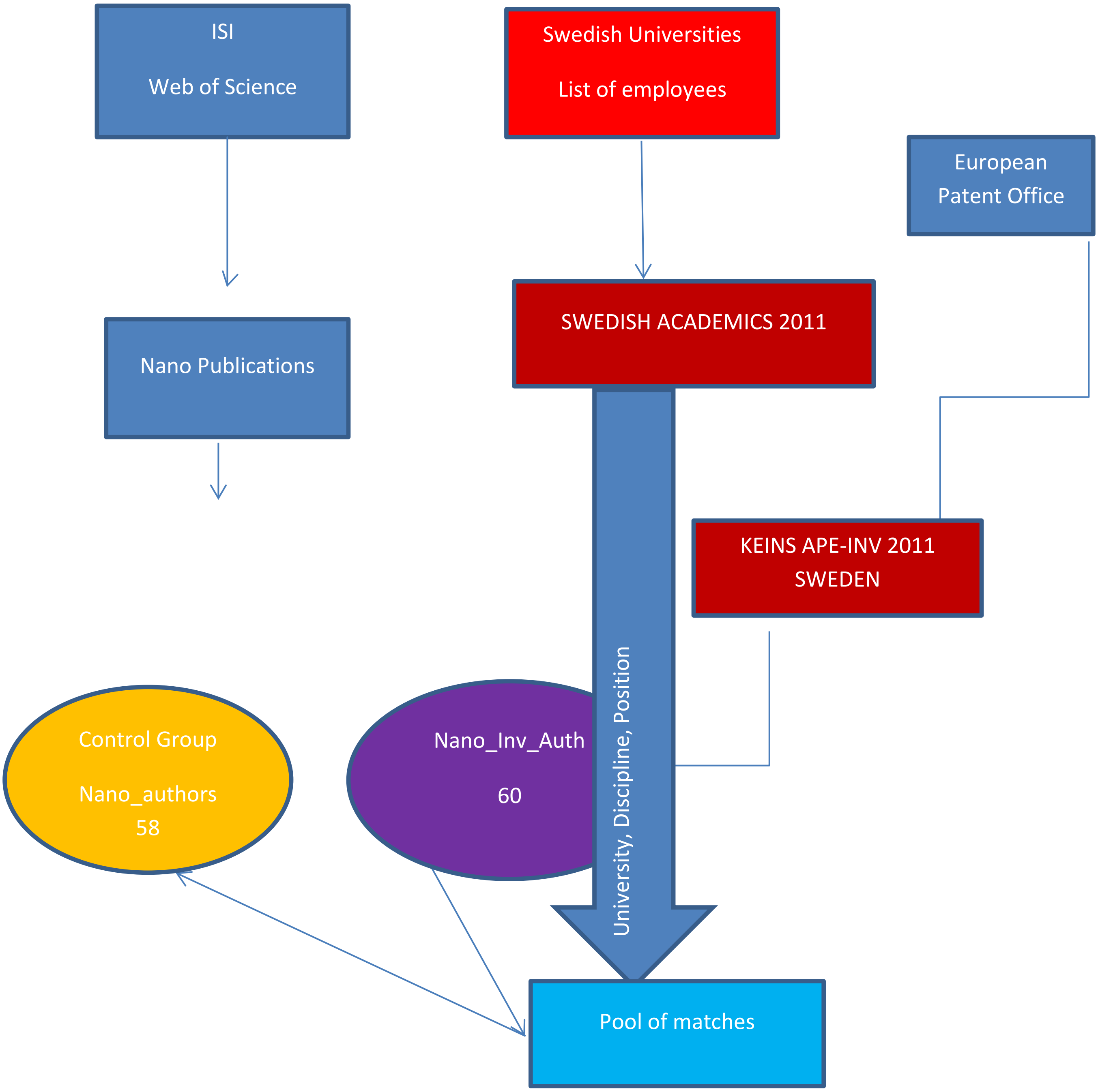
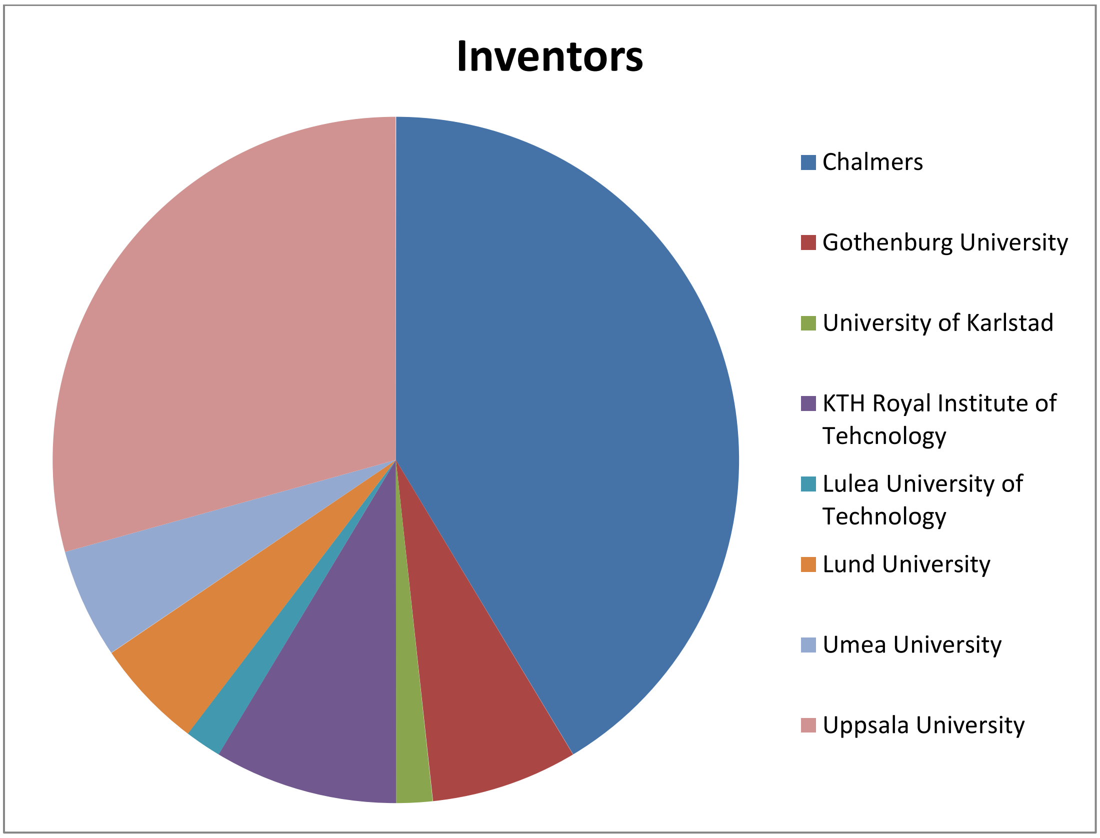
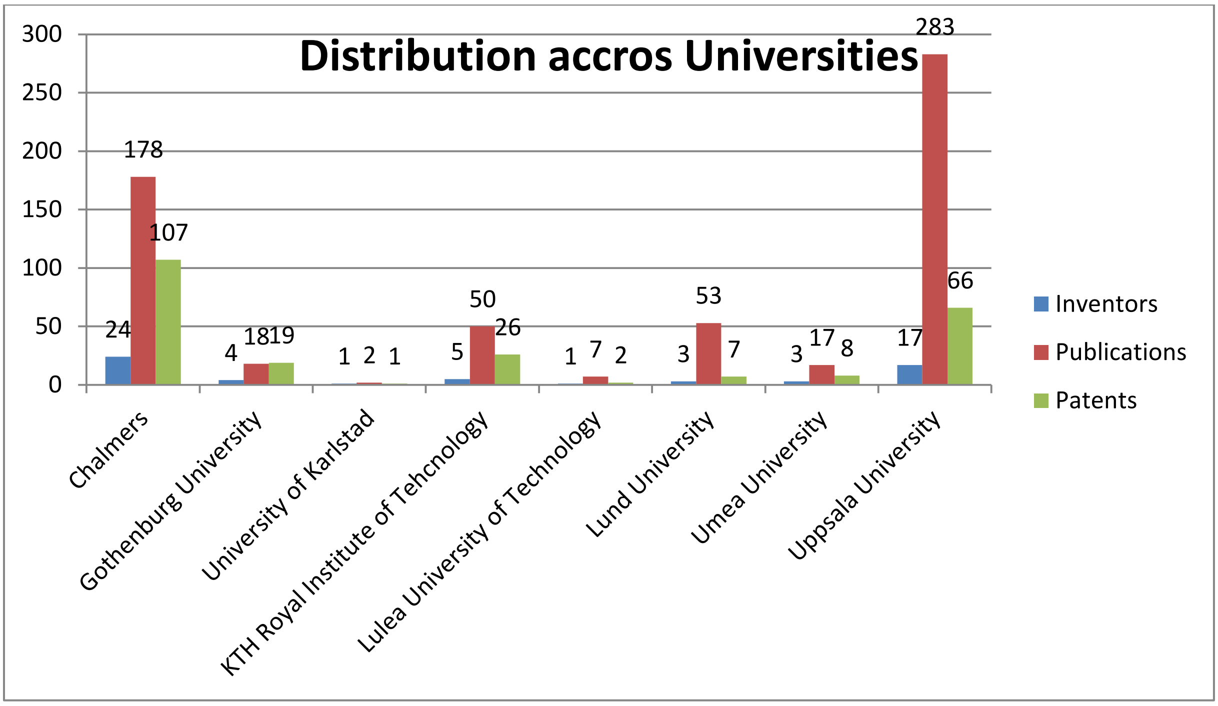
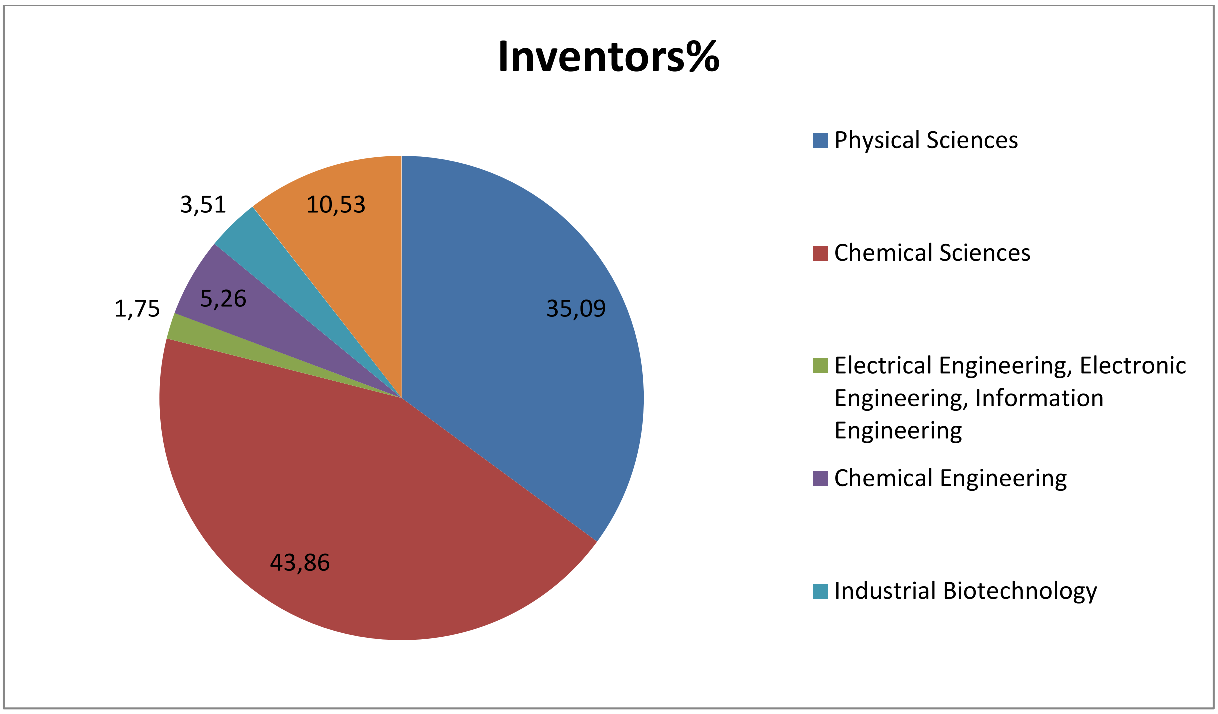


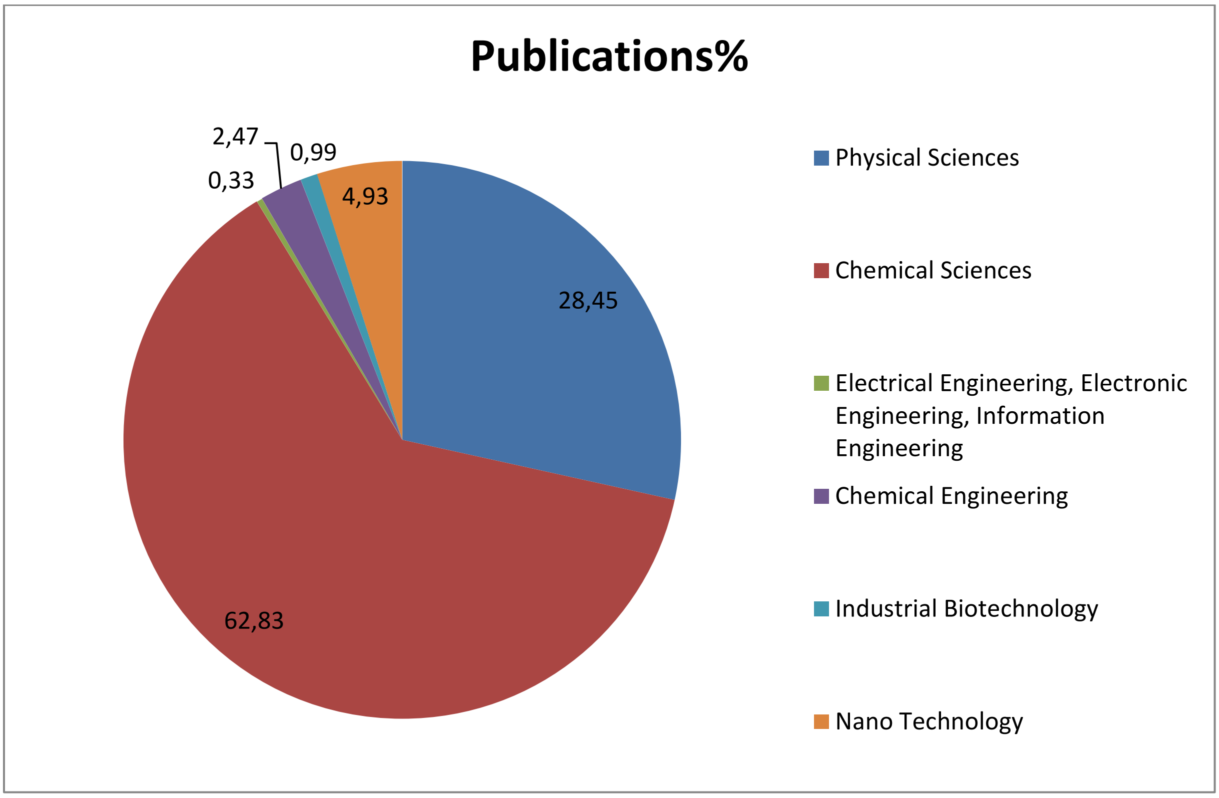
Figure 1

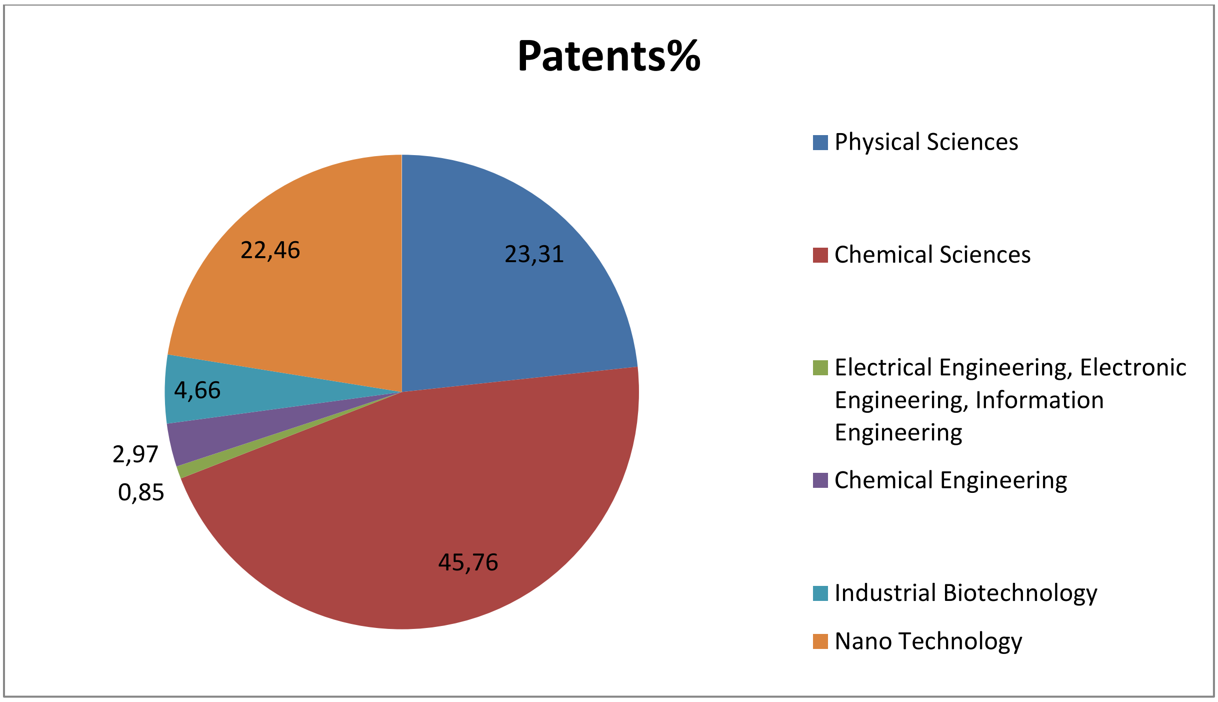
4. Nanoscience Overview in Sweden






Inventors%
35,09
43,86
1,75
5,26
3,51
10,53
Physical Sciences
Chemical Sciences
Electrical Engineering, Electronic Engineering, Information Engineering
Chemical Engineering
Industrial Biotechnology

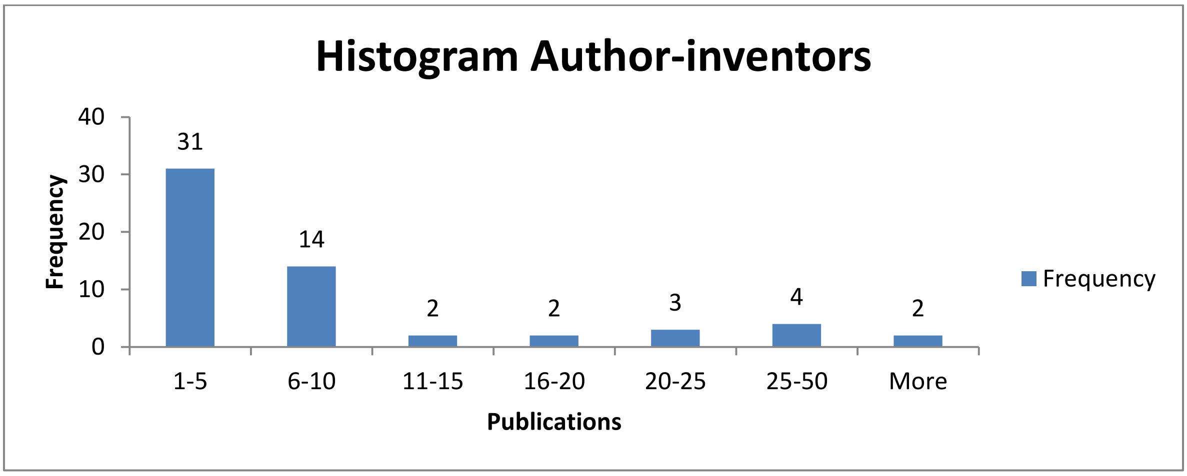

Publications%
2,47
0,99
0,33
4,93
28,45
62,83
Physical Sciences
Chemical Sciences
Electrical Engineering, Electronic Engineering, Information Engineering
Chemical Engineering
Industrial Biotechnology
Nano Technology

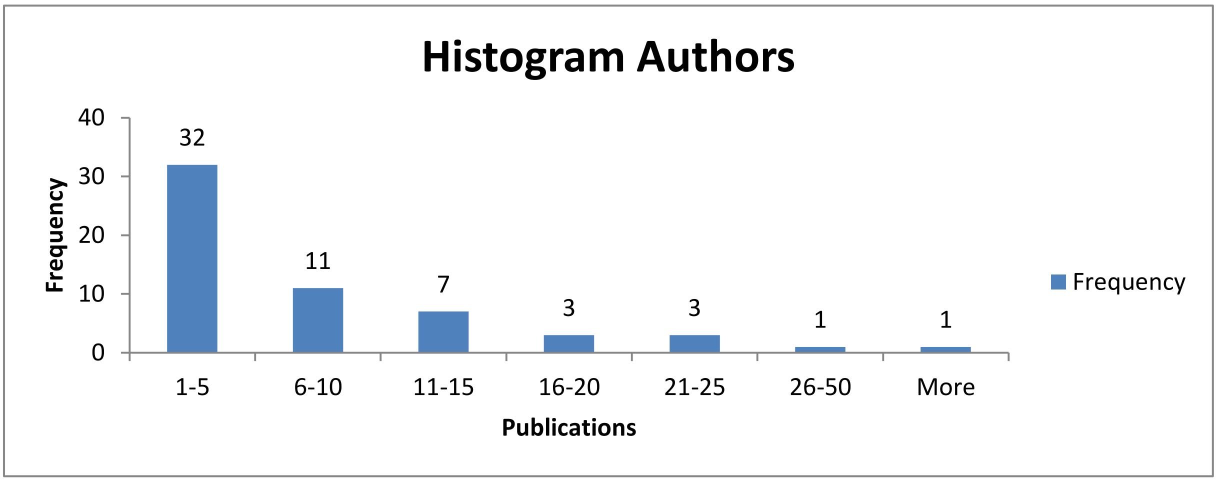

Patents%
22,46
23,31
4,66
2,97
0,85
45,76
Physical Sciences
Chemical Sciences
Electrical Engineering, Electronic Engineering, Information Engineering
Chemical Engineering
Industrial Biotechnology
Nano Technology

Rank	Author-inventors	Publications	Patents
ASSISTANT PROFESSOR	5	44	21
DOCENT	2	7	4
DOCTOR	2	7	3
DOCTORAL STUDENT	1	2	2
RESEARCH ASSISTANT	4	30	5
RESEARCHER	6	51	13
PROFESSOR/CHIEF PHYSICIAN	1	3	1
PROFESSOR	27	358	151
PROFESSOR/ LECTURER	4	74	27
PROJECT MANAGER	1	3	1
LECTURER	5	27	9

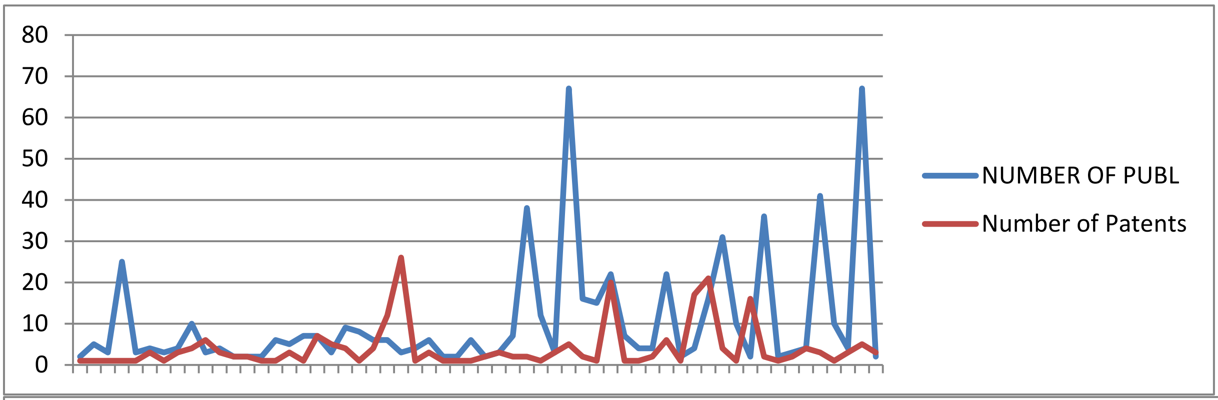
5. Results

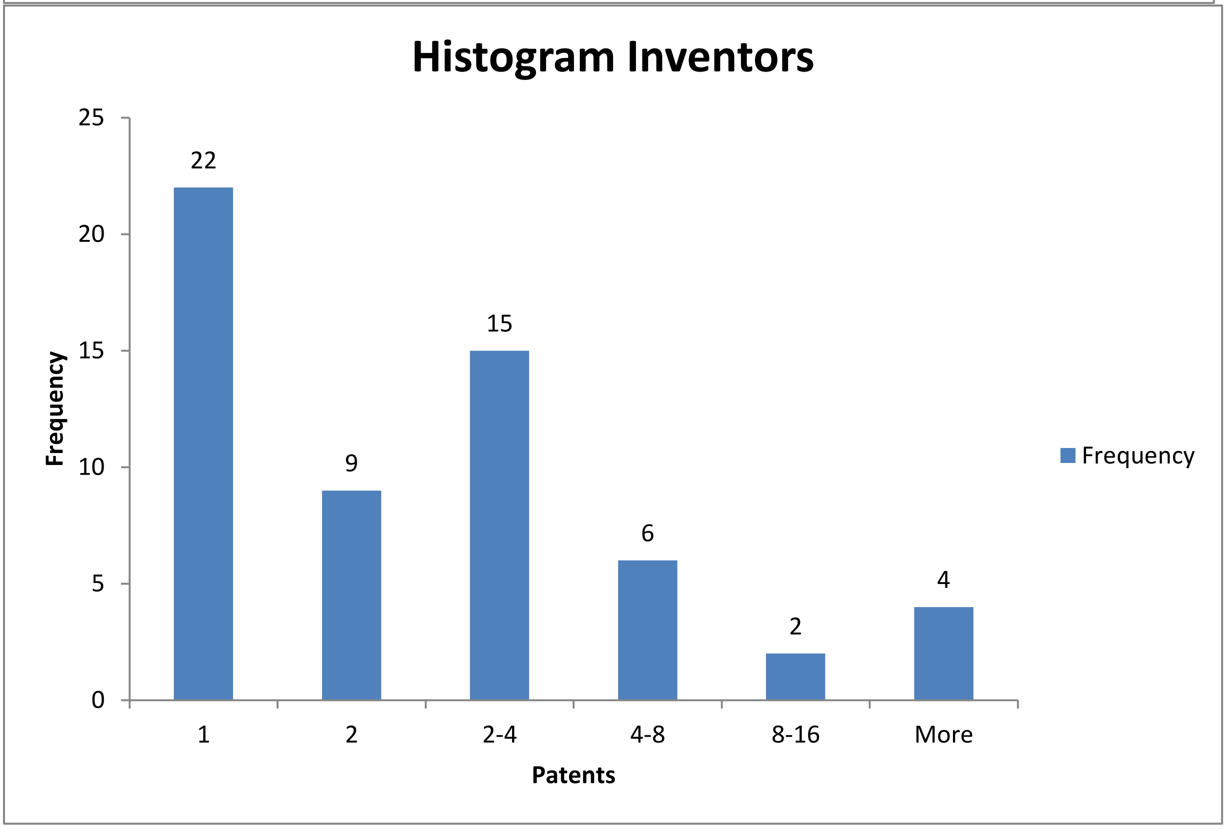
We start by presenting the frequency histograms of publications for the two groups, the author-inventors and the control group, the authors. As we see in graphs 1 and 2, the majority of the academics have within 1-5 publications and the distributions between the treatment and control group follow a similar pattern and are both skewed to the right.





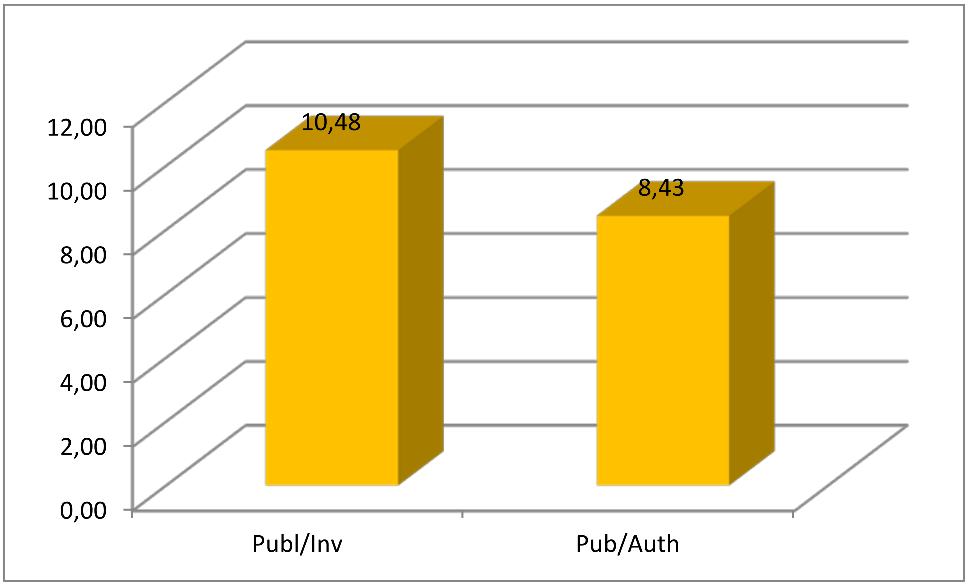
Next in graph 3, we present the group of authorinventors and the trends of patents and publications withing the group.





Graph 4 shows the distribution of patents, showing that the majority has only one patent and 46 out of 58 academics have less than 4 patents.

Graph 5 shows the comparison of the average publications between the author-inventors and the authors.



Academic author-inventors have a premium around 24% comparing to the academic authors in terms of publications, strongly supporting our first hypothesis.

6. Conclusions

- Mapping the nanotechnology field in Sweden revealed that 236 patents belong to academic author-inventors publishing within nanotechnology.
- The nano academic author-inventors are distributed in 8 universities with around 70% being in Chalmers or Uppsala University.
- Approximately 80% of the patents come from physical or chemical science and about 50% of the academic author-inventors are professors.
- Academic author-inventors have on average 24% more publications in nanotechnology in comparison to academic authors after controlling for University, discipline, position, age, department and gender.

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