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What Makes a Gatekeeper?
Insights from the Finnish Nano-Community

By

Tuomo Nikulainen

Danish Research Unit for Industrial Dynamics

www.druid.dk

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Tuomo Nikulainen
ETLA (The Rresearch Institute of the Finnish Economy)
Helsinki University of Technology

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Abstract:
In the process of transferring scientific knowledge to industry the role of individual academics has received less attention than the other actors in this process. This paper aims to identify the characteristics of these key individuals, or gatekeepers, by analysing them within the context of technology transfer in a science and technology community. The estimation results show that individuals who are able to provide firms with relevant research information and results are connected to the firms informally and formally. They have commercial motivations in their research and are more likely to act as gatekeepers in social networks. On the other hand, some of the a priori assumptions of these characteristics fail to have significant influence.

Key words: Technology transfer, nanotechnology, social networks, gatekeepers

Jel codes: O31, O33, O34

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1. INTRODUCTION

1.1. Background

When new science-based technological fields emerge, the transfer of basic scientific research to more applied research, or even commercialised products and processes, requires involvement of several different actors. Universities, research institutes, government agencies and industry all play an important role in this process more commonly known as technology transfer. The literature describing this interaction between different actors has seen a rapid growth in recent years ranging from more theoretical and conceptual works to empirical research and case studies. Within this more general discussion of technology transfer, the interaction between universities and industry has received increasing attention. The level of analysis in the empirical studies has usually been at the meso-level level such as university departments or university technology transfer offices. While this is often appropriate, there are individual level characteristics that facilitate technology transfer. Therefore, it is worthwhile focusing more on those scientists that are able to provide companies with relevant research information. Some researchers are very active in providing their findings for use by the private sector and in this paper they are referred to as gatekeepers. These gatekeepers differ from the less active researchers, in the context of technology transfer, and this study aims to observe in what way they are different.

The context, where these individual level characteristics in the interaction between university scientists and industry is analysed, is a new emerging technological field based on basic research and that is starting to show signs of slowly moving to more applied research orientated activities. Nanotechnology is currently undergoing such a transition. Although nanotechnology has only recently come to the public attention, some of the research activities started over twenty years ago. The current activity in nanotechnology and related scientific disciplines is based on several different areas. All are at different stages of development, but generally they are more basic research orientated.

The public interest in nanotechnology has increased tremendously in the last few years leading to a surge of public investment in nanotechnology. The interest in this field is mostly based on advances in science and technology, but there is a general concern that some of the beliefs associated with nanotechnology are built more on hype than actual materialised possibilities. A similar situation occurred with biotechnology where initial enthusiasm only yielded major breakthroughs in some areas of life science (Nightingale & Martin, 2004).

Nanotechnology is often defined as: "… the understanding and control of matter at dimensions of roughly 1 to 100 nanometers, where unique phenomena enable novel applications, and encompassing nanoscale science, engineering and technology, nanotechnology involves imaging, measuring, modelling, and manipulating matter at this length scale" (http://www.nano.gov/). It is associated with various scientific disciplines and is seen to be potentially able to revolutionise industries and even the way we live our lives (Lipsey *et al*., 2005).

In order to analyse academic gatekeepers in an emerging technological field, there are some aspects that need to be taken into account; the selection of a science-based technology, the regional aspects, level of activity and availability of data. Therefore the focus in this paper is on the Finnish nano-community. Finland is a relatively small but knowledge intensive country. It is a small open economy and depends on exports to fuel the economy, which in return necessitates the ability to innovate and renew industries. In this respect it is worthwhile trying to understand what kinds of individuals can supply industry with relevant research information and therefore contribute to the industrial renewal. The Finnish nano-community is still in its infancy and the networks are still forming. Therefore an empirical analysis possibly provides useful insights into this community. In addition, the public agencies in Finland have invested quite substantially in this new field and it is interesting to see if the general perceptions associated with technology transfer apply in this context or are there differences that need more attention. The question of data availability is also very important. As the Finnish nano-community (researchers' active in academia, research institutes and industry) is still relatively small, the data needed to analyse the research questions sufficiently is fairly manageable and available with a reasonable effort. A similar study in a larger context would require tremendous resources both in time and expense. This community has also attracted interest by other scholars (e.g. Meyer, 2000a & 2000b), where the linkages to science have been analysed through patent statistics and the commercialisation process was discussed in a form of a case study. I seek to expand this discussion by focusing on one particular aspect.

1.2. Aim and structure

The literature on technology transfer is a fruitful starting point in trying to establish why some university scientists are able to provide firms with relevant research results. What I hope to do, in addition to merely identifying the key characteristics, is to link these results to research on social networks. The ability to utilise these social networks might prove advantageous in creating more industry relevant scientific knowledge.

I aim to establish in this paper that key individuals (who are more able to provide firms with relevant research information) in the technology transfer from university research to industry, possess unique characteristics and their position in social networks affects this ability, which is often associated with the term 'gatekeeper'.

A gatekeeper is defined as a key person, who facilitates information transfer by informal communication (Allen, 1969). Another definition is that: '…a gatekeeper is a person that acts as an intermediator of contacts and knowledge' (Tushman & Katz, 1980). Therefore, it can be argued that the role of gatekeepers is very crucial in scientific and technological areas where interdisciplinarity, interaction between different disciplines, is viewed as an important aspect of R&D-activities. In this paper gatekeepers are defined as individuals working in academia, and who possess the ability and opportunities to provide companies with relevant research information.

This paper sheds light on the role and characteristics of academic gatekeepers within the Finnish nano-community. I try to answer some of the questions that have been addressed only to limited extent in existing literature. What are the underlying characteristics of academic gatekeepers? Does one become a gatekeeper based on certain education or work experience? How much do experiences of technology transfer affect the abilities to provide information to companies? Does motivation for current research matter? Are gatekeepers more intensively working on nanotechnology different from others less involved? What is the role of individual's position in social networks?

The paper is structured in the following manner: in Section 2 the conceptual framework is discussed; Section 3 describes the data; Section 4 focuses on the regression analysis; and in Section 5 some conclusions are drawn.

2. ANALYTICAL FRAMEWORK

The conceptual framework of this paper is based on the literature of technology transfer and especially the university-industry relationship. Particularly relevant are the studies focusing on individual level interaction in technology transfer. Another relevant stream of literature is the discussion of gatekeepers and social networks. I review some of the relevant contributions in both streams of literature and clarify the contribution of this paper to the existing body of knowledge.

2.1. Theoretical contributions

The theoretical literature on technology transfer describes the interaction between different societal actors where the aim is to introduce new knowledge, mainly based on basic research efforts, to industry. This process is closely connected to innovation. The first simplistic linear conceptual models were introduced after WWII (Bush, 1945). This concept was then been modified and taken further by including interaction to the complex innovation process. Rosenberg (1982) discussed the international transfer of technology and its implications to industrialised countries. Gibbons *et al.* (1994) viewed knowledge production through marketability and commercialisation of knowledge, while at the same time relating it to interaction between different innovation actors. I base my theoretical definition of technology transfer on a contemporary interactive model that breaks down technology transfer.

Bozeman (2000) presents a model, in addition to providing an extensive review of the earlier research, which takes into account the different elements associated with technology transfer as well as the interaction between them. This ‘Contingent Effectiveness model’ describes the different aspects or dimensions of technology transfer. The model tries to explain the concepts and interaction of transfer agent, transfer media, transfer object, demand environment and transfer recipient, and how these reflect on the effective use of the transfer object. In my research the interest is on the first three elements, which are directly related to individual level activities: agent, media and object of transfer. The reason for this focus is that a researcher in academia can only affect these three dimensions with his or her activities and behaviour. I focus only on university researchers, and thus research institute and private sector researchers are excluded, because of the difference in research activities. Universities are more basic research orientated while the other research instances are more prone to applied research. Therefore the challenges and modes of interaction by default are different (Stephan, 1996; Palmberg *et al*, 2007).

On the basis of Bozeman's model I define technology transfer within the context used in this paper as: '"Technology transfer is the active, informal and formal, interaction between university researchers and companies. It covers the transfer of research information and results from the university to companies and the related knowledge in a broader sense, thus including both codified and tacit types of knowledge."

Although the 'Contingent Effectiveness model' takes several aspects into account, it disregards some of the individual level characteristics of the transfer agent. The transition of science-based research to more applied research and development activities necessitates facilitating this transfer process. Some companies seem to be able to adopt technologies earlier than others. This could be related to their absorptive ability to screen their environment and identify new potential solutions from external sources (Cohen & Levinthal, 1989). One way to achieve this is to have contacts in the supporting scientific community. These boundary- spanning individuals are most likely well connected and informed. They have insight into the related technologies and underlying sciences. These individuals in academia control the flow of information and have access to a vast pool of knowledge. Therefore, this study focuses on these individuals - academic gatekeepers.

It is important to establish that within academic organisations there are gatekeepers who are key individuals internally, for example, within the academic department. At the same time some individuals are external gatekeepers and are able to span the boundaries of their knowledge outside their own organisation. These capabilities are not exclusive and can be possessed by the same individuals. Nonetheless, in this paper the focus is more on the external gatekeepers.

Related to the discussion of gatekeepers within and between organisations, the social network analysis provides very interesting insights. Through analysis of individual level social networks, the centrality of an individual can be established. This centrality provides information on how well connected and what kind of connections an individual has in the social network. These can be connected to the concept of gatekeepers, both internal and external.

To approach this aspect there are a few very useful concepts that require attention. Structural holes are defined as a lack of connectivity with individuals (or companies for that matter) in the associated network (Burt, 1992). In other words, this means that there are no connecting ties between different subgroups within the network. If one is able to fill this structural hole, this creates an advantage for the individual in controlling the flow of information between these subgroups. In network analysis these structural holes, and individuals associated with them, are identified through a betweenness centrality measure. This concept and the associated statistical measurements can be seen as an indicator for external gatekeeper. These individuals are able to bridge and combine different parts of the social network.

Another relevant concept is social capital. It predicts that economic returns depend in some part on an individual's location in the social structure of a network (Coleman, 1988). Social capital is commonly associated with another centrality measure, closeness centrality, derived from social network analysis. This statistical measurement indicates the centrality of an individual within a connected subgroup of a network. It can be said that an individual with high closeness acts as a gatekeeper within the subgroup and thus is an internal gatekeeper.

2.2. Empirical contributions

The empirical contributions in the examination of technology transfer can be roughly divided into three different approaches: the understanding of the whole complex process, the interaction between universities and industry and the role of individuals. The first two have received major interest in the existing research, while the latter has received less.

Investigations into the complexity of technology transfer can be traced to the works of Mansfield. This is evident especially in his works during his final years (e.g. Mansfield, 1991 & 1995). His studies started a stream of research in the area of technology transfer among other innovation related fields. For example Teece (1977), a student of Mansfield's, continued researching why this process occurs and other aspects of public research interaction with industry. The most relevant studies of technology transfer, with respect to this paper, are works related to the university-industry interaction, such as Schartinger *et al* (2002) on sectoral patterns in knowledge interaction in Austria. Even more relevant is

Rahm's (1994) paper on academic perceptions of university-firm technology transfer. There is plenty of empirical literature on technology transfer, but I will focus only on those closely related to this study.

Within the discussion of the importance of technology transfer, the role of university-industry interaction has been viewed as one of the most relevant aspects. For example, Hicks (1995) focused on the movement of scientific and technological knowledge between companies and universities in their publication activities. Another contribution in the literature on university-industry technology transfer is by Schartinger *et al* (2002). They researched the sectoral patterns for different types of knowledge interactions. In their research the aim was to explore the determinants of knowledge interaction between different fields of research and sectors of economic activity in Austria. Their results indicated that the intensity of knowledge interactions fails to follow a sectoral pattern and seems to be influenced by other factors producing a complex pattern of interactions. Their findings encourage the analysis of a single technological area in more detail in order to examine the interaction process more closely.

The role of individuals in technology transfer has received some attention. Most of these studies focus on the differences between scientific disciplines and the academic position of an individual (e.g. Rahm *et al,* 1988). Although very interesting and informative, these studies still fail to answer some interesting questions about the individuals and their characteristics. The most relevant contribution in the existing literature is by Rahm (1994). She studied how researchers in academia perceived the university-firm technology transfer. The sample consisted of 1000 researchers from the top 100 universities. Rahm distinguished between 'spanning researchers' who actively participate in activities with firms and 'university-bound researchers' who were less involved in interacting with firms. Somewhat surprisingly 76% of the researchers belonged to the first group. The 'spanning researchers' tend to initiate communications with companies and are much more likely to have informal links with them. The most common informal interactions were consulting and staying in touch with former students. In addition to these findings, the spanners are more likely to engage in formal interaction, such as research consortia and co-operative R&D. Link *et al* (2006) studied the informal interaction between academic researchers and private sector. They found that male and tenured faculty members are more likely to have informal interaction. These conclusions provide a comparison point when results from the regressions of this study are discussed.

Relating to the ability to ‘span boundaries’, the empirical contributions in social network analysis provide results which are very relevant for this study. Allen (1969) has made seminal contributions to the research of communication networks. His focus has been on the intra-organisational aspects of the information flows and he has made some interesting findings. He identified gatekeepers by observing interaction among members of research organisations. In related studies (e.g. Cross & Cummings, 2004), the general conclusion is that having a central position within or between organisations, especially the position of external gatekeeper, has an impact on the performance, career opportunities and the ability to adapt to changing environments. Tushman & Katz (1980) observed research groups with and without gatekeepers. They concluded that gatekeepers can contribute significantly to the performance level of a research group. This finding was contingent on the type of research conducted. In more research orientated groups the role of gatekeepers was less important than in development projects. This result is supported by Gerstenfeld & Berger (1980) as they found that the most useful information transfer occurs near the start of applied research projects and towards the end of basic research projects. There seems to be a window of opportunity that is somewhat different for basic and applied research.

As discussed earlier the concepts of structural holes and social capital are very relevant when gatekeepers are examined. Cross & Cummings (2004) concluded that centrality in social networks has a positive impact on individual work performance. This was especially true for betweenness centrality. Their sample was from two medium-sized companies and as the sample used in this study is much larger and very fragmented, which will be discussed in the next section, some of his findings have to be interpreted carefully with respect to the results of this paper.

3. DATA

To analyse the research questions posed in this paper three different kinds of data are used: survey data complemented by patent and publication data. The survey data is based on identifying the Finnish nano-community by using search algorithms in patent and publication databases. Next, a survey was conducted among the identified individuals (or community). The survey provides information about educational and work background, experience of technology transfer, motivation for current research, and how intensively their research is connected to nanotechnology.

In addition to the survey data, patent and publication based networks were created. The patent data consists of patent family level data used identify a patent network in the Finnish nano-community. This network is based on co-inventorship. The scientific publications allow the identification of a network based on co-authorship. Use of such an analysis has received much attention (e.g. in nanotechnology Heinze (2006)).

3.1. Survey

The most important data source in this study is the survey aimed at identifying the knowledge base of the Finnish nano-community, and experience of, and attitudes of researchers and inventors towards, technology transfer. The survey data was collected in autumn 2006 through a web-based survey sent to 1002 individuals identified as active in the Finnish nano-community. From this survey I use a subset of answers by the scientists from the academia. The survey was sent to 592 academics and the response rate was 67% (397). When these individuals were then matched to network centrality statistics, the patent network matched with 58 and the publication network with 372 academics. This corresponds to expectations as academics should be more focused on publishing research results than patenting them. As the survey data is discussed in great detail elsewhere I limited my presentation to only the most important and relevant aspects. The more descriptive presentation of the survey data and the underlying variables can be found in Palmberg *et al* (2007).[1]

3.2. Patent and publication networks

Networks based on joint patenting activities indicates codified co-operation between these individuals. Although the patenting practices and ownership aspects differ between organisations, the inventors are usually credited for their work by indicating the inventors of the invention. For publications the co-authorship practices are slightly different. Sometimes the list of authors does not correspond to the actual work conducted, and it is more of a list of contributors. This is especially true in physics where there are papers that have several hundred authors (Newman, 2001). Therefore, in this study we have set a limit for the maximum number of authors allowed in a paper that can be seen to actually interact with

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[1] Including survey questionnaire, basic frequencies and analysis.

each other. The limit is set at 18 since papers having more authors usually have at least several dozen authors. Papers having more than the allowed number of authors were excluded from the sample. An important note here is that in Finland, and probably also in other countries, the incentive structure of academia favours publishing over patenting (Stephan, 1996). This clearly affects the size and structure of the networks presented here.

Another important aspect that needs to be taken into account is the construction process of the networks. In a perfect situation the whole network would be available. This ideal case would include all the patents and publications available without any limitations. As this is very difficult to achieve, the usual situation is to create a network that provides sufficient information. For this paper it means the inclusion of all identified nano-related individuals and their collaborators in patenting and scientific publishing. For these individuals, all patents and publications (not only nano-related) were collected. By including the activities of the associated individuals the networks should provide a more realistic picture of the overall joint activities of these individuals.

The patent data was collected via INPADOC database, which allowed the identification of patent families. First, an advanced search algorithm (created by FHG-ISI, see Palmberg *et al* (2006) - Appendix II for details) was used to identify the patent families that had at least one Finnish inventor or assignee. Then, the inventors' names were extracted. Finally, through INPADOC, all the patent families that included these names were collected. This provided a more extensive picture of the patent network related to the Finnish nano-community as the focus is not only on the nano-related activities but also on the other activities of these individuals. There were 118 pure nano-related patent families and when the other patent families of the same inventors are included the network is created based on 487 observations. Based on this data a patent network of 1,289 individuals was created.

The publication data was collected by using a second algorithm, more suitable for publications (Zitt, 2007). The data source was ISI Web of Science - Science Citation Index Expanded from 1986 to present. Again, all the other publications for the authors were collected in order to have a more accurate view of their academic publishing. When the data was transformed to represent the interaction in publications, the final network consists of 20,077 individuals.

The Finnish nano-related patent network is quite fragmented. Only a few subgroups or cliques of the network seem to be connected. This clearly indicates that the nano-community, at least when patents are concerned, consists of isolated research groups. In this respect the empirical results on the more applied side of the nanotechnology (patenting activity) indicate that this technological area still in its infancy. The publication network, representing the related nanosciences, is even more fragmented than the patent network. I limit my discussion of the patent and publication networks to the structural aspects. Evolution of the networks and interaction between different scientific disciplines and technologies is left for further research. The structure of both networks is highlighted in Table 1.

Table 1. Network statistics

	Patent	**Publication**
Size (# of individuals)	1,289	20,227
Density	0.00155	0.00010
Degree Centralisation	0.02820	0.01019
# of matched obs.	58	372
Closeness (min)	-0.647	-0.795
Closeness (max)	5.749	4.398
Betweenness (min)	-0.174	-0.175
Betweenness (max)	8.216	14.997

The network density is very low in both cases and the degree centralisation is also low, as the values for centrality (closeness and betweenness) derived from network analysis[2] were very low. These values were then standardised[3] with respect to the whole patent or publication network to make differences more clear. By looking at the standardised minimum and maximum values of the centrality measurements, it is clear that they vary greatly and the underlying distributions are very skewed.

3.3. Variables

To explore the individual characteristics of academic gatekeepers only theoretically relevant variables are included. In addition, some of the variables are correlated as they represented the same questions or topic area in a slightly different way. Factor analysis is used for these highly correlated variables, when theoretically justified, to combine the most relevant variables. After this data reduction, the final number of suitable and relevant variables is 33.

[2] For this analysis network analysis software Pajek was used.
[3] The observed value minus the mean value divided by the standard deviation

These new composite variables are summed values of the combined variables. In Table 2 all the variables are presented and followed by a more detailed description and discussion of their relevance in analysing the technology transfer of university researchers and the characteristics of academic gatekeepers.

Table 2. List of variables

Variables	**Abbreviation**	**Obs.**	**Mean**	**Std. Dev.**	**Min**	**Max**	**Details**
Transmitting information	TRANSMIT	384	1.21	0.91	1	4	Categorical
Educational variables	Several variables	389			0	1	Binary
Publications	PUBS	390	4.17	1.49	1	6	Categorical
Patents	PATS	385	1.74	0.95	1	5	Categorical
Work-background variables	Several variables	391			0	1	Binary
Loose interaction	INFORMAL	387	6.79	3.11	1	16	Summed value
Public interaction	PUBLIC	376	2.48	1.15	1	4	Categorical
Direct R&D interaction	DIRECTRD	376	1.88	1.03	1	4	Categorical
Work environment interaction	WORKENVIRON	377	2.54	1.05	1	8	Summed value
Actively contacting	CONTACT	386	0.24	0.43	0	1	Binary
Outputs	OUTPUT	329	2.91	1.20	2	7	Summed value
Basic research related challenges	CHALBASIC	369	8.56	4.25	1	19	Summed value
Applied research related challenges	CHALAPPLIED	346	3.57	1.52	1	8	Summed value
Commercial orientation	COMMER	382	4.03	1.79	1	8	Summed value
Own interest	OWNINT	386	3.77	0.51	1	4	Categorical
Supervisor imposed interest	IMPOSED	386	6.63	2.68	1	12	Summed value
Visit to abroad	VISIT	380	2.26	0.99	1	4	Categorical
Characterisation	CHARAC	375	2.99	1.20	1	4	Categorical
Control	CONTROL	377	2.93	1.06	1	4	Categorical
Implementation	IMPLEM	371	2.53	1.11	1	4	Categorical
Production	PRODUCT	373	2.37	1.27	1	4	Categorical
Nano-definition	NANODEF	377	2.71	1.14	1	4	Categorical
Age	AGE	390	0.00	11.22	-18.38	25.62	Centered
Betweenness (publication)	PUBBTW	372	-0.04	0.72	-0.18	11.05	Standardised
Closeness (publication)	PUBCLNS	372	0.02	0.97	-0.80	4.09	Standardised
Betweenness (patent)	PATBTW	58	-0.02	0.89	-0.17	6.52	Standardised
Closeness (patent)	PATCLNS	58	-0.06	0.92	-0.65	5.12	Standardised

3.3.1. Dependent variable

The most important question relating to the regression analysis is how the academic gatekeepers are identified. The dependent variable in this analysis is the self-reported interaction in actively providing relevant information (excluding scientific publishing) for companies. The precise question was: "*Do you transfer research information/results to firms (through means other than publications)?*". The variable TRANSMIT is a categorical (1-4) and the distribution presented in Table 3.

Table 3. Distribution of TRANSMIT

TRANSMIT		
Value	**Obs.**	**%**
1 (Not at all)	98	25
2 (A little)	138	36
3 (Quite a lot)	119	31
4 (Very much)	29	8
Total	**583**	**100**

3.3.2. Educational and work experience

The binary educational variables are based on the reported education backgrounds: physics, chemistry, and biosciences or medical. Also a dummy variable for having multiple degrees is used. The binary work background related variables are based on working for at least one year in a foreign university, a company with less than 50 employees, a company with more than 50 employees and working for a foreign firm. Using these educational and professional variables allows the analysis between different types of profiles. Individuals with more then one educational degree should be more able to combine different scientific disciplines and technological areas and therefore be more connected. They might be able to provide unique research results that are very relevant to companies. People with more diversified background in professional life should also have more interaction as they have been able to establish contacts in different organisations.

3.3.3. Interaction with firms

The explanatory variables directly related to the transfer of technology should reflect the attitudes and experience of interaction between universities and companies. The questions were directed at activities within the last five years. Some of the variables are summed values created based on correlation matrices and factor analysis (not presented here due to spatial constraints). The next four technology transfer variables presented here are in order of 'level of interaction' of the relationship. The INFORMAL consists of reported interactions, which are more informal by nature. It is a summed variable of perceived interaction in seminars and conferences, supervision of thesis work, joint publications and informal consultation. The PUBLIC variable measures the interaction in public R&D-programmes, and DIRECTRD is related to the interaction through direct R&D co-operation. The WORKENVIRON is a summed measure of interaction in joint work facilities and temporary employment in a company. Another important aspect is the outputs of this interaction. The composite variable OUTPUT comprises of perceived achievements in patenting and licensing. The binary variable CONTACT represents the ability to personally make new contacts with the opposite party. The first four variables should reflect to the possibilities to interact with companies and thus are directly related to the ability to transmit research results. In addition, those individuals who report having achieved concrete output should be more interested in co-operation with companies as they already have successful outcomes from such activity. Active contacting should have some effect on the ability to provide companies with relevant information.

3.3.4. Challenges

The next two variables CHALBASIC and CHALAPPLIED indicate what kind of challenges the respondents see as crucial in the interaction with companies. Both variables are composite variables. The first variable represents the challenges related to characteristics associated with basic research: passiveness of the researchers, basic research orientation of the current projects, identification of new research questions or product ideas, communication problems between parties, and lack of business skill among the researchers. The second variable is more related to applied research and comprises challenges in the determining the ownership of the property rights and the lack of production of technologies. The link to gatekeepers is that those individuals that reported higher levels of challenges in the co-operation could be less inclined to interact with companies than those who feel that there are fewer challenges.

3.3.4. Motivation

The next set of variables is related to reasons and motivations for current research activities. The first variable describes the commercial origins (COMMER) and is a summed variable of motivation based on the needs of firms and potential for commercialisation. The next one indicates the respondent's interest in the current research topic (OWNINT). The IMPOSED variable is the supervisor-imposed interest in the topic and combines: supervision of thesis work, availability of public funding and introduction of new instruments. The final variable motivation related variable is the interest created by a visit abroad (VISIT). The original motivation for current research should be reflected in the level of activity. Those who have imposed interest should be more passive in interaction and commercial interests should promote co-operation with companies.

3.3.6. Nanotechnology and type of research

The next variable (NANODEF) allows the distinction between individuals doing research in more nano-intensive research areas and those whose research is only related to nanotechnology to some extent. The definition used here is presented in the beginning of the paper and is the most commonly used nano-definition. In addition, the type of research conducted should affect the level of interaction. These variables include: characterisation and modelling of new materials structures or appliances (CHARAC), manipulation and/or control of new phenomena or structures (CONTROL), use of new technologies for materials or appliances with new functionalities (IMPLEM), and production of new material, structures, components or appliances (PRODUCT). The last two variables indicate a more applied take on research and providing an indication of type of research conducted.

3.3.7. Centrality measurements

The betweenness and closeness variables are, as mentioned earlier, derived from the network analysis. They are standardised in order to illustrate the relative significance of the individual. As discussed earlier in this paper betweenness measurement is a proxy for boundary spanning gatekeepers and closeness is a proxy for social capital.

3.3.8. Control variables

Publications (PUBS) and patents (PATS) are categorical control variables based on reported figures and represent the overall activity of an individual. Another control variable is age that is centred in order to avoid variance inflation. Overall active in the academic community and the individual’s age should be highly related to the ability to provide companies with relevant research information. Individuals who have been in the community longer should have more opportunities to interact with companies.

4. REGRESSIONS AND RESULTS

In order to identify what elements have a significant impact on an individual’s ability to provide research knowledge to companies and therefore act as a gatekeeper of information flows, regression analysis provides insight to this question. The regressions have the TRANSMIT as the dependent variable. As this variable represents the self-reported ability to provide companies with relevant research information and research results, and is on a 1-4 scale, the logical choice is to use the ordered logit model. This model is appropriate when the dependent variable is ordered and qualitative by nature (e.g. survey based) (Kennedy, 1998). To make sure that model selection was correct an ordered probit model was also used and it yielded very similar results. The most important difference between these two models is the probability distribution and to take this aspect into account robust standard errors were used. Using robust standard in estimations provides correct standard errors in the presence of violations of the assumptions of the model (Long & Freese, 2006). The question how well these models fit with the data are addressed after the discussion of estimation results.

4.1. Results

The basic idea behind in the regression analysis is to identify the most contributing variables that affect the ability to act as a gatekeeper. This approach in based on introducing new variables to the model in stages, and then observing which variables are consistently statistically significant in all of the estimations. The first column uses education and work background variables to explain the ability to transmit relevant information. Also the control variables are included at this stage: age, publication activity and patenting activity. The second regression includes the modes of technology transfer and the achieved outputs. The third column introduces experienced challenges to the model. In the fourth, the motivational aspects are included. The final regression introduces the nano- and research type- related variables. The results from the first set of regressions are illustrated in Table 4.

Table 4. Regressions with all variables (Ordered logistic model)

	(1)	(2)	(3)	(4)	(5)
# of Obs.	374	310	293	290	276
Wald-test	120.04	139.93	139.27	153.09	159.50
Prob>chi2	0.000	0.000	0.000	0.000	0.000
Pseudo R2	0.125	0.281	0.270	0.282	0.296
Dep. var. transmit	**Coef.**	**Coef.**	**Coef.**	**Coef.**	**Coef**
eduphy	-0.901***	-0.108	-0.278	-0.268	-0.237
educhem	0.008	0.439	0.344	0.320	0.420
edubiomed	-1.205***	-0.143	-0.208	-0.132	-0.410
edumulti	0.602	0.290	0.152	-0.036	-0.047
age	0.009	0.016	0.009	0.006	-0.009
pubs	-0.005	-0.098	-0.046	0.058	0.171
pats	0.610***	0.070	-0.005	-0.049	-0.083
workforeignuni	0.151	-0.023	-0.019	0.002	0.119
workfinless50	0.555*	-0.105	0.025	-0.101	-0.042
workfinmore50	1.306***	0.661*	0.691*	0.625	0.764*
workforeignfirm	0.206	0.180	0.587	0.435	0.430
informal		0.139***	0.138***	0.122***	0.108**
public		0.815***	0.797***	0.728***	0.754***
directrd		0.816***	0.738***	0.680***	0.652***
workenviron		0.095	0.097	0.097	0.125
contact		0.199	0.127	0.137	0.177
output		0.077	0.078	0.026	0.008
chalbasic			-0.051*	-0.044	-0.053*
chalapplied			0.054	0.034	0.078
commer				0.242***	0.249**
ownint				-0.064	0.063
imposed				0.072	0.084*
visit				-0.098	-0.088
character					-0.085
control					0.003
implementation					0.094
production					0.155
definition					-0.305

Note: * p<0.10, ** p<0.05, *** p<0.01

The results above show that some of the variables provide similar results throughout the models. The ability to transmit relevant information in Finnish nano-community seems to be a function of interacting with companies in more informal ways, participating in public R&D-programmes, being involved in direct R&D co-operation, and having a commercial motivation for starting current research. Also having work experience from larger companies and having the research topic imposed by the supervisor or employer seems to have an effect but statistically less significantly. The same is true for experiencing challenges related to basic research in technology transfer. From these statistically significant variables, a reduced model is suggested. We exclude all those variables that statistically less significant (p-value higher than 0.05) to ensure that only the most relevant variables are included.

The idea of using a reduced model instead of full model relates to the introduction of network centrality statistics. By having only the relevant variables in this reduced model, the effect of these new variables should be much clearer. The basic reduced model is presented in the first column. In column two the publication network statistics are introduced and the third column introduces the patent network statistics. The last column combines both the publication and patent network statistics (Table 5.).

Table 5. Regressions with reduced model (Ordered logistic model, p-values in parentheses)

	(6)	**(7)**	**(8)**	**(9)**
# of Obs.	365	347	57	52
Wald-test	175.64	169.52	25.92	20.85
Prob>chi2	0.000	0.000	0.000	0.008
Pseudo R2	0.297	0.297	0.248	0.263
Dep. var. transmit	**Coef.**	**Coef.**	**Coef.**	**Coef.**
informal	0.151***	0.145***	0.182**	0.140*
	(0.000)	(0.001)	(0.013)	(0.076)
public	0.828***	0.837***	0.990***	0.958***
	(0.000)	(0.000)	(0.003)	(0.005)
directrd	0.834***	0.837***	0.396	0.307
	(0.000)	(0.000)	(0.233)	(0.357)
commer	0.265***	0.285***	0.200	0.374
	(0.001)	(0.001)	(0.361)	(0.133)
pubbtw		0.145		1.175***
		(0.102)		(0.007)
pubclns		-0.211*		-0.125
		(0.086)		(0.714)
patbtw			-0.880**	-0.714
			(0.016)	(0.298)
patclns			0.952**	0.843
			(0.027)	(0.308)

Note: * p<0.10, ** p<0.05, *** p<0.01

The basic reduced model (model 6) provides results consistent with the other regressions. When the publication centrality measurements are introduced to this model (model 7), it clear that they have statistical significance. This tells us that centrality measurements derived from social networks influence the ability to transmit research knowledge to companies. This is true also for the centrality statistics based on patent networks (model 8). When the patent statistics are introduced, it is important to note that the number of observations drops significantly. The last model (model 9) incorporates both the patent and publication networks and shows how these jointly interact with the ability to transfer knowledge. This smaller group represents the academic researchers with both identified publications and patents. Hence, it could be argued that this is the 'elite' of the Finnish academic nano-community.

4.2. Model fit and statistical significance

The downside of moving away from using standard OLS estimations is that the analysis of multicollinearity and variance inflation becomes more difficult. To avoid some of the problems an extensive amount of cross-tabulations and correlation analysis was performed. This provided a useful insight into the structures and correlations, and showed that regression analysis is feasible with no major concerns of multicollinearity.

In the actual regression it seems that based on Wald-test computations the estimations are statistically valid. All of the probability values with respect to chi-squared tests indicate statistically significant model validity. The second measurement is the pseudo R-squared. As a very straightforward interpretation of this test variable might lead to dubious results, no strong conclusions are drawn. It seems that in model fit the models used have no problems with this respect.

Before going into the discussion of results and their interpretation, it is useful to take a look at the marginal effects of the regression. These marginal effects are related to the dependent variable. Marginal effects are associated with the interpretation of the critical level or the threshold, where the estimated coefficients shift directions from negative to positive and vice versa. For example, in our data that the values are from 1 to 4 (see Table 3 for details) A value of 1 means that no knowledge has been transferred by the individual and a value of 4 that plenty of information has been passed along. In order to interpret the results correctly, it is necessary to know where this critical change happens in each of the models. The results of marginal effect estimations for the basic reduced model (model 6) are presented in Table 6. Although tested the marginal effects for the other estimation models are not reported but a brief summary of the results is presented.

Table 6. Marginal effects after ordered logistic model (basic reduced model)

	Transmit = 1		Transmit = 2		Transmit = 3		Transmit = 4	
variable	**dy/dx**	**P>|z|**	**dy/dx**	**P>|z|**	**dy/dx**	**P>|z|**	**dy/dx**	**P>|z|**
informal	-.016	0.001	-.017	0.006	.030	0.001	.002	0.004
public	-.090	0.000	-.091	0.000	.167	0.000	.014	0.001
directrd	-.090	0.000	-.092	0.001	.169	0.000	.014	0.000
commer	-.029	0.002	-.029	0.004	.053	0.001	.004	0.018

Based on the marginal effects in the basic reduced model (model 6) the threshold is between values 2 and 3. That can be interpreted as people who feel they have provided knowledge to companies on regular basis are more active in all the dimensions (or variables) of the estimations. The other unreported marginal effects provided insights especially in the last estimations (models 8 and 9). In these models the threshold was even higher, between 3 and 4. This could indicate that in this smaller sample the individuals are more active which pushes the threshold higher, but otherwise yielding similar results.

4.3. Discussion

The regression estimates reveal interesting results that question some of the earlier findings in the area and at the same time provide more insight into the characteristics of academic gatekeepers. In addition to the explanatory variables that had statistically significant influence on the ability to provide relevant research information to companies, some of the *a priori* assumptions failed to be relevant.

The control variables of age and activity in patenting and publishing are insignificant in the regressions suggesting that seniority or higher activity in patenting of publishing are not directly related to the ability to transfer results. This finding is somewhat surprising as one might assume that individuals with more experience would have more interaction with companies.

The differences of having a degree in the different disciplines in natural sciences fail to be significant. Having more than one degree provides no additional ability for transmitting information to companies. Work experience is even less relevant for transferring results from academia to industry, although there is some indication that having experience of larger companies might facilitate technology transfer.

The opportunities for interaction between academic researchers and companies should have a significant and positive impact on transferring information. This is confirmed with the regressions where the interaction based on more informal, public R&D programmes and direct R&D co-operation are statistically very significant with positive values. These results are consistent in all the estimation models. The interpretation of this is that looser forms of interaction in seminars and conferences, thesis supervision, joint publications and informal consultation are important venues for information exchange. This variable represents unofficial, and hence less binding, interaction, whereas interaction through public R&D programmes and direct R&D co-operation are official and intensive forms of co-operating with companies. Somewhat less surprisingly both of these variables consistently have a positive and significant impact on the ability to transfer information. More surprising is the finding that having joint facilities or having recently worked in a company is insignificant for transmitting research results.

Even more interesting is the result that contacting companies personally or achieving clear research results such as patents and licensing fail to be significant. This might indicate that establishing contacts is less important than maintaining them or possible becoming involved later on and having frequent interaction after the first contact. The finding that achieved outputs are insignificant could be related to the fact that nanotechnology is still very science driven. Therefore, patenting and subsequent licensing is only slowly starting to materialise.

Experiencing challenges in interaction with companies related to basic or applied research should have a negative impact on the ability to provide information to companies. This assumption remains unverified based on the regressions results. Although some indication can be derived from the negative effect of experiencing challenges related to basic research.

The initial motivation for current research should be linked to providing information to companies. Having commercial motivation, visiting aboard (and possibly learning new skills) and expressing personal interest in the current research topic might have a positive impact on technology transfer. On the other hand, if the research topic is imposed by the supervisor and selected based on the availability of public funding, this should have a negative impact on providing information to companies. The only statistically significant result is for commercial motivations. Based on this result it is clear those individuals, with commercial motivations in mind when choosing their research topic, are able to provide relevant information to companies.

The variables directly related to nanotechnology and the types of research performed are insignificant. The only variable that is close to being statistically significant is how well the NNI nanotechnology definition holds true for the current research topic. Although the results for this variable are insignificant this provides us with some hint that research and development in nanotechnology is different from any other science-based technology. It could be that researchers working more intensively are still working more on topics related to basic science and thus providing fewer opportunities to interact with companies. This could be another indication of the immaturity of nanotechnology and provides further support to the conclusion that nanotechnology is very science based.

The most interesting findings of this paper are related to the centrality statistics. Even in very fragmented networks, such as the ones in question, valid indicators can be calculated. When the publication network statistics are added to the reduced model, we can see that betweenness (global) centrality is statistically insignificant although hinting of a positive connection to the ability to transmit research information. On the other hand, the closeness (local) centrality is significant and negative. This finding is somewhat surprising. It seems that having a central role within a local subgroup of the network, provides a position where one is less likely to provide companies with information. One interpretation of this result is that individuals who are central in their own subgroup are more focused on the basic research activities than interacting with people outside their own group. This can be related to Rahm's (1994) discussion of spanning and university-bound researchers. The university-bound scientists have less interaction with people from different subgroups and therefore also companies. As theory predicted those individuals that are able to utilise structural holes (global centrality) can achieve better outcomes and performance, which in this case manifests in form of ability to provide companies with relevant information. This conclusion is fairly similar to the one by Cross & Cummings (2004).

For the smaller group of individuals that have also been matched to patent networks, we can observe that patent network centrality statistics are significant. Interestingly within this subsample of patentees the direction of centrality measures has changed. In the patent network, betweenness has a high negative impact on providing research information and closeness has a high positive impact. This indicates that spanning boundaries in the more applied side of R&D hinders ones ability to provide companies with research information. At the same time closeness centrality within the local group provides opportunities to transmit results. One interpretation of this result is that the technological field on the applied side of this community is still immature. In the current patent network the connecting links between subgroups are missing. This strengthens the role of most central individuals within the subgroup. Additionally, the reduced model yields somewhat different results for this reduced sample. The direct R&D collaboration and commercial motivation are no longer statistically significant. This might indicate that the attributes of this group are somewhat different from the overall sample.

5. CONCLUSIONS

In this paper the aim was to provide some insights to what characteristics academic gatekeepers have in the Finnish nano-community with respect to technology transfer. This was achieved by analysing extensive survey data and combining some statistical centrality measures from patent and publication networks. Academic gatekeepers were identified by using self-reported ability to provide companies with relevant research related information. This activity was then explained with a variety of survey-based variables and finally matched with social network centrality measures.

The regressions analysis provided evidence that the ability to transmit relevant information in the Finnish nano-community is related to interacting with companies in informal ways, participating in public R&D programmes, being involved in direct R&D co-operation and having a commercial motivation for starting current research. At the same time some characteristics often associated to this ability lacked statistical significance. Age, publication and patenting activity, work experience, challenges experienced in technology transfer, achieved outcomes and type of R&D conducted were insignificant to the ability to provide companies with relevant research information.

The contribution to existing literature is the detailed analysis on characteristics of academic gatekeepers in a new emerging technological field. By using a very unique data set, some new insights to this community and to the process of technology transfer are presented. In addition, combining survey data with large network data provided interesting and encouraging results in using social network centrality statistics in identifying gatekeepers even in larger contexts.

Some of the aspects will require more attention. The evolution of the network over time could provide interesting results on the strengths and weaknesses of the Finnish nano-community. A related investigation into the scientific and technological profiles of individuals would also yield results that could possibly be compared to some other national community with similar national characteristics.

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