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COMMERCIALIZATION OF ACADEMIC RESEARCH

A comparison between researchers in the U.S. and Finland

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Commercialization of academic research
- A comparison between researchers in the U.S. and Finland

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ETLA

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Abstract:

This paper aims to identify factors that relate to scientists' propensity to make commercially significant scientific discoveries (inventions) and to describe how these inventions are commercialized. Based on a large survey of academics active in different fields of science at U.S. universities, the paper benchmarks the top 20 universities against the rest, identifying the impact of different institutional settings. To highlight the institutional setting, the paper also compares these results to similar survey data from Finland, representing a small, highly educated European country. This comparison addresses the 'European paradox' in university technology commercialization, which is characterized by high investments in university research and disappointingly low levels of inventions and related commercialization activity. The results show that the likelihood of making commercially valuable scientific discoveries in the U.S. is driven by motivations related to the identification of commercial opportunities and working in interdisciplinary research environments. There are also significant differences between the various fields of science. In the top U.S. universities, the funding sources for scientists more likely to make inventions are more diversified and unique. The results for Finland are surprisingly similar, suggesting that the cause of the 'European paradox' seems to originate in the commercialization of inventions rather than their generation. When focusing on inventors who actively pursue commercial goals, both U.S. and Finnish inventors prefer licensing as the most popular way of taking scientific discoveries to the market. Consulting and entrepreneurship rank second and third, respectively. The countries differ with respect to both the inventors' motivations to commercialize inventions and their reasons to refrain from it. In Finland, the motivations for not pursuing commercial opportunities are much more prominent than among U.S. scientists.

Key words: Academic inventions, innovation, commercialization of research, academic entrepreneurship

JEL: O30, O38, O33, O34

Tiivistelmä:

Tutkimuksen tavoitteena on tunnistaa tekijöitä, jotka liittyvät akateemisten tutkijoiden todennäköisyyteen tehdä kaupallisesti merkittäviä tieteellisiä löydöksiä (keksintöjä) ja kuvailla miten nämä keksinnöt kaupallistetaan. Laajan eri tieteenaloja Yhdysvalloissa kattavan kyselyaineiston avulla tutkimus vertaa toimintaympäristön vaikutusta Yhdysvaltojen huippuyliopistojen ja muiden sikäläisten yliopistojen välillä. Korostaakseen tätä asetelmaa, kyselyn tuloksia verrataan vastaavanlaisen kyselyn tuloksiin Suomesta. Tämän vertailun avulla voidaan analysoida niin sanottua eurooppalaista tieteen kaupallistamisen paradoksia, jossa suuret investoinnit yliopistotutkimukseen ovat tuottaneet vähissä määrin akateemisia keksintöjä ja kaupallista toimintaa. Tämän raportin tutkimustulokset osoittavat, että todennäköisyys tehdä kaupallisesti merkittäviä tieteellisiä löydöksiä riippuu Yhdysvalloissa erityisesti tutkijoiden motivaatioista liittyen kaupallisten mahdollisuuksien tunnistamiseen ja poikkitieteelliseen tutkimusympäristöön. Lisäksi on huomioitava, että tieteenalojen välillä on huomattavia eroja. Yhdysvaltojen huippuyliopistoissa tutkijoilla rahoituksen lähteet ovat monipuolisempia ja ainutlaatuisempia kuin muissa sikäläisissä yliopistoissa. Suomea koskevat keksintöihin liittyvät tulokset osoittavat, ettei todella merkittäviä eroja Yhdysvaltoihin ole. Tämä viittaa siihen, että eurooppalainen paradoksi liittyy todennäköisesti enemmän keksintöjen kaupallistamiseen kuin keksintöjen tuottamiseen. Keskittyessä niihin keksijöihin, joilla on mahdollisuus kaupallistaa keksintöjään, voidaan Yhdysvalloissa ja Suomessa todeta lisensoinnin olevan yleisin kaupallistamisen muoto. Sitä seuraa keksintöihin liittyvä konsultointi ja yrittäjyys. Keskeisimmät erot Suomen ja Yhdysvaltojen välillä ovat motivaatioissa kaupallistaa tai olla kaupallistamatta keksintöjä. Suomessa tutkijat kokevat haasteet keksintöjen kaupallistamisessa kautta linjan paljon suuremmiksi kuin tutkijat Yhdysvalloissa.

Avainsanat: Akateemiset keksinnöt, innovaatiot, tieteen kaupallistaminen, akateeminen yrittäjyys

JEL: O30, O38, O33, O34

1. Introduction

The role of innovation has been prevalent in policy discussions addressing the competitive advantage of nations in an ever-globalizing world in which strategies that are purely production cost-based are fast becoming obsolete. Developed economies such as the U.S. are hard pressed to focus on facilitating the discovery and development of innovations that enable industrial renewal. This is achieved by creating a strong knowledge base and exploiting it commercially to sustain economic growth (Dosi and Nelson, 2010).

Innovations often require considerable freedom in researching their underlying phenomena, prerequisites that companies often lack. Thus, universities are considered a significant source of knowledge leading to the development of platforms that future technologies build upon (Eztkowitz et al., 2000). To facilitate the improvement of premises for university research and its application in industry, much academic research has been devoted to understanding the university innovation process. Specifically, the transfer of knowledge and technology between universities and companies has been broadly discussed (for reviews, see Bozeman, 2000; Rothaermel et al., 2007; Siegel, 2007).

The existing research and the related discussions on university innovations have been conducted on the national, regional or organizational levels (e.g., Mansfield and Lee, 1996; Arundel and Geuna, 2004; Segarra-Blasco and Arauzo-Carod, 2008). The focus on these institutional actors has largely ignored another important one - the individual researcher. For example, in the U.S. there has been a long tradition of exploiting academic research in industrial contexts, a phenomenon often driven by prominent individual academics (Zucker and Darby, 1996). Other countries, including the most developed, often perceive the U.S. as the primary point of reference when discussing the role of academia in industrial renewal (Tahvanainen and Hermans, 2008). Thus, the perception of the researcher as a commercial agent might be somewhat different in other countries where the academy has only recently been afforded the role of a significant source of industry-relevant knowledge. To introduce new insights into this discussion, international comparison is warranted.

Finland is a developed, small and open economy with high a GDP per capita and, in recent years, has ranked high in competitiveness (IMD & WEF) and education (PISA). At the same time, Finnish universities are ranked relatively low (ARWU). Despite these university rankings, Finland does boast world-class research in many areas of science, even leading-edge research in some. However, Finland seems to face challenges in spawning university-based economic activity at an equivalent scale. Innovation policy experts speak of a commercialization paradox (Georghiou et al., 2003; VNK, 2006; TEM, 2009). So far, no clear empirical evidence has emerged that would support the validity of this claim or unravel its potential causes. To rise to this challenge, the current paper presents fresh empirical findings on the commercial endeavors of U.S. researchers and compares them with similar data collected from Finland. There are two key research questions: *Who are the inventors in academia? How are these inventions commercialized?* By answering these questions, the paper aims to open up and shed more light on the black box of academic inventions and their commercialization.

The paper is structured as follows. Section 2 describes the methodology and data applied and used in the study. Section 3 provides insights into the characteristics of inventors in academia. Section 4 discusses the commercialization of academic inventions. Section 5 concludes the paper with a discussion and implications.

2. Data and methodology

The focus of this paper is on the innovation and commercialization activities of researchers in the fields of natural and engineering sciences. Thus, a large body of academic disciplines is excluded from the analyses. The reason for this choice is the nature of research conducted in different academic fields. In other areas, such as social sciences, discoveries with commercial potential may also emerge, but on a much smaller scale, and often in a less tangible form. The commercialization of such discoveries would require a separate study taking into account the unique nature of the respective sciences. To focus on the natural and engineering sciences, we made several methodological choices that need to be addressed. These choices are identical in both the U.S. and the Finnish surveys (see Tahvanainen and Nikulainen 2011 for detailed results specific to Finland).

The targeted population of researchers was identified from the Thomson ISI - Science Citation Index Expanded, which indexes citations to articles published in over 8,000 journals across 150 disciplines. The use of Thomson ISI also served as a quality control, as journals included in the ISI indexes can be perceived to be of higher quality than journals that are not. In the next step, the locations of the corresponding authors were identified. If the author was affiliated to the U.S., his/her contact information was retrieved from the database. To focus on researchers most likely to have an active career, only articles published in 2010 and 2011 were collected. Because the targeted population was academia, only contact information for researchers with university affiliations were retrieved (i.e., an email address with a .edu suffix). The final population consisted of 159,592 individuals.

After identifying the relevant population, an online survey questionnaire was sent out to each individual researcher between May and June 2012. Altogether, 5554 valid responses were received, translating to an adjusted (exclusion of incorrect email addresses) response rate of 4.0%. The respondents were classified into different institutional settings based on their affiliation. Two institutional settings were considered – the Top 20 U.S. universities (2011 ARWU ranking) and the remaining U.S. universities. The aim of this stratification was to take into account the different institutional environments and their impact on inventions and commercialization activities. Table 1 lists the Top 20 universities according to the number of responses. The listing shows that the number of respondents at leading U.S. universities amounts to 1229 (22% of all respondents) in total.

Table 1 Number of respondents in the Top 20 U.S. universities

Top 20 U.S.	
University domain	**# of obs**
harvard.edu	127
washington.edu	90
cornell.edu	89
umich.edu	86
umn.edu	83
wisc.edu	82
columbia.edu	62
stanford.edu	62
berkeley.edu	59
mit.edu	58
ucla.edu	57
upenn.edu	56
ucsd.edu	43
illinois.edu	42
yale.edu	42
ucsf.edu	39
jhmi.edu	37
caltech.edu	31
princeton.edu	30
uchicago.edu	24
Total	**1229**

The next section profiles the most likely academic inventors. In doing so, the propensity to make inventions is reflected against several background variables. The aim is to identify the most important factors that drive the generation of inventions. Later, the focus shifts from academic inventions to their commercialization (Section 4).

3. Inventors in academia

What drives the propensity of academics to make inventions? In the existing literature, academic patenting and invention disclosures made to university technology transfer offices are the most common indicators of academic innovation (e.g., Agrawal and Henderson, 2002; Breschi et al., 2007; Dietz and Bozeman, 2005). While academic patents can be linked to aggregate individual-level data, such as affiliations, overall patenting and publication activities, the challenge is that not all inventions are patented. Thus, some of the inventions are left outside the scope of these studies. Invention disclosures more accurately measure potential commercially relevant inventions. However, detailed individual level information is difficult to obtain due, for instance, to confidentiality issues. Therefore, the approach and data used in this paper can be seen as complementary to the previously mentioned methods of addressing academic inventorship.

In this paper, academic inventors are identified using a variable that identifies respondents as inventors if they claim to have produced at least one invention with "obvious commercial potential" in the past five years prior to survey implementation. The assessment of the commercial potential is, of course, subjective. However, for the study of *personal* motivations and inhibitors of commercialization, objective potential is irrelevant. What counts is the individuals' own perception of her invention's value. Based on the answer, the respondents were categorized into inventors and non-inventors.

The shares of inventors are reported in Table 2 below, which shows they are fairly similar across the established categories. The share is 36% for the Top 20 U.S. universities and 37% for the remainder of U.S. universities. Roughly one-third of academics report that they have made scientific discoveries with significant commercial potential. Interestingly, the comparison with Finland reveals that in Finnish universities the share of inventors is slightly higher than in the U.S., as 40% of the respondents stated that they made at least one scientific discovery that has potentially significant commercial value.

Table 2 Share of inventors in the U.S. and Finnish academia

	Top 20 U.S.	**Rest of U.S.**	**Finland**
# of obs	1229	5554	1162
Share of inventors	35.6%	36.8%	40.4%
# of inventors	438	2043	637
Inventions per inventor	2.37	2.51	2.48

Making inventions in academia involves to a large set of factors. These factors include age of the respondent, their educational level, field of research, personal motivations for research, publication and patenting activity, previous work experience, current work environment, allocation of time and research activities, and importance of different funding sources. The following section discusses the dimensions indicating the propensity of being an academic inventor. The results are first discussed in light of descriptive statistics, followed by statistical analyses that control for cross-impacts of different dimensions through econometric techniques.

3.1. Characteristics of academic inventors and non-inventors

When discussing individual researchers and their characteristics, one of the first dimensions that come to mind is the age of the individual. In the context of this paper and its research themes, the age of the respondent may play a significant role. A long career can provide many opportunities to interact with industries and to engage in commercially relevant activities. Younger academics have a shorter career and fewer opportunities to engage in commercial activities. At the same time, they might be more inclined to pursue innovative activities as a way to explore alternative career opportunities.

The results in Table 3 reveal that when looking at averages, the inventors (approximately 46 years old in the Top U.S. universities) are older than the non-inventors (approximately 42 years old in the Top U.S. universities). In Finland, the respondents are younger on average than in the U.S., and inventors are older than non-inventors (40 vs. 36 years).

The result is somewhat baffling given the common perception that academia in the U.S. has traditionally embraced bilateral relationships with industry as part of its research culture. While we lack robust data to unravel the causes of the phenomenon, one potential explanation could be the relatively established role of the tenure track system in the U.S. The system ties post-doctoral researchers to a professor and her research team for several years, providing researchers with the opportunity to fully claim freedom of movement regarding inventions only after completing the track. In Finland, the tenure track system is a fairly new institution and has only been adopted by a very small number of universities. In Finland, it is not uncommon to see fresh PhD graduates leading entire teams of researchers as senior researchers. Claiming ownership of inventions in this setting is possible in much earlier stages of a researcher's career.

Table 3 Age by group (averages; categorical variables)

	Top 20 U.S.		Rest of U.S.		Finland	
Variable	**Inv.**	**Non-inv.**	**Inv.**	**Non-inv.**	**Inv.**	**Non-inv.**
Age	4.64	4.17	4.65	4.30	4.03	3.61

Note: categorical variable averages; higher value indicates higher age
Categories: 1 = under 20 yrs 2 = 20-29 yrs … 7 = 70-79 yrs 8 = over 80 yrs

The level of education is another factor that might be connected to innovation activities. A large majority of the respondents (90%) reported having a Ph.D. The interesting aspect of including this background variable in the analysis is the difference between researchers with a Ph.D. and the rest of the respondents with lower academic degrees. We can see only small differences in the educational levels of inventors and non-inventors, suggesting that the level of education may play only a limited role in the propensity to make inventions. Thus, we expect to see that the more predominant roles are played by factors that characterize the research and lesser roles by those related to the researcher.

Table 3 Level of education by degrees (averages; categorical variables)

	Top 20 U.S.		Rest of U.S.		Finland	
Variable	**Inv.**	**Non-inv.**	**Inv.**	**Non-inv.**	**Inv.**	**Non-inv.**
Education	1.28	1.23	1.41	1.28	1.15	1.27

Note: categorical variable averages; higher value indicates higher education level
Categories: 1 = Ph.D. 2 = Master's degree 3 = Bachelor's degree 4 = Other

One of the most influential determinants of the generation of inventions is the respondent's field of research. This aspect could be addressed by looking at the educational background of the researchers. Instead, this paper's attention is on the current activities of the respondents. In the course of a long career, it is quite likely that researchers will move away from their initial research areas to undertake new ones. By focusing on the current research area, this paper aims to highlight the differences between research areas in their likelihood of yielding inventions.

Areas that are closer to industrial application, such as chemistry, are most likely are quite different from areas that are typically distant from industries, such as astronomy. The classification of research areas in the U.S. and in Finland differ to some extent, but Table 4 reports both. From the U.S. results, we can see that the areas with the largest shares of inventors include chemistry, computer sciences, electrical and material engineering, and medical sciences. The largest shares of non-inventors are found in astronomy, geosciences and mathematics. The results for Finland are quite similar. Parallel to the U.S. results, chemistry, computer sciences and electrical and material engineering have higher inventor vs. non-inventor ratios, among which biology, physics and mathematics stand out. All results are in line with the argument that in more application-oriented areas of science it is also more likely that inventions will emerge.

Table 4 *Current research area (averages; binary variables)*

	Top 20 U.S.		Rest of U.S.			Finland	
Variable	**Inv.**	**Non-inv.**	**Inv.**	**Non-inv.**	**Variable**	**Inv.**	**Non-inv.**
Natural sciences					*Natural sciences*		
Astronomy	0.00	0.10	0.01	0.10	Mathematics	0.09	0.11
Chemistry	0.12	0.07	0.19	0.11	Computer sciences	0.08	0.04
Physics	0.14	0.27	0.15	0.20	Physics	0.12	0.15
Geosciences	0.06	0.17	0.07	0.15	Chemistry	0.11	0.07
Mathematics	0.07	0.16	0.09	0.24	Biology	0.07	0.19
Computer sciences	0.17	0.06	0.18	0.07	Biochemistry	0.07	0.05
Agricultural sciences	0.06	0.03	0.11	0.06	Environmental sciences	0.06	0.08
Biology	0.65	0.52	0.63	0.54	Biosciences	0.19	0.11
Engineering					*Engineering*		
Aerospace	0.00	0.00	0.02	0.01	Mechanical	0.03	0.01
Chemical	0.08	0.01	0.06	0.02	Energy	0.03	0.01
Civil	0.02	0.01	0.05	0.03	Electrical	0.07	0.02
Electrical	0.14	0.07	0.13	0.04	Physics	0.04	0.02
Mechanical	0.05	0.02	0.07	0.03	ICT	0.10	0.03
Material	0.09	0.03	0.10	0.03	Chemistry	0.06	0.02
Industrial	0.00	0.00	0.02	0.01	Environmental	0.03	0.01
Other	0.10	0.05	0.11	0.04	Forestry	0.03	0.01
					Material	0.06	0.02
					Industrial	0.01	0.01
Other					*Other*		
Medical sciences	0.72	0.47	0.59	0.35	Medical sciences	0.27	0.21
Other life sciences	0.05	0.07	0.07	0.06	Economics and mgmt.	0.03	0.01
Psychology	0.06	0.10	0.07	0.10	Law	0.00	0.00
Social sciences	0.10	0.17	0.07	0.18	Other	0.09	0.12

Note: The current research areas are categorized based on NSF's educational classifications for the U.S. and based on Ministry of Education classifications in Finland.

Although business training is not typical for scientists in natural sciences and engineering, in the survey this aspect was accounted for because it could have a significant impact on the innovation-oriented activities of researchers. Table 5 reveals that inventors are more likely to have additional business training in both the U.S. and Finland. This finding supports university-level efforts to promote business skills through, e.g., seminars and intensive courses. Such training seems to be effective in providing researchers with the necessary knowledge to overcome insecurities related to conquering unknown terrain and to try their hands at commercialization.

Table 5 Additional business education (averages; binary variables)

	Top 20 U.S.		Rest of U.S.		Finland	
Variable	**Inv.**	**Non-inv.**	**Inv.**	**Non-inv.**	**Inv.**	**Non-inv.**
Business education	0.06	0.03	0.08	0.05	0.11	0.07

If researchers are driven to their research topic by commercial ambitions, one could easily expect them to work in areas with relatively large potential for inventions. However, other motivations for research also exist, including personal interest, the interest of the research supervisor, availability of funding and access to new instrumentation. Table 6 shows the respective results, which are surprisingly similar in the U.S. and Finland. Inventors are more likely to choose their research area based on the availability of new research instrumentation, companies' needs, and commercial opportunities than non-inventors.

Table 6 Motivations to enter current research area (averages)

	Top 20 U.S.		Rest of U.S.		Finland	
Variable	**Inv.**	**Non-inv.**	**Inv.**	**Non-inv.**	**Inv.**	**Non-inv.**
Own research interest	3.83	3.82	3.80	3.81	3.74	3.63
Supervisor interest	2.19	2.39	2.16	2.31	2.36	2.59
Availability of funding	2.75	2.51	2.82	2.49	2.65	2.54
New instrumentation	1.96	1.74	2.11	1.76	2.12	1.85
New data	2.26	2.18	2.34	2.18	2.14	2.08
Visits abroad	1.67	1.58	1.74	1.63	2.26	2.09
Company's needs	1.69	1.22	1.83	1.32	2.10	1.46
Commercial opportunities	1.82	1.16	1.85	1.19	2.05	1.35
Employment opportunities	2.33	2.13	2.41	2.14	2.42	2.36

Note: Scale variables; 1 – Not at all, 4 – Very much

The existing literature on individual academics' innovation activities commonly makes use of patents and publications as direct indicators of such activity, largely because they are readily available. In addition to their direct use, they are even more useful as controls for the level of different types of activities.

Patents indicate that the research conducted in academia is industrially applicable. The downside is that not all academic inventions are patented. This leaves out a large share of inventions that should be included in analyses that investigate inventions and the commercialization of science. Publication activity is not directly linked to inventions but is often used to indicate the level of academic productivity. In empirical research, high levels of both patenting and publication activity have been associated with 'star scientists', individuals who have high levels of patents and publications and actively engage with industry (Zucker & Darby, 1996). Related to regulations and customs in patenting and publishing, scientists working on software are often excluded from studies because they are rarely able to patent their inventions and because they prefer to publish their results in conference proceedings rather than in traditional peer reviewed journals.

For this reason, the survey explicitly asked whether the respondents were primarily engaged in software development. Through this variable, the uniqueness of software development in academia can, at least partially, be taken into consideration. The results in Table 7 show that inventors are more productive than non-inventors in all three dimensions, both in the U.S. and Finland. The most striking finding is that in Finland both inventors and non-inventors patent and publish significantly less than their U.S. peers. Direct comparison between the two is difficult as the respondents were asked about a range rather than exact number of publications. We estimate (average * category range) that scientists in Finland have an average of have an average of approximately 18 publications, whereas in the U.S. the number is approximately 30.

Table 7 Publications, patents and software development (averages)

	Top 20 U.S.		Rest of U.S.		Finland	
Variable	**Inv.**	**Non-inv.**	**Inv.**	**Non-inv.**	**Inv.**	**Non-inv.**
Publications	3.74	3.15	3.66	3.09	2.88	2.19
Patents	1.06	0.20	0.95	0.19	0.66	0.10
Software development	0.08	0.04	0.08	0.04	0.09	0.04

Note: Publications and patents are categorical variables; a higher value indicates a higher activity level
Software is a binary variable

Categories:

Publications	*Patent applications*
0 = 0	*0 = 0*
1 = 1-9	*1 = 1-5*
2 = 10-19	*2 = 6-10*
3 = 20-49	*3 = 11-20*
4 = 50-100	*4 = 20+*
5 = 100+	

Having work experience in companies, both domestic and foreign, or in foreign universities may play a role in broadening scientists' perspectives on different types of opportunities, potentially leading to a higher propensity to invent. Table 8 lends support to this argument and indicates that inventors indeed have more work experience outside the domestic university system both in the U.S. and Finland.

Table 8 Work experience (averages; binary variables)

	Top 20 U.S.		Rest of U.S.			Finland	
Variable	**Inv.**	**Non-inv.**	**Inv.**	**Non-inv.**	**Variable**	**Inv.**	**Non-inv.**
Foreign university	0.24	0.21	0.24	0.21	Foreign university	0.36	0.27
Small US company	0.07	0.04	0.11	0.04	Small Finnish company	0.09	0.04
Large US company	0.13	0.10	0.15	0.09	Large Finnish company	0.13	0.07
Foreign company	0.03	0.01	0.05	0.02	Foreign company	0.03	0.01

The work experience of scientists is closely related to the environment they work in. Here, work environment means the department or laboratory in which the individual researcher currently works. The discussion of the work environment takes into account a variety of team characteristics (including their size and interdisciplinarity) that can be argued as having an impact on the generation of inventions. For instance, it can be assumed that researchers in higher positions are more likely to be 'star scientists' and, therefore, have a higher propensity to generate or make claims to inventions and engage in commercialization activities. A large body of literature confirms the impact of interdisciplinarity on producing more industry-relevant knowledge than traditional discipline-bound research (Foray and Gibbons, 1996; Gibbons et al., 1994; Mowery and Sampat, 2004).

Our results are in line with these expectations. Table 9 shows that inventors usually have a higher position in research teams both in the U.S. and Finland. They also work in a larger number of teams than non-inventors. In the U.S., inventors work in larger teams than non-inventors, whereas in Finland team sizes do not appear to make a difference. The work environment of inventors is often more interdisciplinary, and their teams have a slightly higher share of international researchers. In Finland, the share of international researchers in teams is roughly half that of the U.S. research teams. This finding clearly resonates with the reportedly low degree of internationalization of Finnish universities, which is considered a challenge to increasing the quality of Finnish research (TEM, 2009).

Table 9 *Work environment (average)*

	Top 20 U.S.		**Rest of U.S.**		**Finland**	
Variable	**Inv.**	**Non-inv.**	**Inv.**	**Non-inv.**	**Inv.**	**Non-inv.**
Position in teams	1.91	2.41	1.88	2.45	2.03	2.87
Number of teams	2.22	1.98	2.19	1.95	2.14	1.74
Size of teams	2.00	1.87	1.84	1.72	1.84	1.85
Interdisciplinarity	0.68	0.50	0.68	0.48	0.66	0.50
Share of int. researchers	41.46	38.95	40.38	34.39	22.55	21.07

Note: Position, number and size are categorical variables; a lower value in position indicates a higher position in teams; a higher number and size value indicates a higher number of teams and a larger average group size, respectively.
Interdisciplinarity is a binary variable.
Multicultural is a scale variable from 0 to 100.

Categories:

Position in teams	*Number of teams*	*Size of teams*
1 = Head of several teams	*1 = 1*	*1 = 1 - 3*
2 = Head of a single team	*2 = 2-3*	*2 = 4 - 6*
3 = Researcher	*3 = 4-5*	*3 = 7 - 10*
4 = PhD student	*4 = 6-10*	*4 = 11+ individuals*
	5 = 11+ teams	

The allocation of work time and a more detailed breakdown of research activities are two further aspects that help distinguish inventors from non-inventors. The respondents were asked to estimate how they divided their time between research activities, teaching obligations and administrative work. The inclusion of this dimension potentially reveals whether inventors are more focused on research than administrative duties. The survey also addressed what type of research the scientists were engaged in. The respondents were asked to estimate how they divided their time among basic research, applied research, and development efforts. The assumption here is that scientists who focus more on applied research would also be more likely to generate inventions.

Table 10 shows that in the top U.S. universities inventors are spending less time on research and more time on teaching than non-inventors. In other U.S. universities, this trend does not occur. In Finland, inventors also spend less time on research. However, instead of teaching, they report spending their time on administration. It should be noted that in Finland researchers spend significantly more time on research than teaching and administration than in the U.S. Looking at the research activities, the inventors in the U.S. spend more time on applied research and development activities than non-inventors and less time on basic research. In Finland, the results are similar, but, interestingly, the level of development activities is much lower than in the U.S. universities.

Table 10 Time and research activity allocation (average)

	Top 20 U.S.		Rest of U.S.		Finland	
Variable	**Inv.**	**Non-inv.**	**Inv.**	**Non-inv.**	**Inv.**	**Non-inv.**
Time						
Research	42.5	47.6	41.6	43.4	54.12	61.05
Teaching	26.9	21.5	27.3	25.1	19.81	17.29
Administration	30.6	30.9	31.1	31.5	24.34	17.50
Research activities						
Basic	46.4	59.4	44.1	60.2	47.90	64.50
Applied	40.7	37.0	41.3	36.3	44.13	32.23
Development	12.9	3.7	14.6	3.5	7.04	1.97

Note: All variables are on a scale of 0 to 100.

The last aspect to be addressed in the descriptive part of the paper focuses on funding. The scientists were asked how significant different funding sources are for their own activities. The list of potential funding sources for the U.S. was identified based on the National Science Board (NSB) and was complemented with additional funding sources, such as funding provided by the scientists' own organizations, foundations and corporate-sponsored funding. For Finland, the list of potential sources is based on the authors' own research. Due to different funding sources, the results for the U.S. and Finland are not comparable. The aim of including the funding aspect in the discussion is to highlight the different roles specific funding sources play in promoting academic innovation activities.

Table 11 provides only a few interesting observations. Inventors in the U.S. are more likely to be funded by external parties, such as DOD, NIH, DARPA, foundations and companies than non-inventors. This outcome is somewhat intuitive, as many of the listed parties tend to fund more application-oriented research. In Finland, however, comparing results between inventors and non-inventors provides rather interesting insights. Funding provided by companies, Tekes (Finnish Funding Agency for Technology and Innovation) and the EU seems to be more important for inventors than non-inventors. This is most likely an indication of a closer relationship with industry. Most of the projects funded by Tekes involve collaborations with companies, as this is one of the most central criteria Tekes imposes on its approved projects.

Table 11 Importance of funding sources (average)

	Top 20 U.S.		Rest of U.S.			Finland	
Variable	**Inv.**	**Non-inv.**	**Inv.**	**Non-inv.**	**Variable**	**Inv.**	**Non-inv.**
Own organization	2.19	2.35	2.33	2.44	Own organization	2.56	2.71
Dep. of Defense	1.59	1.29	1.75	1.35	Academy of Finland	2.96	2.82
Dep. of Energy	1.45	1.46	1.49	1.39	Tekes	2.50	1.62
NASA	1.29	1.41	1.31	1.38	Foundations	2.46	2.67
NIH	2.91	2.36	2.67	2.16	European Union	2.08	1.71
NSF	2.23	2.41	2.36	2.45	Other foreign	1.53	1.47
USDA	1.25	1.16	1.41	1.30	Companies	2.13	1.43
DARPA	1.42	1.14	1.40	1.13			
Other federal	1.56	1.59	1.68	1.57			
Foundations	2.25	2.06	2.16	1.97			
Companies	2.10	1.33	2.26	1.42			

Note: Scale variables; 1 – Not at all, 4 – Very much

The above variables were used in a statistical analysis to identify factors that determine a scientist's likelihood of making scientific discoveries with potentially significant commercial value. By including all the variables in the analysis, we aim to identify the most significant determinants of being an academic inventor.

3.2. Statistical evidence

The statistical analysis focuses on all three groups of scientists: top 20 university scientists, scientists in other U.S. universities, and, as an international comparison, academics working in Finnish universities. Instead of reporting the probit regression results with coefficients and their statistically significant levels, the statistical results reported below show the marginal effects of probit regressions. This provides a good approximation of the proportional change in the dependent variable (making an invention) that will be produced by a one-unit change in the independent variable in question. Table 12 below presents the results for the marginal effects taken after each model. We only report statistically significant variables. The full sets of marginal effects are reported in Appendix 1.

In Table 12, the results are categorized into four different groups: positive probability (research areas), positive probability (other factors), negative probability (other factors) and negative probability (research areas). The impact of research areas is separated from the other variables to make the interpretation and comparison of results clearer.

Table 12 Factors related to the ability to make inventions
(marginal effects of the probit regression; only statistically significant results)

	U.S. Top 20		U.S. Rest		FIN
	dy/dx		dy/dx		dy/dx
Positive probabilities - research areas					
Agriculture	0.126	Civil eng.	0.126	Forestry eng.	0.173
Computer sc.	0.109	Computer sc.	0.104	Electrical eng.	0.127
		Agriculture	0.067	Biochemistry	0.121
		Biology	0.023	ICT eng.	0.091
				Medical sc.	0.081
				Computer sc.	0.072
Positive probabilities - other factors					
Age	0.026	Age	0.013	Patents	0.195
Fund - company	0.079	Fund - company	0.062	Software dev.	0.083
Fund - DARPA	0.036	Fund - DOD	0.015	Work - foreign	0.001
Fund - DOD	0.036	Fund - NIH	0.020	Team - number	0.026
Fund - NASA	0.029	Mot - com. opp.	0.084	Funding - Tekes	0.031
Fund - NIH	0.036	Mot - instrum.	0.014	Mot - com. opp.	0.123
Mot - com. opp.	0.072	Patents	0.141		
Patents	0.130	Publications	0.016		
Res - develop.	0.001	Res - develop.	0.001		
Team - interdis.	0.041	Team - interdis.	0.045		
Team - position	0.039	Team - position	0.028		
Time - research	0.001	Time - teaching	0.000		
Negative probabilities - other factors					
		Mot - data	-0.014	Team - position	-0.041
		Res - basic	-0.001	Fund - own org.	-0.023
		Work - big US	-0.057	Mot - supervis.	-0.023
Negative probabilities - research areas					
Physics	-0.087	Social sc.	-0.047		
Astronomy	-0.162	Astronomy	-0.205		

3.3. The impact of research areas

Looking at the impact of research areas on the ability to make inventions, it is evident that there are significant differences among the different groups. The main purpose for including the research areas in the analysis was to control for their impact on making inventions. This yields more robust results for the other relevant variables. Instead of merely controlling for the research areas, the results indicated significant differences that are worth discussing. In the top 20 U.S. universities, the research areas most likely to generate inventions are computer sciences and agricultural sciences. Areas less likely to produce inventions are astronomy and physics. The most interesting results emerge when looking at the differences between the Top 20 universities and rest of the U.S. universities. The results of the marginal effects on the rest of the U.S. universities indicate a positive connection with inventors can be established with civil engineering, computer sciences, agricultural sciences and biology. A negative connection can be established with social sciences and astronomy.

The comparison to Finland regarding the research area results is difficult due to different classifications. While in the U.S., the fields most likely to generate inventions are computer sciences and civil engineering, in Finland, these areas are forestry-related engineering, biosciences, electrical engineering and ICT, and life sciences. Interestingly, none of the research areas had a clearly negative impact on the likelihood of making inventions. Based on the comparison, it is evident that research areas more prone to generate inventions are fairly different between the U.S. and Finland. This difference is largely driven by Finland's smaller size and industry structure, affecting the research areas of Finnish academia through, for example, industry sponsored research.

3.4. The impact of other factors

Next, we turn our attention to the other factors that describe in greater detail the determinants for making academic inventions.

3.4.1. U.S. universities

Several observations can be made from the results on U.S. universities. In line with the descriptive results, we make the intuitive finding that older scientists are indeed more likely to make inventions in both top and other universities. In parallel, a high position in a research team has a positive impact on generating inventions in both groups. Additionally, having a high number of patents has a positive impact on inventions in all universities. Patenting has a significant role to play, but this finding is quite obvious, even endogenous, as discoveries with commercial potential are often protected by patents. Interestingly, a higher number of publications only have a positive impact in non-top universities. With respect to time and research activity allocation, time allocated to research activities, and development-oriented research activities, both have a positive impact in both groups. In the leading universities, time allocated to research has a positive impact on the generation of inventions, whereas in the other universities teaching has the same effect.

Motivations for engaging in a specific type of research should have an impact on making inventions. Motivations related to the Identification of commercial opportunities, for instance, have a positive connection to inventions in both groups, while the availability of new instrumentation is a key driver only in non-top universities. Interestingly, the interdisciplinarity of research teams has a positive impact. While this argument has often been made in the existing literature, it has so far been difficult to empirically verify.

Focusing on the importance of funding sources, we can see that the two groups are different. For the non-top universities, three funding sources seem to stand out as having a positive impact: company funding, the Department of Defense (DOD) and the National Institute for Health (NIH). All three play a role in promoting the generation of inventions in these universities. The funding sources for the top 20 U.S. universities differ somewhat. Company, DOD and NIH funding play a positive role, but so does funding from DARPA and NASA. The availability of funding from these unique sources could be explained by the quality of research conducted at these universities.

In addition to the factors that have a positive impact on inventions, there are factors with the opposite effect. Interestingly, we did not identify any factors that would have a negative connection with making inventions for the leading universities. At the other universities, researchers more engaged in basic research are less likely to make inventions. This outcome is not very surprising and is potentially related to the motivation of entering a specific research area due to the availability of data. Interestingly, having work experience in a larger (more than 50 employees) U.S. firm has a negative connection to inventions. It is often argued that work experience in industry would lead a scientist to work on topics more relevant to firms. The results of this paper do not support this conclusion, at least when discussing the non-top U.S. universities.

3.4.3. Comparison to Finland

The aim of comparing the results of the U.S. data to the Finnish data was to identify areas where significant differences exist. By identifying these differences, it might be possible to shed light on the often-mentioned 'European paradox', which states that universities in Europe play a smaller role in industrial renewal than the U.S. economy. If clear differences can be identified, it might help universities strengthen their impact on society, their third mandate in addition to research and teaching. Within the context of this paper, the societal impact refers to taking academic research to the markets.

The results for Finland reveal the following aspects. The statistical analysis confirms our descriptive findings in that inventions are more frequently generated by Finnish researchers working in areas where the Finnish national economy is strongest. They focus on science-related forestry engineering, electrical engineering and computer sciences. Although direct comparison to the U.S. is challenging, it is clear that computer science is an area with a greater potential for inventions than many other less application-oriented areas of science. Higher patenting activity is a factor that also has a positive impact in Finland.

The analysis identified several differences between the U.S. and Finland. For Finnish researchers, research in software development is a major determinant of making potentially commercially significant inventions. This result is again most likely related to the structure of the Finnish economy. Determining factors also include a higher share of foreigners in the research teams and a higher number of research teams the scientists are involved in. These factors are not statistically significant in the U.S. sample, whereas the interdisciplinarity of research teams is. This finding is interesting because interdisciplinarity is not a significant factor in Finland.

From the funding perspective, Tekes is the most important source for researchers making inventions. Tekes provides public funding for private and public sector research. In most cases, public sector funding requires matching funding from the private sector. The importance of Tekes and the absence of company funding in Finland as a positive factor can be partially explained by this somewhat unique funding structure. Interestingly, the importance of funding from the researcher's own university has a negative impact on inventions. This could mean that researchers who are financially backed by their own university more frequently work on topics that the industry and other important external funders of research find irrelevant or too basic. In the U.S. sample, the university's funding does not have statistical significance.

In cases where the supervisor's impact on the choice of the research topic has been great, researchers seem to produce fewer inventions. This finding highlights the importance of personal interest in making inventions with potential commercial value. Supervisor-imposed research interest is not a prevailing factor in the U.S., suggesting that U.S. scientists might have more freedom to engage in research that is driven by their personal interest rather than the interest of other parties.

To summarize the comparison, a few key observations can be made. First, the profile of a typical Finnish academic inventor does not match the profile of her U.S. counterpart. Second, the prevailing industrial structure in Finland clearly has an impact on the fields of science that trigger innovation activity, which may be due to Finland's more specialized industry structure. Third, funding sources are not directly comparable between the U.S. and Finland, but the statistically insignificant role direct company funding plays in Finland does raise some questions about the interaction between academia and industry. The main public funder, Tekes, does require that academics have joint research projects with companies to be eligible for funding. It might be that this funding mode substitutes direct company funding. The consequences of this arrangement need to be addressed in greater detail in future research.

4. Commercialization in academia

The previous section identified the characteristics of academic inventors. We turn our attention to those academics that are the most likely candidates to take their inventions to the market, with a focus on those who own the rights to and have commercialized their inventions. We label these scientists innovators. Although there is a magnitude of literature on academic commercialization (for a review, see Rothaermel et al., 2007), the perspective has mostly been on entrepreneurship and academic spin-offs. In the current paper, the perspective is broadened to cover more intangible forms of commercialization as well as the underlying motivations for and against commercialization.

One of the most informative indices related to the commercialization of academic inventions is the number of scientists who pursue such goals. The ownership of inventions is another key aspect in this discussion. The ownership rights of the inventions are usually with a sponsoring company, the university, or the scientist. We are primarily interested in those cases in which the scientist has the ownership rights to her inventions, and thus full autonomy to commercialize them. This gives us the opportunity to observe entirely unrestricted and unbiased choices. Table 13 reports the share of academic innovators who own the rights to their innovations and the share of academics who have commercialized some or all of their innovations.

Table 13 *Ownership and commercialization of inventions (%)*

	Top 20 U.S.	**Rest of U.S.**	**Finland**
% of all inventors			
Own rights to inventions	64.4%	65.0%	72.7%
Have commercialized some or all inventions	38.4 %	40.0 %	35.0%
% of all scientists			
Own rights to inventions	22.9%	23.9%	29.4%
Have commercialized some or all inventions	13.7%	14.7%	14.1%

For the U.S. academics, the share of inventors who own rights to their inventions is approximately 65%, which corresponds to 24% of all scientists. In Finland, the share is higher, with 73% of inventors owning their rights, corresponding to 29% of all Finnish scientists. The share of inventors who have commercialized some or all of their inventions is approximately 40% in the U.S. universities (15% of all scientists). In Finland, the share of innovators who have engaged in commercialization is somewhat lower than in the U.S., at 35% (14% of all Finnish scientists). This finding indicates that there are actually proportionally more opportunities for Finnish scientists to commercialize their inventions than for U.S. scientists, but fewer are actually interested in doing so.

This lower share leads us to the next topic, which is the different ways of commercializing academic discoveries. In Table 14 below, we address the three main modes of commercialization: consulting, licensing and entrepreneurship.

Table 14 Modes of commercialization (% of inventors who own rights)

	Top 20 U.S.	Rest of U.S.	Finland
Consulting	11.3 %	15.1 %	5.4 %
Licensing	29.4 %	30.8 %	17.9 %
Entrepreneurship	13.8 %	14.6 %	11.9 %

Note: The original scale for responses was 1-4, where 1 was not at all significant and 4 very important. The reported percentage is the share of innovators who reported values of 3 or 4.

Looking first at commercialization modes in the U.S. universities, we can see that in the top universities 11% of the innovators (scientists with ownership rights who have commercialized some or all of their inventions) are commercializing their inventions through consulting. For the rest of the U.S. universities, the share is higher, at 15%. The licensing of inventions is the most common mode of commercialization, with 29% in leading universities and 31% in other U.S. universities. Entrepreneurship is an option for 14% of the innovators in top universities to take their discoveries to the market and for 15% in the rest of the universities. Overall, it seems that innovators at the top universities are slightly less active in commercialization than at other U.S. universities. This finding may relate to the higher opportunity cost at top universities when changing from a sought-after academic position to more commercially oriented activities.

The comparison to Finnish innovators clearly shows that commercialization in Finland is far less popular than at the U.S. universities. Consulting plays a marginal role, with just 5%, and licensing at 18%, both well below the U.S. figures. The share of entrepreneurs among the Finnish academic innovators is 12%, which is just slightly lower than the U.S. shares. The differences between the U.S. and the comparably lower levels of commercialization in Finland could be related to motives to engage in commercialization as well as reasons not to engage in these activities. Table 15 below addresses the motives to commercialize innovations: potential financial returns, job variation, career reorientation, support from the university, securing research funding and promotion of academic career.

Table 15 Motives for commercialization (% of inventors who own rights; sorted based on the Finnish results)

	Top 20 U.S.	Rest of U.S.	Finland
Securing research funding	32.3 %	43.6 %	30.5 %
Financial returns	32.3 %	34.8 %	22.7 %
Job variation	14.5 %	18.2 %	21.8 %
Promotion of academic career	20.9 %	27.0 %	21.8 %
Career re-orientation	6.4 %	10.9 %	15.1 %
Support from the university	13.1 %	15.1 %	9.1 %

Note: The original scale for responses was 1-4, where 1 was not at all significant and 4 very important. The reported percentage is the share of inventors (who own rights to their inventions) who reported values of 3 or 4.

Looking at the U.S. universities, two motivations for commercializing innovations stand out. Securing research funding is perceived by 32% of the innovators in the leading universities, and 44% in the other U.S. universities, to be an important or very important reason for them to engage in commercialization. The potential financial returns motivate 33% of the innovators in the top universities and 35% in the other universities. The least-significant motivation in both groups is the opportunity to reorient ones career. Overall, in the top 20 U.S. universities all the shares for motivations are lower than the national average, but the order of significance remains the same. The underlying reason for this result may be the previously discussed differences in funding structure and opportunity costs. Additionally, working in the top universities in the U.S. might diminish the need for academic career promotion. Based on these results, a conclusion could be drawn that innovators in non-top universities see more commercial alternatives outside academia than their peers in top universities. This is reflected in both the propensity to engage in commercialization activities and the underlying motivations for the engagement.

In Finland, the motivations for commercialization are quite different from those of U.S. academics. Securing research funding is the most important motivation, at 31%, but is well below the U.S. figure of 44%. The potential financial returns motivate only 23% of Finnish innovators compared with 35% in the U.S. universities. The Finnish academic innovators are more motivated by careers outside academia, as job variation (22%) and career re-orientation (15%) matter more than among their U.S. peers.

A discussion of motives to commercialize academic inventions also requires the other side of the story - the reasons not to commercialize. Table 16 below addresses these reasons, which include: lack of commercialization expertise, difficulties with financing, complications with university administration, difficulties with ownership rights, lack of time, financial risks, lack of personal interest and prior experiences in commercialization.

Table 16 *Motives not to commercialize*
(% of inventors who own rights; sorted based on the Finnish results)

	Top 20 U.S.	Rest of U.S.	Finland
Lack of time	31.2 %	32.8 %	61.1 %
Difficulties with financing	16.3 %	21.1 %	42.8 %
Financial risks	11.3 %	14.5 %	34.8 %
Lack of personal interest	18.1 %	19.8 %	31.7 %
Complications with university administration	10.6 %	14.2 %	24.4 %
Difficulties with ownership rights	7.8 %	9.4 %	18.8 %
Lack of commercialization expertise	16.7 %	19.5 %	12.1 %
Prior experiences in commercialization	7.4 %	8.2 %	9.9 %

Note: The original scale for responses was 1-4, where 1 was not at all significant and 4 very important. The reported percentage is the share of inventors (who own rights to their inventions) who reported values of 3 or 4.

The most significant motive for not commercializing inventions among the U.S. scientists is lack of time (31% in the top 20 universities and 33% in the rest), followed by difficulties in financing (16% vs. 21%), lack of personal interest (18% vs. 20%) and lack of commercial expertise (17% vs. 20%). The most insignificant negative motives are difficulties with ownership rights (8% vs. 9%) and prior experiences in commercialization (7% vs. 8%). Overall, there are less negative motives in the leading universities.

In Finland, the negative motives are very different from those of the U.S. universities. Almost all the shares are higher, some by a wide margin, than in the U.S. universities. Lack of time is by far the most significant inhibiting factor (61% of the Finnish scientists), followed by difficulties with financing (43%), financial risks (35%) and lack of personal interest

(32%). The shares that are not significantly higher than in the U.S. are lack of commercialization expertise (12%) and prior experiences in commercialization (10%). Most interestingly, the Finnish inventors perceived lack commercial expertise to be less of a challenge than for U.S. academic innovators. Overall, based on these results it seems that the Finnish academic inventors experience more reasons not to participate in the commercialization of their own inventions than their U.S. counterparts.

5. Concluding discussion

This paper examined the characteristics of those unique academic scientists who are able to make scientific discoveries with potentially significant commercial value. We labeled these discoveries as inventions. Based on two large survey data sets, one from the U.S. and one from Finland, the paper focused on a comparative setting where, first, the U.S. scientists were divided based on the institutional environment by utilizing university ranking and, second, an international comparison was made in which the results from the U.S. were compared to the Finnish results.

The paper made several findings that not only provide insights into the commercialization of academic inventions but also to the challenges smaller countries face with increasing demand for academia to engage in the industrial renewal process. In U.S. academia, there are surprisingly minor differences between the top universities and the rest of the universities regarding the propensity to make inventions and commercialize them. Compared with Finland, there are more differences, but the overall picture remains largely the same, even if the leading universities are excluded from the comparison. Looking at the results in greater depth, the following findings were made.

1. The propensity to make academic inventions is significantly related to the field of research. Application-oriented areas more often lead to discoveries than basic research areas.
2. There are clear differences between U.S. and Finnish universities with respect to making inventions. For example, the role of interdisciplinarity has a positive impact on inventions in the U.S. but no impact in Finland.
3. In commercialization activities there are, again, significant differences between the U.S. and Finland. Although, it should be noted that in the U.S. and Finland academics produce equally likely inventions and in similar numbers (per inventor), in Finland more inventors own the rights to commercialize their inventions. Therefore, the potential pool of inventions to be commercialized is proportionally larger in Finland.
4. Commercialization through consulting, licensing and entrepreneurship is much more common in the U.S. than in Finland, where only entrepreneurship is close to the U.S. levels.
5. The motives for commercialization in the U.S. are related to financial aspects. In Finland, career-related motives play a more significant role.
6. The results of the reasons not to commercialize indicate that Finnish scientists face nearly twice as many challenges as their U.S. counterparts.

Based on the results, several implications with respect to Finland can be made for university administrations that wish to promote commercialization and for policymakers aiming to tie universities more tightly into the Finnish innovation system. It is evident that the Finnish universities produce roughly the same number of inventions per scientist as the U.S. universities. This indicates that a large pool of inventions to be commercialized is available. The question is how to commercialize these inventions. In related studies that address technology transfer activities at universities in Finland and in the U.S., it was found that Finnish universities are significantly under resourced to properly facilitate the transfer of scientific inventions to markets (Tahvanainen & Hermans, 2008; Tahvanainen, 2009). The current study supports this argument by showing that the pool of potential commercially valuable inventions is same as in the leading countries. The challenge is to change the attitudes of Finnish scientists toward commercialization. This will require higher prioritization of commercialization in the universities, particularly with allocated resources. This allocation should not come at the expense of education and research, which are the main functions of the university system. Therefore, policymakers who wish to promote the role of universities in the Finnish innovation system should consider an array of alternatives to facilitate the commercialization of academic inventions.

The second policy recommendation is the promotion of interdisciplinary research. Based on the U.S. data, it is evident that such research leads to higher propensities of academic inventions. This argument has been made several times in the existing academic research on the topic, but without concrete empirical evidence. With the results of this paper, there is proof that interdisciplinarity does matter if a higher level of innovative activities is desired. Although interdisciplinarity is often encouraged when applying for research funding, in reality the collaboration is often marginal, as the groups work separately. There have been suggestions of ways to promote interdisciplinarity, such as rearrangement of facilities and joint seminars, but what actually works is dependent on factors beyond the scope of this paper.

Although universities and their commercial activities have been studied extensively in academic research, few implications for future research can be drawn. Most of the extant academic research on university commercialization has been conducted at the national or organizational level. The results of this paper provide evidence that more emphasis should be given to the micro-level analysis of individuals when discussing academic inventions. This is the only way to identify what is inside the black box of commercialization at universities. It is clear that one of the main aspects affecting commercialization activities is the field of research, which highlights the need to focus more on discipline-specific aspects in future research. The empirical results of this paper also indicate that interdisciplinarity in research activities is connected to the propensity to make inventions, which suggests that more emphasis should be given to the understanding of collaboration across traditional academic discipline boundaries.

References

Agrawal, A., and R. Henderson (2002): "Putting patents in context: exploring knowledge transfer from MIT", Management Science, 48:1 (44 ‐ 60).

Arundel, A. and A. Geuna (2004): “Proximity and the use of public science by innovative European firms”, Economics of Innovation and New Technology, 13:6 (559 ‐ 580).

Bozeman, B. (2000): "Technology Transfer and Public Policy: A Review of Research and Theory", Research Policy, 29:4 ‐ 5 (627 ‐ 55).

Breschi, S., F. Lissoni and F. Montobbio (2007): "The Scientific Productivity of Academic Inventors: New Evidence from Italian Data", Economics of Innovation and New Technology, 16:2 (101 ‐ 118).

Dietz, J. S. and B. Bozeman (2005): "Academic careers, patents, and productivity: industry experience as scientific and technical human capital", Research Policy, 34:3 (349 ‐ 367)

Dosi, G. and R. Nelson (2010): “Technological change and industrial dynamics as evolutionary processes”, LEM Working Paper Series 2009/7 (forthcoming in “Handbook of Innovation”, eds. Hall, B. and R. Nelson)

Etzkowitz, H., A. Webster, C. Gebhart and C. Terra (2000): "The future of the university of the future: evolution of ivory tower to entrepreneurial paradigm", Research Policy, 29:2 (313 ‐ 330).

Foray, D. and M. Gibbons (1996): “Discovery in the context of application”, Technological Forecasting and Social Change, 53:3 (263 ‐ 277).

Georghiou, Luke – Smith, Keith – Toivanen, Otto – Ylä-Anttila, Pekka (2003): ”Evaluation of the Finnish Innovation Support System,” Kauppa- ja Teollisuus Ministeriön julkaisut, 5/2003, Edita, Helsinki.

Gibbons, M., H. Nowotny, C. Limoges, M. Trow, S. Schwartzman and P. Scott (1994): "The New Production of Knowledge: The Dynamics of Science and Research in Contemporary Societies".

Mansfield, E. and J.‐Y. Lee (1996): “The modern university: contributor to industrial innovation and recipient of industrial R&D support”, Research Policy, 25:7 (1047‐1058).

Mowery, D. and B. Sampat (2004): "Universities in National Innovations Systems", in “The Oxford Handbook of Innovation” (eds. Fagerberg, Mowery & Nelson).

Rothaermel, F.T., Agung, S., Jiang, L. (2007): “University entrepreneurship: A taxonomy of the literature”, Industrial and Corporate Change, 16:4 (691‐791).

Segarra‐Blasco, A. and J.‐M. Arauzo‐Carod (2008): Sources of innovation and industry‐university interaction: Evidence from Spanish firms”, Research Policy, 37:8 (1283‐1295).

Siegel, D. (2007): “Quantitative and qualitative studies of university technology transfer: synthesis and policy recommendations”, in “Handbook of Research on Entrepreneurship Policy” (eds. Audretsch, D., Grilo, I. and Thurik, A. R.)

Tahvanainen, Antti-Jussi – Hermans, Raine (2008): “Value Creation in the Interface of Industry and Academy - A Case Study of Intellectual Capital of Technology Transfer Offices At US Universities”, ETLA Discussion Papers no. 1148.

Tahvanainen, Antti-Jussi – Nikulainen, Tuomo (2010): “The Finnish Research Environment in Flux – The Researcher’s View on the Impacts of the Universities Act, the University Inventions Act and the Strategic Centres for Science, Technology and Innovation”, ETLA Discussion Paper no. 1233.

Tahvanainen, Antti-Jussi – Nikulainen, Tuomo (2011): “Commercialization at Finnish Universities - Researchers’ Perspectives on the Motives and Challenges of Turning Science into Business”, ETLA Discussion papers no. 1234.

Tahvanainen, Antti-Jussi (2009): "Finnish University Technology Transfer in a Whirl of Changes - a Brief Summary”, ETLA Discussion Papers no. 1188.

TEM – Ministry of Employment and Economy (2009): “Evaluation of the Finnish National Innovation System - Policy Report”, TEM Publications.

Valtioneuvoston kanslia (2006): ”Suomen vastaus globalisaation haasteeseen. Talousneuvoston sihteeristön globalisaatioselvitys - Osa II,” Valtioneuvoston kanslian julkaisusarja, 17/2006, Edita Prima Oy, Helsinki.

Zucker, Lynne – Darby, Michael (1996): “Star scientists and institutional transformation: Patterns of invention and innovation in the formation of the biotechnology industry”, Proceedings of National Academy of Science, vol. 93 (23), 12709-12716.

APPENDIX 1

Determinants of making discoveries with commercial potential (marginal effects of probit regressions)

	Top 20				Rest of				FIN		
	dy/dx	P>|z			dy/dx	P>|z|			dy/dx	P>|z|	
age_cat	0.026	0.02	**	age_cat	0.013	0.024	**	birth_year	0.001	0.634	
edu_business	**-0.028**	**0.55**		edu_business	0.028	0.223		**ctrl_pats**	**0.195**	**0**	***
edu_cat	0.014	0.28		edu_cat	-0.005	0.532		ctrl_pubs	0.015	0.184	
edu_usa	-0.014	0.65		**edu_usa**	**-0.016**	**0.304**		**ctrl_soft**	**0.083**	**0.028**	**
fun_compan~s	**0.079**	**0**	***	**fun_compan~s**	**0.062**	**0.000**	***	**cur_eng_ch~y**	**-0.067**	**0.353**	
fun_darpa	0.036	0.07	*	fun_darpa	0.015	0.179		**cur_eng_el~r**	**0.127**	**0.034**	**
fun_dod	0.036	0.01	**	fun_dod	0.015	0.020	**	**cur_eng_en~n**	**-0.069**	**0.38**	
fun_doe	-0.021	0.17		fun_doe	-0.006	0.420		**cur_eng_en~y**	**0.115**	**0.198**	
fun_found	0.008	0.47		fun_found	-0.005	0.400		**cur_eng_ict**	**0.091**	**0.056**	*
fun_nasa	0.029	0.07	*	fun_nasa	-0.006	0.508		**cur_eng_in~t**	**0.166**	**0.169**	
fun_nih	0.036	0.00	***	fun_nih	0.020	0.000	***	cur_eng_ma~	0.061	0.482	
fun_nsf	0.005	0.62		fun_nsf	-0.002	0.658		cur_eng_ma~l	0.051	0.34	
fun_oth_fed	-0.019	0.14		fun_oth_fed	-0.004	0.451		cur_eng_ph~s	0.019	0.728	
fun_own_org	0.008	0.45		fun_own_org	0.006	0.275		**cur_eng_woo**	**0.173**	**0.019**	**
fun_usda	0.003	0.89		fun_usda	0.004	0.626		**cur_ns_bio~e**	**0.121**	**0**	***
mot_com_opp	0.072	0.00	***	**mot_com_opp**	**0.084**	**0.000**	***	cur_ns_bio~m	0.015	0.717	
mot_compan~s	0.018	0.42		**mot_compan~s**	**-0.008**	**0.396**		**cur_ns_bio~y**	**-0.02**	**0.543**	
mot_data	-0.01	0.45		**mot_data**	**-0.014**	**0.028**	**	cur_ns_che~y	0.004	0.915	
mot_employ~t	0.005	0.67		mot_employ~t	0.006	0.278		cur_ns_dat~s	0.072	0.087	*
mot_funding	-0.003	0.80		mot_funding	0.001	0.916		cur_ns_env~n	0.001	0.98	
mot_instru	-0.001	0.93		mot_instru	0.014	0.062	*	cur_ns_math	0.018	0.6	
mot_own_res	0.017	0.43		mot_own_res	0.005	0.620		cur_ns_phy~s	0.042	0.186	
mot_res_int	-0.005	0.68		mot_res_int	-0.005	0.390		**cur_ot_econ**	**0.131**	**0.017**	**
mot_visits	-0.001	0.93		mot_visits	-0.007	0.277		cur_ot_med	0.081	0.001	***
pats_cat	**0.13**	**0**	***	**pats_cat**	**0.141**	**0.000**	***	cur_ot_other	0.027	0.36	
pubs_cat	0.016	0.20		pubs_cat	0.016	0.007	***	edu_extra_~s	0.047	0.162	
res_aero	**0.164**	**0.23**		res_aero	0.031	0.630		education_~l	-0.013	0.661	
res_agri	**0.126**	**0.07**	*	**res_agri**	**0.067**	**0.034**	**	**education_~n**	**-0.036**	**0.414**	
res_astron~y	**-0.162**	**0.05**	*	**res_astron~y**	**-0.205**	**0.000**	***	**emp_fi_large**	**-0.031**	**0.367**	
res_biology	0.027	0.31		res_biology	0.023	0.088	*	emp_fi_sme	0.004	0.922	
res_chem_eng	**0.168**	**0.13**		**res_chem_eng**	**0.038**	**0.401**		**emp_for_com**	**-0.047**	**0.541**	
res_chemis~y	**-0.052**	**0.37**		res_chemis~y	0.011	0.631		**emp_for_uni**	**-0.024**	**0.345**	
res_civ_eng	**0.14**	**0.24**		**res_civ_eng**	**0.126**	**0.001**	***	emp_g_for	0.001	0.036	**
res_comput~s	**0.109**	**0.05**	*	**res_comput~s**	**0.104**	**0.000**	***	emp_g_interd	0.027	0.215	
res_elect_~g	0.02	0.73		res_elect_~g	0.019	0.564		emp_g_size	0.006	0.639	
res_geosci~s	-0.006	0.91		res_geosci~s	-0.006	0.805		emp_groups	0.026	0.056	*
res_ind_eng	**0.08**	**0.50**		**res_ind_eng**	**0.087**	**0.135**		**emp_pos**	**-0.041**	**0.004**	***
res_life_s	**-0.115**	**0.03**	**	res_life_s	-0.003	0.911		funding_aka	0.008	0.377	
res_mat_eng	0.06	0.38		res_mat_eng	0.015	0.671		funding_eu	0.01	0.278	
res_mathem~s	0.032	0.45		**res_mathem~s**	**-0.028**	**0.207**		funding_firm	0.008	0.583	
res_mech_eng	**0.084**	**0.30**		res_mech_eng	0.013	0.736		funding_fo~d	0.008	0.371	
res_med_s	-0.009	0.76		res_med_s	0.018	0.241		funding_ot~r	-0.016	0.181	
res_other	-0.011	0.86		**res_other**	**-0.031**	**0.351**		**funding_own**	**-0.023**	**0.01**	**
res_other_~g	**-0.036**	**0.62**		res_other_~g	0.006	0.858		funding_te~s	0.031	0.007	***
res_physics	**-0.087**	**0.06**	*	**res_physics**	**-0.021**	**0.363**		**mot_com**	**0.123**	**0**	***
res_psycho~y	0.001	0.97		res_psycho~y	-0.001	0.964		mot_data	0.001	0.906	
res_social_s	0.005	0.90		**res_social_s**	**-0.047**	**0.042**	**	mot_emp	-0.003	0.797	
research_a~d	0	0.29		research_a~d	0.000	0.593		mot_firmne~s	-0.002	0.916	
research_b~c	-0.001	0.20		research_b~c	-0.001	0.010	**	mot_funding	-0.018	0.106	
research_d~p	0.001	0.01	**	research_d~p	0.001	0.000	***	mot_instrum	0	0.974	
software	0.018	0.72		software	0.009	0.731		mot_own	0.017	0.326	
team_int_dis	0.041	0.09	*	**team_int_dis**	**0.045**	**0.000**	***	**mot_super**	**-0.023**	**0.022**	**
team_multi~l	0	0.61		team_multi~l	0.000	0.834		mot_visit	0.005	0.692	
team_number	-0.006	0.67		team_number	0.009	0.189		restype_app	-0.001	0.267	
team_pos	**-0.039**	**0.00**	***	**team_pos**	**-0.028**	**0.000**	***	restype_ba~c	-0.002	0.105	
team_size	-0.006	0.65		team_size	0.002	0.823		restype_dev	0.002	0.11	
time_admin	0	0.63		time_admin	0.000	0.217		work_admin	0	0.925	
time_resea~h	0.001	0.02	**	time_resea~h	0.000	0.159		work_res	0	0.772	
time_teach	0	0.23		time_teach	0.000	0.027	**	work_teach	-0.001	0.316	
work_big_us	**-0.044**	**0.26**		**work_big_us**	**-0.057**	**0.002**	***				
work_com_for	**-0.092**	**0.26**		work_com_for	0.010	0.766					
work_sme_us	**-0.056**	**0.29**		work_sme_us	0.032	0.154					
work_uni_oth	0.019	0.51		work_uni_oth	0.011	0.456					
work_uni_us	**0.161**	**0.14**		**work_uni_us**	**0.073**	**0.217**					

* p<0.10, ** p<0.05, *** p<0.01