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Tuomo Nikulainen

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The role of interdisciplinarity and networking

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Generating commercial ideas in Finnish universities
– The role of interdisciplinarity and networking

Tuomo Nikulainen

ETLA

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Corresponding author:
Tuomo Nikulainen, ETLA (The Research Institute of the Finnish Economy), Lönnrotinkatu 4 B, 00120 Helsinki, Finland. Phone: +358 50 548 1336. Fax: +358 9 601753. E-mail: tuomo.nikulainen@etla.fi

Abstract:

Existing research argues that the keys to generating industry-relevant knowledge are interdisciplinary and networked research. The aim of this paper is to address statistically whether interdisciplinary and networked research are related to a higher potential to generate ideas with significant commercial value. Using a unique survey of academics in Finland, we identify several factors that relate to idea generation. In different types of research networks, we find a positive connection to an interdisciplinary work environment and networking. We also identify significant differences among fields of research.

Key words: universities, research, idea generation, commercial ideas, interdisciplinarity, networks, networking

JEL: O30, O38, O33, O34

Tiivistelmä:

Aiemmissa tutkimuksissa on esitetty, että yrityksille hyödyllisen tutkimuksen tuottamiselle keskeistä on poikkitieteellinen ja verkostoitunut tutkimus. Tämän paperin tavoitteena on tilastollisesti tarkastella missä määrin poikkitieteellisyys ja verkostoituminen liittyvät kaupallisesta potentiaalia omaavien ideoiden luomiseen. Tutkimuksessa hyödynnetään ainutlaatuista suomalaisten yliopistotutkijoiden keskuudesta kerättyä kyselyaineistoa, jonka kautta tunnistetaan useiden eri tekijöiden liittyvän ideoiden luomiseen. Erityisesti työympäristön poikkitieteellisyys sekä perustutkimukseen ja soveltavaan tutkimukseen liittyvä verkostoituminen ovat positiivisesti yhteydessä ideoiden syntymiseen. Lisäksi havaitaan merkittäviä eroja eri tutkimusalojen välillä.

Avainsanat: yliopistot, tutkimus, ideoiden syntyminen, kaupalliset ideat, poikkitieteellisyys, verkostot, verkostoituminen

JEL: O30, O38, O33, O34

1. Introduction

Universities are an essential part of national economies and crucial for national innovation ecosystems. Universities not only promote and create knowledge but also act as drivers of technological change in knowledge-based economies. Universities' traditional tasks of education and research can also be considered strategic assets if their links to industry are strengthened and knowledge exchange is facilitated (Mowery and Sampat, 2004). The increasing importance of universities and their research activities in national innovation ecosystems relates to the private sector's low incentive to engage in basic research-oriented R&D. This low engagement is due to the perception that knowledge is a public good and to the uncertainties of new technologies. Thus, publicly funded R&D in universities fills an important gap in innovation ecosystems.

In addition to education, the main tasks of universities are to produce knowledge, which can be perceived as a flow of ideas, and the task of companies is to commercialize these ideas (Erkal and Scotchmer, 2009). In other words, universities create a flow of research, which turns into a series of random commercial opportunities. The facilitation of the commercialization of these ideas has been labeled as the 'third' role of universities, after education and research (Etzkowitz et al., 2000).

The flow of ideas and their commercialization are closely connected to the concept of the 'Mode 2' type of research. 'Mode 2' is associated with interdisciplinary and networked innovation systems and creates more industry-relevant knowledge than does the traditional discipline-focused 'Mode 1' type of academic research (Gibbons et al., 1994; Foray and Gibbons, 1996; Mowery and Sampat, 2004). The importance of 'Mode 2' research is growing in university-industry interactions and thus highlights the increasing scale and diversity of knowledge inputs required in scientific research (Gibbons et al., 1994). This argumentation is one of the reasons why policymakers, in an effort to steer universities towards more industry-relevant knowledge creation, often promote interdisciplinarity and networking when providing research funding.

Interdisciplinarity and networking in universities have been addressed in the existing literature through network analysis and scientometrics, focusing on measuring and analyzing scientific efforts. In practice, scientometrics and network analysis are conducted by measuring different characteristics of scientific publications and patents. The limitation is that the existing literature has not addressed those ideas as commercial investment opportunities. In this paper, the discussion of interdisciplinarity and networked research is tied to scientists' idea-generation capabilities. We shed light on the following question: what roles do interdisciplinarity and networking play in generating ideas in academia that potentially have significant commercial value? We approach this question by observing the impact of interdisciplinarity in scientists' work environments (an input to academic knowledge creation) and different types of interdisciplinary and networked research outputs, on idea generation. We also account for a variety of different factors, such as current research areas and institutional settings, when addressing the idea generation.

This paper focuses on idea generation by Finnish scientists working in natural and engineering sciences. This paper also gives specific attention to emerging technologies of interest to policymakers due to their alleged high growth potential. These technologies are biotechnology, nanotechnology, and environmental technologies, which have the potential to develop into general purpose technologies that would have a profound impact on how we live our lives in the future (Lipsey et al., 2005; Youtie et al., 2008, Palmberg and Nikulainen, 2006), and where interdisciplinary 'Mode 2' type of research is seen as a prevailing mode of knowledge creation (Schummer, 2004; Miyazaki and Islam, 2007; Nikulainen, 2010b). Despite high expectations for all three technology fields, which may be partially overstated, it should be remembered that many of these technologies are still in the early stages of development.

The rest of the paper is structured as follows: Section 2 provides an analytical framework by discussing relevant contributions in the existing literature on idea generation, interdisciplinarity and networking in academia; Section 3 describes the data and focuses on methodological questions; Section 4 presents the empirical statistical analysis and discusses the results; Section 5 presents implications for research and policy.

2. Analytical framework

To set the scene for the empirical analysis presented later in this paper, we need to review some of the most relevant contributions in the existing literature that answer the following questions.

- What is idea generation in universities?
- What are interdisciplinarity and networking?
- How do interdisciplinarity and networking relate to idea generation in universities?
- What is the relationship between idea generation and emerging technologies?

Universities are built to create and distribute knowledge. Knowledge creation is conducted primarily through research activities, often in collaboration with scientists both within and outside a university, and within and across traditional academic disciplines. The results of these activities are then dispersed through education and by publishing those results. Some of the research results are commercially significant and worth investing in. In this paper, we are interested in which types of scientists are more likely to produce ideas with potential commercial significance.

Idea generation

Idea generation in academia is based on the research efforts of the scientists. Every research activity leads to an output. In its simplest form, research can result in an accumulation of knowledge without a concrete output, such as an article. On the other end of the spectrum, discoveries can lead to Nobel prizes. We can also assume that commercially viable ideas are scarce and that their distribution is heavily left-skewed, as only few ideas have very high commercial value. Furthermore, it can be argued that the flow of ideas is random and the scientist's ability to have a significant idea depends on various factors, some of which are measurable while others are more intangible.

University research output is commonly measured through publication and patenting activity (in the fields of natural and engineering sciences). Publishing indicates accumulation of knowledge that may be incremental or radical in nature but takes no stance on the commercial potential of the scientific discoveries. Patents originating from academia, on the other hand, are based on discoveries that are perceived to be commercially investable but in reality rarely have commercial value. The challenge in addressing idea generation in academia is that not all ideas are patentable. Patents primarily cover technological innovations. Ideas that are not "technological" in a patent legislation sense, such as most software-related ideas, are largely not patentable (this is particularly true in European patent systems). Thus, using patent statistics to measure scientists' ability to create ideas falls somewhat short of capturing the broader idea generation activities within academia. If we agree that patent statistics have limitations, it should be noted that university-based patents are built on research that is typically published at some stage. Therefore, another approach to looking at commercial ideas is to study publications and their relation to ideas with potential commercial value.

It can be argued that academic publications broadly cover knowledge accumulation and idea generation and include non-patentable ideas. University research can be perceived as a flow of newly created knowledge out of which commercial ideas emerge randomly and rarely. We assume that patents cover only a part of these ideas, leaving some of the ideas unobserved. To grasp the full scale of idea generation, we need to have a way to identify non-patentable ideas. Scientific publications do not provide direct information on their commercial potential and thus are a weak approximation of commercial ideas. Because information on commercial ideas is very challenging to acquire through existing data sources, we need to take a more direct, complementary approach.

To gain information on commercial ideas originating from academia, we approached the scientists directly and inquired about their activities. By asking the scientists themselves whether they have made any scientific discoveries with significant potential commercial value, we can provide a complementary perspective to the discussion of idea generation both for patentable and non-patentable research outputs. Naturally self-reported assessments of the commercial potential are subjective. Thus, we emphasize the complementary nature of the current analysis to the patent- and publication-related research efforts.

Interdisciplinarity and networking

Interdisciplinarity in today's universities is seen as crucial in creating more industry-relevant knowledge (Gibbons et al., 1994; Foray and Gibbons, 1996; Mowery and Sampat, 2004). Interdisciplinarity refers to new knowledge creation among or beyond existing academic disciplines. Interdisciplinary research is conducted by scientists from different academic disciplines working together to create new knowledge. The need for creating knowledge outside the traditional disciplines comes from the inability of existing academic disciplines to address new research themes. The complex nature of these new themes requires interaction among different disciplines to help improve their ability and efficiency in working within the new interdisciplinary area. An interdisciplinary scientist typically works in an interdisciplinary environment drawing on a shared pool of knowledge and produces a research output that can be considered interdisciplinary. The industry relevance of interdisciplinary research comes from the opportunities that arise from novel research efforts in areas with high commercial potential. These activities are outside the traditional knowledge creation efforts, thus creating opportunities to identify market niches with high growth potential.

Interdisciplinarity often relates to networking. Collaborative networks among university scientists have been found to have a positive effect on productivity, such as with the number of publications and patents, suggesting that the role of these networks should not be underestimated (Landry et al., 1996). Instead of individual scientists accumulating all the required knowledge by themselves, research is typically a collaborative effort with other scientists. These collaborating scientists can, naturally, be from the same or different disciplines. Collaboration with scientists outside a discipline is commonly labeled as interdisciplinary research. While interdisciplinarity has been discussed on a conceptual level (e.g., Gibbons et al., 1994), only a few related empirical findings are available. Even then, the results of the role of interdisciplinarity on commercially oriented activities in academia are mixed (Nikulainen, 2007 & 2010b)

Why would networks matter in the idea generation process? There is a large body of literature indicating that through networks, individuals are able to combine different ideas and are more creative and productive than less networked individuals (Burt, 1997; 2004; Seidel et al. 2000; Mehra et al. 2001; Cross and Cummings, 2004; Nerkar and Paruchuri, 2005). Individuals can act as brokers by bridging two parts of a network that are not otherwise directly connected (Scott, 1991). This lack of connectivity is referred to as a structural hole (Burt, 1992). By bridging this hole, an individual is placed in a brokerage position where he is able to capture the flow of information between the different parts of the network. In this paper, we aim to provide evidence that a connected position in research networks is related to a higher propensity of commercial idea generation in Finnish academia.

Emerging technologies

We also take into account three technology areas that have received significant academic as well as public interest in recent years: biotechnology, nanotechnology, and environmental technologies. All three emerging technologies have been hailed to not only have significant impact on everyday life but also to provide sources of economic growth. The latter has been identified by many industrialized countries and has resulted in global efforts to boost regional and national competitiveness in these technology areas. The rationale of some of these investments is partly due to hype, partly based on reality, but mainly due to the need for new sources of growth in highly industrialized countries. It seems that all of these technologies are following an investment wave that seems to find a new technology receiving significant publicity every few years (Perez, 2002).

Biotechnology relates to technological applications that use biological systems, living organisms, or derivatives thereof to make or modify products or processes for a specific use. Biotechnology emerged as its own distinct field in the 1970s and has now become a very relevant source of new products and processes, particularly in the pharmaceutical industry, which was one of the first adopters. The expectations for biotechnology have diminished somewhat in recent years; it has been claimed that major breakthroughs are related primarily to the development of new pharmaceuticals (Hopkins et al., 2007). Biotechnology has attracted significant interest in Finland from research, business and policy perspectives (for further discussion, see Nikulainen et al. 2012).

Nanotechnology emerged in the 1980s and is primarily in an early and more uncertain phase of technological evolution than is biotechnology. Nanotechnology focuses on the control of matter on an atomic and molecular scale and involves developing materials or devices on that scale. This field is multidisciplinary and encompasses both organic and inorganic research areas and by definition covers a wider set of sciences and technologies than does biotechnology. Nanotechnology has been hailed as a new revolutionary technology building on advances in a variety of scientific disciplines and is viewed as a very interdisciplinary field (Schummer, 2004; Shea, 2005; Hullman, 2006; Lipsey et al., 2005; Meyer, 2007; Youtie et al., 2008; Nikulainen and Palmberg, 2010). The potential technological and economic impact of this field is still unclear, but it is estimated that the future market for nanotechnology-based products and processes will be significant due to its diverse applications in a variety of industries. Nanotechnology has also attracted significant interest in Finland from research, business and policy perspectives (Palmberg and Nikulainen, 2006; Nikulainen, 2010; Nikulainen and Palmberg, 2010).

Environmental technologies have been topical for decades due to the discussion of global warming and climate change. To battle these changes and to provide sources for industrial growth, many countries have made significant investments in these environmental technologies. The pace of these investments has increased in recent years due to public and policy debate over the increasing impact of environmental changes on everyday life in many regions. In the existing literature, environmental technology includes air pollution control and abatement, water pollution control (including water and wastewater management), solid waste management, and renewable energy (OECD, 2009; Johnstone et al., 2010). In this paper, we will pool all these technologies into one, allowing us to compare the three broader technology areas with each other in terms of commercial idea generation.

3. Data

Idea generation in Finnish academia is addressed by studying the activities of researchers in the fields of natural and engineering sciences. Thus, many academic disciplines are excluded from the analysis. The reason for this exclusion relates to the nature of research conducted in different academic fields. The fields chosen to be analyzed represent areas in which academic discoveries with commercial potential are most likely to occur. In other areas (such as social sciences, humanities, and the arts), discoveries with commercial potential may also emerge, but they are much less likely. To focus our analysis on the natural and engineering sciences, we have made several methodological choices that need to be addressed.

To identify the researcher target population, we used the Thomson Reuters ISI - Science Citation Index that indexes citations to articles published in more than 6,000 journals across 150 disciplines and excluded the Social Sciences Citation Index and Arts and Humanities Citation Index. In addition to delimiting the targeted population, this provided quality control, as journals included in the ISI database are perceived to be of higher quality than journals not included due to a more vigorous peer-review process. In the second stage, we identified the Finland-based scientists by looking at the corresponding author information. To focus on researchers still pursuing an active career, we only collected information from articles dated between 2008 and 2009. After removing duplicates from the corresponding author list, the final population consisted of 6876 individuals. In summary, the procedure identified individual researchers who are active in Finland and have published articles in journals indexed by the ISI database in areas of science that are known to spawn ideas with commercial potential. This includes researchers working in the public sector (universities, research institutes and hospitals) and the private sector (companies) (see also Tahvanainen and Nikulainen, 2011).

After the identification of the relevant population, an online questionnaire was sent to each researcher between February and May 2010 with two reminders. Because our focus in this paper is on university researchers, our analysis is based on a subsample of the data that included only those researchers who were primarily affiliated with a university. This identification was made based on the respondents' email address, which indicates the affiliated university. We received 1,724 responses from a population of 4,524 university researchers, corresponding to a response rate of 38.1%. The sample consists of researchers from 11 major Finnish universities. There have been some changes in the Finnish university system due to university mergers. This paper considers the situation prior to these changes when describing the differences among the universities. The number of respondents per university is shown in Table 1.

Table 1 The distribution of respondents

Affiliation	Obs.	%
Åbo Akademi University	61	3.5
Helsinki University of Technology	213	12.4
University of Helsinki	481	27.9
University of Joensuu	59	3.4
University of Jyväskylä	131	7.6
Lappeenranta University of Technology	30	1.7
University of Oulu	203	11.8
Tampere University of Technology	101	5.9
University of Kuopio	120	7.0
Univeristy of Tampere	91	5.3
University of Turku	234	13.6
Total	1724	100.0

In addition to the survey data, this paper utilizes publication and patent data to address the role of interdisciplinarity and networking in research outputs. The identification process for the publication data is the same as for the survey but without the time limit. We gathered all the publications for the researchers who provided valid answers to the survey. The academic publications can be seen as an indicator of basic research-related activities. Co-authorship in the articles is used in the identification of each respondent's network in publication networks.

Patent data were collected for researchers who provided valid answers to the survey using the EPO PATSTAT database from which inventor names were matched to the survey respondents. We gathered data for patent applications, which can be used as an indicator of applied research-related activities. These data were collected without a time limit. Co-inventorship was used for the identification of each respondent network in applied research related networks.

4. Descriptive statistics

Before proceeding to the statistical analysis, it is worthwhile to discuss the variables in more detail. The dependent variable in this paper is the propensity to make academic discoveries with significant commercial potential. This survey-based variable approximates the individual's level of idea generation. A scientist was identified to be involved in idea generation if he claimed to have produced at least one scientific discovery with "obvious commercial potential" in the five years prior to survey implementation. The assessment of the commercial potential is, of course, subjective. A total of 40.4% of the respondents reported having generated at least one commercial idea.

The independent variables are factors that may have a connection with the propensity to generate ideas. Our primary interest is in two perspectives that potentially have an impact on idea generation: interdisciplinarity and networking.

To take into account the impact of an interdisciplinary work environment, we asked the respondents the following question - "*Do your research teams usually feature researchers from different scientific fields?"* with a potential answer of yes or no. We defined *"… a project team to comprise of those researchers actively participating in your current research project that you are in direct and constant collaboration with. Thus, the team does not necessarily comprise the entire laboratory, unit, or department unless all researchers of that particular unit participate in your project."* The assessment is, of course, subjective and depends on the respondent's perception of differences in scientific fields. This indicator represents interdisciplinary inputs to research efforts. A large share (56%) of the respondents indicated working in teams consisting of researchers from multiple scientific fields.

Research inputs lead to research outputs. To measure the output of basic research, we use an indicator that focuses on interdisciplinarity and networks. Interdisciplinarity is measured by how many different scientific journal categories the scientist has published papers in. The categories are based on the ISI database of 150 categories. Network connectivity is the author's average number of co-authors in academic journal articles. The final indicator is created by multiplying these two elements together.

To measure the output related to applied research, we use an indicator that also focuses on interdisciplinarity and networks. Interdisciplinarity is measured by how many different patent classification categories the scientist has patented in. The categories are based on aggregated patent classes that divide the patents into 30 different categories (Mancusi, 2003; Nikulainen et al., 2005). The network connectivity is the inventor's average number of co-inventors indicated in his patent applications. The final indicator is created by multiplying these two elements.

As mentioned earlier, the aim of the paper is to also address three emerging technologies and take their unique characteristics into account when discussing idea generation in academia. We asked the respondents to indicate to what degree their research relates to biotechnology (23% of respondents worked in this field), nanotechnology (14%) and environmental technologies (13%).

The next perspective is work environment and work experience. We consider the research groups' characteristics in more detail, in addition to their interdisciplinarity, by including the number of groups a scientist is involved in as well as the average size of these groups. We also take into account the average share of international scholars in the research groups. Furthermore, previous work experience is also addressed. Scientists with experience at companies or foreign universities may be more inclined to take part in more explorative research because they have insights into research environments beyond Finnish academia.

Different funding sources might also be relevant to idea generation in academia. For this reason, we consider the main research funding sources in Finland. If the different funders have on their agenda to promote idea generation, the inclusion of this dimension to the discussion sheds light on the differences between the funders.

In addition, we take several other factors into account: the age of the respondent, current research area and affiliated university. By including the age dimension, we aim to control for the impact of a longer academic career. The current research area variables control for the field specific differences. Finally, we also take into account the scientist's institutional setting by controlling for the specific university affiliation of each respondent. In Table 2, we have listed all the variables with descriptive statistics.

Table 2 Descriptive statistics

Variable	Obs	Mean	Std. Dev.	Min	Max	Notes
Dependent variable						
Idea generation	1724	0.404	0.491	0	1	Binary
Interdisciplinarity and connectivity						
Interdisc. work environ.	1724	0.563	0.496	0	1	Binary
Publication network	1724	34.57	14.24	1	60	Linear
Patent network	1724	13.31	06.73	1	50	Linear
Emerging tech. areas						
Biotechnology	1724	0.227	0.419	0	1	Binary
Nanotechnology	1724	0.138	0.345	0	1	Binary
Environmental technology	1724	0.128	0.334	0	1	Binary
Employment history						
Foreign university	1724	0.307	0.462	0	1	Binary
Finnish SME	1724	0.068	0.252	0	1	Binary
Finnish large firm	1724	0.102	0.302	0	1	Binary
Foreign firm	1724	0.021	0.145	0	1	Binary
Work environment						
Number of research groups	1724	1.904	0.818	1	5	Category
Average size of a group	1724	1.847	0.809	1	4	Category
Share of internat. researchers	1724	21.50	21.49	0	100	Linear
Funding sources						
Own university	1724	2.544	1.133	1	4	Scale
Academy of Finland	1724	2.759	1.266	1	4	Scale
Tekes	1724	1.879	1.181	1	4	Scale
Foundations	1724	2.472	1.120	1	4	Scale
EU	1724	1.763	1.025	1	4	Scale
Other foreign	1724	1.425	0.808	1	4	Scale
Firms	1724	1.626	0.972	1	4	Scale
Age						
Age of the respondent	1724	42.05	11.25	23	82	Linear
Current research area						
Mathematics	1724	0.099	0.298	0	1	Binary
Data sciences	1724	0.060	0.237	0	1	Binary
Physics	1724	0.136	0.343	0	1	Binary
Chemistry	1724	0.085	0.279	0	1	Binary
Biology	1724	0.137	0.344	0	1	Binary
Biochemistry	1724	0.057	0.233	0	1	Binary
Environmental sciences	1724	0.074	0.261	0	1	Binary
Biosciences	1724	0.139	0.346	0	1	Binary
Machinery engineering	1724	0.016	0.126	0	1	Binary
Energy technology	1724	0.016	0.126	0	1	Binary
Electrical engineering	1724	0.040	0.196	0	1	Binary
Technical physics	1724	0.028	0.166	0	1	Binary
ICT engineering	1724	0.059	0.236	0	1	Binary
Chemical engineering	1724	0.034	0.182	0	1	Binary
Environmental engineering	1724	0.017	0.131	0	1	Binary
Wood processing engineering	1724	0.016	0.126	0	1	Binary
Material engineering	1724	0.036	0.186	0	1	Binary
Industrial engineering	1724	0.008	0.087	0	1	Binary
Medical sciences	1724	0.233	0.423	0	1	Binary
University affiliation						
Abo Academia	1724	0.035	0.185	0	1	Binary
Helsinki University of Tech.	1724	0.124	0.329	0	1	Binary
University of Helsinki	1724	0.279	0.449	0	1	Binary
University of Joensuu	1724	0.034	0.182	0	1	Binary
University of Jyvaskyla	1724	0.076	0.265	0	1	Binary
Lappeenranta Univers. of Tech.	1724	0.017	0.131	0	1	Binary
University of Oulu	1724	0.118	0.322	0	1	Binary
Tampere University of Tech.	1724	0.059	0.235	0	1	Binary
University of Kuopio	1724	0.070	0.255	0	1	Binary
University of Tampere	1724	0.053	0.224	0	1	Binary
University of Turku	1724	0.136	0.343	0	1	Binary

5. Statistical evidence

The aim of this paper is to address, through statistical analysis, idea generation and its connection to interdisciplinarity and connectivity in networks. We run a probit likelihood regression for the binary dependent variable of commercial idea generation. The regression results with estimated coefficients, statistical significance levels and marginal effects are reported in Table 3.

Table 3 Regression results for idea generation (probit with robust standard errors, and marginal effects)

Number of obs	1724		
Prob > chi2	0.00		
Log pseudolikelihood	-729.91		
Dependent variable: Idea generation			
Variable	Coef.	P>|z|	dy/dx
Interdisciplinarity and connectivity			
Interdisc. work environ.	0.250	***	0.068
Publication network	0.086	*	0.023
Patent network	0.794	***	0.215
Emerging tech. areas			
Biotechnology	0.567	***	0.153
Nanotechnology	-0.087		-0.024
Environmental technology	0.149		0.040
Employment history			
Foreign university	-0.032		-0.009
Finnish SME	0.100		0.027
Finnish large firm	0.069		0.019
Foreign firm	-0.575	*	-0.155
Work environment			
Number of research groups	0.128	**	0.035
Average size of a group	-0.061		-0.017
Share of internat. researchers	0.003		0.001
Funding sources			
Own university	-0.082	**	-0.022
Academy of Finland	0.006		0.002
Tekes	0.180	***	0.049
Foundations	-0.012		-0.003
EU	0.064	*	0.017
Other foreign	-0.064		-0.017
Firms	0.091	*	0.025
Age			
Age of the respondent	0.006		0.002
Current research area			
Mathematics	0.093		0.025
Data sciences	0.407	**	0.110
Physics	0.057		0.016
Chemistry	-0.046		-0.013
Biology	-0.371	***	-0.100
Biochemistry	-0.095		-0.026
Environmental sciences	0.058		0.016
Biosciences	0.113		0.030
Machinery engineering	0.516	*	0.140
Energy technology	0.471		0.127
Electrical engineering	0.550	***	0.149
Technical physics	0.367		0.099
ICT engineering	0.419	**	0.113
Chemical engineering	-0.044		-0.012
Environmental engineering	-0.009		-0.003
Wood processing engineering	0.416		0.113
Material engineering	0.131		0.035
Industrial engineering	0.788		0.213
Medical sciences	0.325	***	0.088
University affiliation			
Abo Academia	-0.037		-0.010
Helsinki University of Tech.	0.084		0.023
University of Joensuu	0.594	***	0.161
University of Jyvaskyla	0.009		0.002
Lappeenranta Univers. of Tech.	0.186		0.050
University of Oulu	0.069		0.019
Tampere University of Tech.	0.121		0.033
University of Kuopio	0.294	*	0.080
University of Tampere	0.249		0.067
University of Turku	0.087		0.024
University of Helsinki	(omitted)		(omitted)
_cons	-2.832	***	

Note: For university affiliation, University of Helsinki is used as the reference point.
*Statistical significance levels: ***(<0.01), ** (<0.05), * (<0.10)*

The regression results show that both interdisciplinarity and connectivity have a strong positive connection with idea generation. As suggested in the literature on Mode 2 type of research, we identify that an interdisciplinary working environment and applied research-related networking increase the likelihood for idea generation in the Finnish academia. We also find that basic research-related networking has a positive connection with idea generation, but it is weaker than the applied research-related networking connection. These findings show that interdisciplinary and networked research lead to more industry relevant research outcomes, which confirm the existing theoretical and conceptual discussions.

When looking at the results for the different technologies (biotechnology, nanotechnology and environmental technologies), we find that the only area more likely to produce ideas with significant commercial potential is biotechnology. This can be considered surprising because biotechnology has often been perceived as a largely failed industry in Finland. In recent research, this notion of failure has been challenged (Nikulainen et al., 2012). Many of the ideas in the Finnish biotechnology industry originate from academia, but the reason for the failures in the industry are generally not related to the quality or number of ideas, but rather to the business side. Lack of business knowledge from both entrepreneurs and financiers combined with poorly developed private equity markets are to blame. Furthermore, it is not very surprising to find that results for nanotechnology are not conclusive due to the basic science nature of the field. The results for environmental technologies are also inconclusive. This might be due to the technological diversity of the field. Environmental technologies cover a wide set of different technologies in which some are basic research-oriented, resulting in fewer potentially commercial ideas, and others are ready for market.

The age of the respondents does not seem to influence the propensity to generate ideas, suggesting that ability to generate ideas is independent from academic career length. Looking at work experience, having experience only from non-Finnish companies seems to make a difference. This background lessens the likelihood of generating ideas. This finding is interesting, but unfortunately the data at hand does not directly explain the negative connection to idea generation and requires more exploration in future efforts. It should be noted that only 2% of respondents had experience with foreign companies and thus the overall impact on idea generation in Finnish academia is less drastic.

We have already discussed the interdisciplinarity dimension of the work environment. When looking at the other dimensions of work environment, we find further evidence of a positive connection between idea generation and an individual's willingness to network and work with different people. The number of research teams the respondent is involved in is positively connected to idea generation. The average size of the research team and the share of international researchers fail to have a statistical connection with idea generation.

We also took into account the funding aspect. Funding from one's own university has a negative connection to idea generation. This suggests that the scientists relying more on direct university funding seem to work on research themes that are potentially less commercially oriented and thus less attractive to external financiers. Funding that is positively connected to idea generation comes from Tekes, the European Union and companies. Tekes has an especially strong positive connection with idea generation in Finnish academia. All of these funding sources actively promote commercially oriented academic research, which explains our findings.

Turning our attention to respondents' current research areas, we can identify significant differences across the areas. Ideas in Finnish academia are more likely to emerge from data and computer sciences, electrical engineering, mechanical engineering and medical sciences. All of these fields can be perceived as catering to specific industry needs in the ICT, machinery and healthcare sectors. These industries have a very strong position in the Finnish economy. Idea generation is negatively connected only to biology, suggesting that the research in this field is more focused on basic research outside the commercial paradigm.

The final results relate to the institutional environment of the respondents. The comparison point in these controls is the University of Helsinki, and the results reflect the position of other universities against it. The results show that the

University of Joensuu and the University of Kuopio (these two recently merged to become University of Eastern Finland) have higher likelihoods of producing ideas. The reasons for this finding are unfortunately beyond the reach of this paper and would require more in-depth analysis on the institutional characteristics of the universities. We do not find that any university stands out as being less likely to generate ideas.

6. Conclusions

In this paper, we have identified factors related to idea generation in Finnish academia. Based on a large survey data set combined with publication and patent data, the statistical analysis revealed several interesting insights. The main finding is that interdisciplinarity and networking have a significant positive role in idea generation even after controlling for several factors.

The implications of the findings of this paper on research are that both interdisciplinarity and networking should be given more emphasis in the discussion of creation of industry-relevant knowledge in academia. The empirical results of this paper verify the conceptual discussion in the existing literature, at least in the case of Finnish academia. In addition, the typical approach in the existing literature is to approach knowledge creation mostly from an output perspective, such as publications and patents. The findings of this paper show that more emphasis should also be given to the work environment because it has a significant impact on idea generation.

The results also provide insights for university management. Because universities are increasingly required to contribute to society more than just through education and research, university administration should focus more on promoting activities such as commercializing research-based ideas. This should happen primarily by giving higher priority to activities such as training and business networking but also by encouraging researchers to interact with other researchers (see also Tahvanainen and Hermans, 2011; Tahvanainen and Nikulainen, 2010 & 2011). Increased idea generation could be achieved by facilitating interaction between researchers with different backgrounds and research areas. Providing a work environment that induces interaction might create commercial opportunities.

For public policy, the findings of this paper highlight the opportunities that promoting interdisciplinarity and networking provide for commercial idea generation. Although both of these are often requirements for receiving public funding, it should be noted that the results of this paper verify their relevance in future policy formulation.

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