SCIENCE AND TECHNOLOGY POLICIES RESEARCH CENTER
TEKPOL Working Paper Series
STPS-WP-11/06

Individual and Organizational Aspects of University-Industry Relations in Nanotechnology: The Turkish Case

Berna Beyhan

Erkan Erdil

Mehmet Teoman Pamukçu

TEKPOL | Science and Technology Policies Research Center
Middle East Technical University
Ankara 06531 Turkey
http://www.stps.metu.edu.tr

Science and Technology Policies Research Center
TEKPOL Working Paper Series

Individual and Organizational Aspects of University-Industry Relations in Nanotechnology: The Turkish Case

Berna Beyhan[1]
Erkan Erdil[2]
Mehmet Teoman Pamukçu[3]

Abstract

Emerging nanotechnologies bring a new challenge for developing countries to improve knowledge and technology transfer between universities and firms. In developing countries, weaker ties between academia and the industry seem to be one of the main barriers to the dissemination of nanotechnology innovations. This study aims to understand individual and organizational factors affecting university-industry interactions in emerging nanotechnologies in a developing country context, namely Turkey. For this study, 181 questionnaires were collected from a sample of nano-science and nanotechnology academics who are currently employed by Turkish universities. The results provide that informal / interpersonal and research-related interactions are the most common forms of relationship between academics and firms. On the other hand, the study provides a useful insight to understand how human and social capitals of university-scientists as well as organizational resources/ capabilities influence the formation of links between universities and the industry.

Keywords: Nanotechnology, nanoscience, emerging technologies, technology transfer, university-industry relations, science and technology policies, probit model, disproportionate stratified sampling, emerging economies, Turkey.

---

[1] Department of Science and Technology Policy Studies, Graduate School of Social Sciences, Middle East Technical University, MM Building, No: 220, 06531, Ankara, Turkey; Email: berna.beyhan@gmail.com Phone: +90-312-2103719; Fax: +90-312-2107993 (corresponding author).

[2] Department of Economics, Middle East Technical University, 06531, Ankara, Turkey; Email: erdil@metu.edu.tr Phone: +90-312-2103082; Fax: +90-312-2107957.

[3] Department of Science and Technology Policy Studies, Graduate School of Social Sciences Middle East Technical University, Ankara, Turkey; Email: pamukcu@metu.edu.tr Phone: +90-312-2103719; Fax: +90-312-2107993.

1. Introduction

Knowledge and technology transfer (KTT) between universities and firms has recently gained impetus not only in the academic literature but also in policy making. There are many reasons for such interaction such as the (i) decreasing public funds devoted to scientific research; (ii) decreasing R&D investments by private companies and their desire to exploit more intensively external knowledge sources; and (iii) the rise of knowledge-based economy which is mainly based on new developments in science-based technologies i.e. ICT, biotechnology and nanotechnology.

This study deals with university-industry relations in the emerging field of nanotechnology in a developing country context. Our aim is to explore individual and organizational factors which influence the tendency of nanoscience and nanotechnology academics (nano-scientists) at Turkish universities to engage in university-industry KTT activity. To this end, a questionnaire survey was carried out with 181 nano-scientists who are currently holding a position in Turkish universities.

Despite the growing attention by scholars and policy makers to academia-industry relations in the recent period, there are many gaps in the literature to understand the formation of linkages between universities and firms. First of all, most studies in the literature deal with patent, licensing and creation of academic spin offs as the main channels of university-industry relations. However, the number of studies focusing on a larger number of channels has recently increased (Schartinger et al 2001; D'este and Patel, 2007; Link et al 2007; Arvenitis et al 2008). In these studies, it is emphasized that there are many different forms of interactions other than patenting, licensing and spin-offs; and some of them are informal and interpersonal. One of the purposes of this study is to focus on this wider spectrum of channels through which nanoscience and nanotechnology researchers at universities interact with industry.

Second, in this study we account for a broad range of individual- and organizational-level factors to explain the propensity of nano-scientists in Turkish universities to interact with private firms. Individual factors examined in this study include research experience, scientific research productivity, having access to external funding resources (industry funding and public grants), being engage in applied research, social capital, having peers well connected to industry. On the other hand, organizational factors are the presence of physical resources needed for nanotechnology research; nanoscience and nanotechnology- (NST-) related research quality of the university and finally organizational capabilities of the university to enhance university-industry interactions. To understand the effects of these individual- and organizational-level factors on the likelihood of nano-scientists in Turkish universities to have engaged in university-industry KTT activity probit regression analyses were carried out.

2. Literature review and hypotheses

There is a large literature investigating inter-organizational and/or inter-personal variations affecting the likelihood of university-scientists to engage in KTT activity. Instead of reviewing the large number of empirical work on university-industry interactions, in this study, we develop our hypotheses using this body of literature.

2.1. Individual Factors

2.1.1 Research experience

There are some empirical studies examining the influence of university-scientists' research experience on KTT activities. Landry et al. (2007) use the number of years passed since PhD completion to measure the impact of experience on KTT activity. They find a positive and significant relationship between a university researcher's tendency to engage in KTT activity and the number of years of her/his experience in research since PhD completion. Some empirical studies use tenure status, tenure experience, seniority or academic career stages to measure individual experience.

Boardman and Ponomariov (2009) provide that being tenured positively affects the likelihood of engaging in some forms of interactions (i.e. consultancy) with the industry. Link et al (2007) find that tenured faculty members are more likely than untenured faculty members to engage in informal technology transfer; moreover years with tenure also has a positive impact especially on co-publications. Azagro-

Caro (2007) creates a binary variable named seniority as based on age, teaching experience, academic career (full professorship) or academic rewards; and shows that being senior has a positive and significant influence on the tendency of individual academics to interact with the industry. Boardman (2008) also use a binary variable (tenured or not) as an indicator of experience and finds a positive and significant relationship between being tenured and having linkages with the industry. Haeussler and Colyvas (2011) measure the seniority of a university scientist with her/his age and provide evidence for the strong relationship between seniority / experience and being engaged in technology transfer activities from universities to the industry.

The empirical studies reviewed here suggest that the number of years of research experience, seniority or tenure status have strong influence over being engaged in KTT activity. There are many possible explanations of the significant impact of research experience over the formation of university-industry KTT linkages. One explanation might be that more experienced university scientists have more accumulated knowledge, skills, and know-how; and also have a wider social network including previous students, colleagues some of whom reside in academia and some in the industry, and hence, more accumulated human and social capital. As an indication of human capital and social capital, research experience is expected to influence KTT activity positively. Therefore we hypothesize that

Hypothesis 1: The greater the research experience of a nano-scientist is, the higher is her / his likelihood to engage in KTT activity.

2.1.2. Scientific productivity

Knowledge is the key resource of individual academics which can be mobilized in the interactions with the industry. Zucker et al (1998) argue that some breakthrough innovations are better characterized by tacit knowledge which cannot be transferred easily through formal KTT methods. According to authors, biotechnology as well as nanotechnology (Darby and Zucker, 2004) innovations are among those “inventions of a method of inventing”, and has an ample tacit component. Since tacit knowledge is embodied in individuals, collaborations and networks are the ways of mobilizing tacit knowledge.

The relationship between research productivity and university scientists' tendency to engage with KTT activities is analyzed in a number of empirical studies. Lowe and Gonzalez-Brambila (2007) investigate whether faculty entrepreneurs are more productive (star scientists) than their colleagues; the results of the study confirm their hypothesis that more productive faculty members are more likely to become entrepreneurs. Stuart and Ding (2006) also provide evidence for the positive and significant impact of higher number of publications on the tendency of biotechnology scientists to become an academic entrepreneur. Landry et al. (2007) include the number of publications in their models as an indicator of inimitable knowledge assets of university scientists; and demonstrate that there is a strong and positive relationship between the number of publications and university scientists' proclivity to engage in knowledge transfer to the industry. Haeussler and Colyvas (2011), in their research including university scientists both from Germany and the UK, provide evidence for the strong relationship between publication productivity of scientists and their tendency to engage with commercial technology transfer activities, i.e. patenting, consulting and founding a start-up firm.

Patenting activity is another indicator of human capital endowments of individual university scientists. The changing system of scientific knowledge production (Etzkowitz and Leydesdorff 1997; 2000; Etzkowitz et. al. 2000; Gibbons et al., 1994), Bayh-Dole fashion regulations and the formation of TTOs (or other intermediary organizations) to support university researchers for disclosing their research outputs for patenting increase their tendency to engage more in patenting activities. Since the rise of nanotechnology has occurred in this changing environment of scientific production, patenting has become a crucial part of NST-related academic research. Meyer (2006a; 2006b) and Bonaccarsi and Thoma (2007) provide evidence for the strong relationship between NST-related publications and patenting activities. Meyer (2006a) suggests that nano-scientists who both publish and patent are the most productive in terms of publications.

Azoulay et al. (2009) and Stephen et al. (2007) posit that publication and patenting activities of university-scientists are interconnected. These two empirical studies provide that patents are positively and significantly related to the number of publications (Stephen et al., 2007); and patenting activity has also a positive effect on the pace of publications and their quality (Azoulay et al., 2009). Stuart and Ding (2006), on the other hand, find that university biotechnology scientists who have ever patented are more likely to become entrepreneurs. On the other hand, Baba et al. (2009) confirm that engaging in research collaborations with scientists who both publish and patent (they are also called as Pasteur scientists) increases firms' R&D productivity.

The empirical studies reviewed here provide evidence for the relationship between the scientific productivity (measured by the number of publications and patents) and tendency of university-scientists to engage in KTT activity. Therefore we hypothesize that

Hypothesis 2: The greater the number of NST-related publications of a nano-scientist is, the higher is her/his likelihood to engage in KTT activity.

Hypothesis 3: The greater the number of patents of a nano-scientist is, the higher is her/his likelihood to engage in KTT activity.

2.1.3 Applied research

A strong relationship between applied research and the formation of university-industry KTT activity can be expected due to the fact that firms are not interested in scientific outcomes without industrial / commercial applications. Some empirical studies use industrial funds granted to university-scientists to capture the role of applied research in KTT activity (O'Shea et al., 2005; Boardman and Ponomariov, 2009). Arvanities et al. (2008) collect data regarding to the share of applied research in total research activities on the academic department level; and find a positive and significant relationship between applied research and departments' KTT activities. Landry et al. (2007), on the other hand, ask university scientists how often their research projects focus on users' (firms') needs and provide that focusing more oftenly on users' needs positively influence the tendency of university researchers to engage in knowledge transfer activities to the industry. Thus we hypothesize that

Hypothesis 4: The greater the extent to which a nano-scientist's research outcomes meet the needs of industry is, the higher is her/his likelihood to engage in KTT activity.

2.1.4 Having access to external funding opportunities

Having access to external funding opportunities is an indicator of human capital endowment of university scientists; and it contributes positively to the improvement of the human capital. Therefore, in the empirical studies investigating the determinants of KTT activity, the impact of industry funding and government grants on KTT activity are frequently investigated.

Using survey data collected from university researchers in Norway, Gulbrandsen and Smeby (2005) show that those who have access to industry research funds are more likely do applied research and hence collaborate more with the industry in comparison to the researchers without industry funding. Bozeman and Gaughan (2007) examine the impact of industrial funding on a university scientist's tendency to interact with the industry with the number industry research grants and provide that grants from industry have a significant and positive impact on a university researcher's propensity to work with industry. In a case study research on a single university in Belgium, Van Looy et al (2004) find out that industry funds positively influence academic researchers' entrepreneurial activities. Boardman and Ponomariov (2009) demonstrate that the number of industry grants received by a university scientist positively correlates with almost all types of university-industry interactions tested in their survey.

Landry et al. (2007) suggest that the level and variety of funding controlled by university researchers are indicators of the magnitude of the equipment they employ in their research projects; and the source of funding may influence knowledge transfer by providing different incentives. Therefore, authors investigate the impact of three types of funding on the propensity to engage in knowledge transfer activity in their research and provide evidence for the significant and positive impact of private and government fundings.

Empirical studies reviewed here provide strong evidence for the positive impact of having access to industrial funds on the formation of university-industry KTT linkages. In order to measure the impact of industry funding on a nano-scientist's propensity to engage in KTT activity we use the variable, 'the percentage share of industry funding in total research budget of the scientist'. Hence, we hypothesize that

Hypothesis 5: The greater the percentage share of industry funds in total research budget of a nano-scientist is, the higher is her/his likelihood to engage in KTT activity.

Landry et al. (2007) and Bozeman and Gaughan (2007) also provide evidence for the positive impact of government research grants on university-industry interactions. Authors demonstrate that government grants have a positive impact on increasing interactions with the industry; however this impact is moderate as compared to the impact of industry grants. Boardman and Ponomariov (2009), on the other hand, measure the impact of government grants with the percentage of a university-scientist's time supported by government grants and find no direct impact of publicly funded research on the various forms of interactions with industry.

In Turkey where, industrial funding opportunities provided to university-scientists are limited, we expect that public grants will influence positively the formation of university-industry KTT linkages in NST-field. Thus, we hypothesize that

Hypothesis 6: The greater the number of publicly funded research projects of a nano-scientist is, the higher is her/his likelihood to engage in KTT activity.

2.1.5 Social capital

The notion of social capital has become popular in a wide range of disciplines in social sciences in the search for answers to various questions (Adler and Kwon, 2002). It is different from the human capital which is embodied in individuals, “social capital inheres in the structure of relations between actors and among actors” (Coleman, 1988). In spite of differences between human and social capital, these two are strictly connected to each other and feed each other (Coleman, 1988; Burt, 1997; Bozeman et al. 2001). Burt (1992) posits that through social capital individuals receive opportunities to use their human capital; without the social capital of opportunities human capital is useless (Burt, 1997).

Murray (2004) provides evidence for the importance of social capital as well as human capital in the formation of relations between university scientists and entrepreneurial firms. Author demonstrates that the university scientists working together with a firm for the commercialization of an invention simultaneously exploits her/his social capital / network to build relationships between members of her/his social network and the firm. Shane and Stuart (2002), based on data on histories of 134 MIT start ups, find out that social capital of company founders (i.e. pre-established linkages with venture capitalists and angel investors) represent an important endowment for these early stage companies. D’Este and Patel (2007) consider the number of collaborative grants and find a positive and significant relationship between research collaborations of academic scientists and the variety of channels they use for transfering knowledge and technology to the industry. Boardman and Ponomariov (2009) test the impact of the number of academic collaborators on the formation of various forms of KTT linkages; however they find weak evidence for its impact. Wang and Shapira (in press), based on their research investigating the impact of human, social and positional capital[4] of university scientists on their collaboration with nanotechnology start ups, utilize the number of scientific collaborators of academics to measure their social capital. Authors find that the social capital of academic scientists has no impact on the success of nanotechnology start-ups. Landry et al. (2007), on the other hand, find a positive

---

[4] Positional capital of a university-scientists is related to the position and reputation of her/his academic institution.

impact of a university researcher’s relational assets (i.e. the intensity of relations with the potential nonacademic users) on her intensity to engage with industry.

Although the review of the empirical studies provides different findings about the impact of social capital on the formation of KTT linkages we argue that the intensity of personal relations with other nano-scientists at Turkish universities provide a university scientist an opportunity to reach others’ resources and hence exploit her/his human capital more. Therefore we hypothesize that

Hypothesis 7 : The higher the intensity of personal relations of a nano-scientist with other nano-scientists at Turkish universities is, the greater is her/his likelihood to engage in KTT activity.

2.1.6 Peer effect

The impact of peer effects on the tendency of researchers to engage in KTT activity has not been studied much in the empirical literature. However, Bercovitz and Feldman (2003, 2008), Stuart and Ding (2006) and more recently Tartari et al (2010) provide evidence for its role in the formation of university-industry KTT links.

Bercovitz and Feldman (2003; 2008), based on the argument that knowledge and technology transfer is learned in organizational environments, suggest that individuals with colleagues having a good record of technology transfer also tend to engage in technology transfer activities. Authors argue that researchers may learn from their colleagues with whom they frequently interact. On the other hand, Stuart and Ding (2006) find that academic-entrepreneurs strongly influence their collaborators and co-workers to become an entrepreneur. Tartari et al. (2010) provide evidence for the positive impact of cohort effect on the engagement of university researchers with industry.

Firstly, the positive impact of peer effect might be a consequence of social learning; individual researchers may learn how to interact with firms from their colleagues who are successful in their relations with the industry. Secondly, university-industry interaction is one of the hot issues of our time and it is much more supported by organizational and public policies / strategies. The most recent discourse on the university-industry relations emphasize the role of universities in economic development, national and regional innovation systems (Etzkowitz et al. 2000). Therefore, university-scientists having connections with the industry might be perceived as an indication of academic success; and others surrounding such successful researchers tend to imitate this behavior. Third, it can be expected that researchers engaging in university-industry KTT activity might play the role of intermediaries between two spheres of industry and academia. A researcher having collaborators or co-workers engaging in KTT activity may benefit from their networks.

The review of the recent empirical studies investigating the impact of peer effect on the propensity of university scientists' to engage in KTT activity provide strong evidence to consider peer effect in this study. Hence, we hypothesize that

Hypothesis 8: Nano-scientists with peers who have stronger industrial ties are more likely to engage in KTT activity.

2.2 Organizational-level factors

Establishing ties with the industry is not merely a consequence of human and social capital of university scientists. University reputation, tradition, academic culture, technology transfer strategies / efforts, laboratories, instruments, equipments all reside at universities; students, alumni, or simply its location influence the individual level behavior and performance of the scientists employed in these institutions. We suggest that organizational context at the university level affects individual scientists' interactions with the private sector by providing a set of resource constraints and opportunities; and an organizational environment supporting such interactions.

In this study we identified three different resources / capabilities of universities that may influence the formation of university-industry linkages. These are (i) physical resources; (ii) human capital resources; and (iii) organizational capabilities.

2.2.1 Physical resources

In the empirical literature investigating university-industry relations physical resources of universities are not much examined. Powers (2003) tests the impact of physical resources of the universities on technology transfer activities; and finds no significant impact. In this research Powers (2003) uses two measures as proxies for physical resources: the presence of either a medical school or an engineering school.

However, in the field of nanotechnology, instrumentation of science and technology has reached the peak; therefore scientific discoveries and innovations in this technology field cannot be achieved without special labs, microscopies (AFM, STM) or other special devices for observing and manipulating atoms at nano level. Therefore physical resources (i.e. labs, equipments, devices) play an important role in the accumulation of NST-related knowledge assets at universities and in the formation of interactions in the field of nanotechnology. Since equipments, instruments, labs are expensive to be built up in the individual firms; and, in Turkey, the researchers to use these equipments are mostly reside at universities.

Thus, it is expected that universities having NST-related physical resources are more advantageous situation to attract firms to collaborate or to interact (Palmberg, 2008; Merz and Biniok, 2010). Moreover, presence of physical resources also indicates the presence of skilled technicians who are capable of using specialized equipments and instruments. Therefore, we hypothesize that

Hypothesis 9: Nano-scientists who are employed at the universities where a NST-related research center, laboratory or research group exists are more likely to engage in KTT activity.

2.2.2 Human capital resources

Prestigious and reputable universities with high academic quality are expected to attract much more attention from the industry. Human capital resources play a key role in the formation of universities' reputation; and are the main indication of accumulated knowledge residing at universities. Such resources take long time to be accumulated and include tacit knowledge and therefore it is very difficult to be imitated by other universities. A number of empirical studies (i.e. O'Shea et al., 2005; Powers, 2003) examining the determinants of university-industry relations consider the human capital resources of universities as a facilitator of these relations; and human capital resources are proxied, in these studies, by the variables related to academic quality.

O'Shea et al. (2005) measure human capital of the universities with the quality ranking done in the Gourman Report in the USA; and demonstrate that science and engineering faculty quality positively influence the university spin off activity. DiGregoria and Shane (2003) and Powers (2003) use the same index to measure faculty quality; both confirm the positive impact of faculty quality on spin off and technology transfer activities. Powers and McDougall (2005), on the other hand, use the total number of citations that universities under investigation receive in a three-year period and find a positive and significant relationship between university's academic quality and the number of university spin offs. Schartinger et al (2001) measure the quality of academic output of university departments using the number of international publications; and provide evidence for its positive and significant influence on joint research activities between universities and firms.

Using a quality ranking list for the universities of the UK, while D'Este and Patel (2007) find a negative and significant impact of the research quality of the academic department on the probability of a university researcher engaging in a wide variety of interactions Perkmann et al (2011) demonstrate that for the technology-oriented disciplines, the researchers in the best departments are also those with high industry involvement. On the other hand, Ponomariov (2008) finds out that academic quality negatively affects the tendency of individual university scientists to interact with the industry. In other words, the higher the average quality of an institution the smaller the propensity of university scientists to interact with firms.

Since our research focuses on a specific technology field, any kind of measurement related to the overall research quality of a university would be an imperfect indicator of the quality of human capital. Therefore, in this study we measure human capital of universities in the NST field with two variables (i) total number of citations received by university's NST-related articles published in a five-year period from 2005 to the end of 2009; and (ii) the number of international links (which is measured by co-authorship with foreign institutes) per article (published in the same period from 2005 to 2009). These two variables are used as indicators of academic research quality and hence human capital of universities in the field of nanotechnology. Citations have long been used for measuring the scientific quality of articles, research groups, universities or even individual researchers (Leydesdorff and Amsterdamska, 1990; Porter, 1977).

On the other hand, the most characteristic tendency of today's scientific production is intensified research collaboration (De Solla Price, 1963; Hudson, 1996; Katz and Martin, 1997; Glanzel, 2002). Moreover, international scientific collaboration has increased both in volume and importance (Luukkonen et al., 1992). Empirical studies provide evidence for the positive influence of international collaboration on the overall productivity of academic institutes or on the impact or quality of the articles (Katz and Hicks, 1997; Leta and Chaimovich, 2002). Internationally collaborated scientific publications provide a good indication of human capital in the sense that accessing international scientific networks requires human and social capital; and in return increases human capital endowments of scientists. Therefore it is expected that universities with higher international collaboration have larger human capital; and more opportunities to improve their current human capital due to the connections to the international scientific networks; and having access to the most recent knowledge that resides in these networks. Therefore we hypothesize that

Hypothesis 10: The higher the total citations to a university's NST-related publications are, the greater is the likelihood of a nano-scientist employed at this university to engage in KTT activity.

Hypothesis 11: The higher the number of international links per a university's NST-related publication is, the greater is the likelihood of a nano-scientist employed at this university to engage in KTT activity.

2.2.3 Organizational capabilities

Amongst the changes in the context of commercialization of university research outputs, empirical studies are mostly concerned with TTO experience, number of TTO staff allocated for technology transfer activities; or experience of the university in certain KTT activities as the main indicators of organizational capabilities and resources of the universities in the industry involvement process.

While Thursby and Thursby (2002) emphasize the importance of faculty willingness and the propensity of central administration to engage in KTT activities, university policies and strategies to promote university-industry KTT activities attract attention from some scholars of technology transfer. These policies are mainly related to the share of licensing income and incentives or rewards for faculty involvement in KTT activites in the universities. Friedman and Silberman (2003) and Di Gregoria and Shane (2003) posit that various technology transfer policies used by the university administrations enhance technology transfer and spin-off activities. On the other hand, Lockett and Wright (2005) provide that organizational routines for providing incentives or rewarding developed by universities play an important role in the creation of university spin-offs.

In Turkey, TTOs are very recent organizations for universities; they are very limited in numbers. Only five universities have TTO-fashion organizational capabilities;

however their activities and role to promote KTT are very limited. For this research, the attitude of university administrations or their willingness to promote university-industry interactions and develop routines for supporting scientists in the formation of relationships and in the creation of feasible solutions to problems possibly occurring between university scientists and firms during this process seems much more important than some formal organizations (i.e. TTOs or technology transfer companies established within the universities). Therefore we hypothesize that

Hypothesis 12: The higher the support of a university to promote university-industry relations is, the greater is the likelihood of a nano-scientist employed at this university to engage in KTT activity.

3. Data collection and methodology

The data for this study were collected through questionnaire survey from nano-scientists at Turkish universities. However, identifying nano-scientists is not an easy task due to the fact that there is no easy definition of ‘nano-scientist’ or ‘nanotechnologist’. For the identification of nano-scientists we used NST-related research articles published by scientists linked to Turkish universities in the period 2005-2009. The publication data were retrieved from ISI Web of Science SCI (science citation index); for the identification of NST-related research articles we relied on keyword research algorithm developed by Kostoff et al. (2007).

We identified 3266 NST-related articles published by scholars affiliated to Turkish institutes over a five year period from the beginning of 2005 to the end of 2009. There were 5806 different names of scientists linked to these articles. However, these researchers are involved in nanotechnology to different degrees; 3741 (nearly 64.5 %) scientists in the list are linked to only one article in our database and nearly 80% of researchers in the list have less than three articles.

For the description of survey population, a threshold level of 3 articles was decided to be applied. Hence, the target population of this research was identified as the nano-scientists at Turkish universities who have published at least three NST related articles in a five year period from 2005 to the end of 2009. After an intense research to check the list of researchers for duplicates, misspelled names or the current institution; and to identify the contact information using internet we are left with a list of 703 researchers who are currently affiliated with a Turkish university. 181 questionnaires were collected from 703 nano-scientists.

The main objective of this research is to collect more information about the main features of NST research and researchers at Turkish universities and investigate how these features affect the university-industry interactions at the individual level. Therefore, in this thesis, to collect data from nano-scientists a disproportionate stratified sampling method was used for the selection of university scientists to be interviewed. In other words, with this design some members of the sampling frame were given a higher probability of selection than the others.

Although authors of NST-related articles with less than three articles were discarded from the sampling frame, the distribution of the number of articles keeps its highly left-skewed characteristics with a long left tail of authors having a low number of articles. The distribution of articles shows that 75 percent of the authors have published 3 to 7 articles in the five-year period 2005-2009. However, the number of articles among the nano-scientists varies between 8 and 106 articles in the fourth quartile. The statistics related to the distribution of the number of articles are provided in Table 1.

Table 1 Statistics related to the number of articles between different quartiles

	Freq.	*Median*	*Mean*	*Std. Dev.*	*Min.*	*Max.*
The highest 25%	173	10	13.66	9.95	8	106
The rest 75%	530	4	4.23	1.26	3	7
Total	703	5	6.55	6.48	3	106

Nano-scientists in the highest 25 percent are called as Group 1 scientists and the rest is called as Group 2. Since the fundamental objective in sampling is “to gain the most information for the least cost" (Lohr, 1999), we decided to use a disproportionate stratified sampling technique to select academicians for the sample from Group 1 and Group 2. According to the applied sampling design 81 questionnaires are collected from the nano-scientists in Group 1 and 100 from those in Group 2 (Table 2). In this way, a rare population of academicians who are much more interested in nanoscale research could be oversampled.

Table 2 Distribution of the sample across groups and probability of selection

	n_h	N_h	***Prob. of selection*** (n_h/N_h)
Group 1	81	173	0.47
Group 2	100	530	0.19
Total	181	703	

4 Measuring KTT activity

In this study, to measure the KTT activity, nano-scientists are asked 18 questions. Three of these questions measure direct channels of technology transfer (or commercialization of knowledge), namely (i) joint patents with firms; (ii) licensing; and (iii) entrepreneurial activity. These questions are binary response questions; in other words, they take value 1 if the respondent confirms to engage in these activities.

Remaining 15 questions are asked on a five point Likert scale and respondents are expected to provide how frequently they engage in the given forms of KTT activities (1=never; 5=very frequently). Among those 15 questions, four questions measure how frequently respondents consult firms in their nanotechnology related R&D projects. The rest of the questions (11 questions) deal with various forms of KTT activities related to laboratory research, education, informal contacts, etc. Since the number of activities is too high for a robust analysis we decided to decrease the number of KTT activities with a factor analysis. In this study, principal component factor analysis is used to decrease the number of KTT channels (Table 3).

Table 3 Principal component factor analysis of KTT activities

	Factor 1 RES	*Factor 2 ACAD*	*Factor 3 INFORMAL*
Ad-hoc research for firms	**0.89**		
Special test and analyses for firms	**0.85**		
Joint research projects	**0.70**		
Firms' accession to special nanotechnology equipments and labs at universities	**0.71**		
Master/PhD theses jointly supported by firms and Ministry of Industry		**0.73**	
Joint publications with firm scientists/researchers		**0.76**	
Joint supervision of Master/PhD theses with firm scientists/researchers		**0.89**	
Participating conferences, seminars and meetings where firm scientists / researchers are present			**0.76**
Supervising graduate students employed at firms			**0.54**
Informal / interpersonal relations with graduates employed at firms			**0.78**
Informal / interpersonal relations with firm scientists / researchers			**0.75**
Number of observations	**174**		
Kaiser-Meyer-Olkin (KMO) measure of sampling adequacy	**0.84** *		
Bartlett's test of sphericity	**835.96** ǂ		
Variance explained by each component	**6.15**	**1.12**	**1.08**
Proportion of variance explained by each component	**55.91%**	**10.18%**	**9.82%**

* 0.00 to 0.49 unacceptable; 0.50 to 0.59 miserable; 0.60 to 0.69 mediocre; 0.70 to 0.79 middling; 0.80 to 0.89 meritorious; 0.90 to 1.00 marvelous

ǂ p-value= 0.000 (H0= Variables are not intercorrelated)

Finally we have 5 fundamental forms of KTT activities.

(1) Commercialization channels (*COMM*)
  a. Joint patents with firms
  b. Licensing
  c. Firms founded by academics
(2) Consultancy (*CONS*)
(3) Research activities (*RES*)
  a. Ad-hoc research for firms
  b. Special tests and analyses for firms
  c. Joint research projects

d. Firms’ accession to special nanotechnology equipments and labs at universities

(4) Academic activities (*ACAD*)
  a. Master/PhD theses jointly supported by firms and the Ministry of Industry
  b. Joint publications with firms scientists / researchers
  c. Joint-supervision of Master / PhD Thesis with firm scientists / researchers

(5) Informal contacts (*INFORMAL*)
  a. Participating conferences, seminars and meetings where firm scientists / researchers are present
  b. Supervising Master/PhD students who are currently employed at firms
  c. Informal / interpersonal relations with graduates employed at firms
  d. Informal / interpersonal relations with firm scientists / researchers

The aim in this study is investigate the factors influencing the formation of KTT links between universities and firms. Therefore, in order to measure the formation of KTT links, we transformed the responses provided by academics on a 5 point Likert scale to a simple binary response (yes or no).

The intensity of interactions between different agents is important because intense relations improve the trust between agents and increase the amount of transferred knowledge. Thus, in measuring the formation of KTT activity we decided to take the values of 4 “frequent” and 5 “very frequent” into account as an indicator of KTT activity. Table 4 provides how different forms of KTT activity are constructed and defined on a binary scale.

Table 4 The measures of KTT activity

Name	*Definition*
INFORMAL	If the respondent reported the values 4 "frequent" or 5 "very frequent" for any form of INFORMAL university-industry interaction it takes value 1 otherwise 0.
RES	If the respondent reported the values 4 “frequent” or 5 “very frequent” for any form of RESEARCH based university-industry interaction it takes value 1 otherwise 0.
ACAD	If the respondent reported the values 4 “frequent or 5 “very frequent” for any form of ACADEMIC activity based university-industry interactions it takes value 1 otherwise 0.
CONS	If the respondent reported the values 4 “frequent” or 5 “very frequent” for any form of CONSULTANCY for firms it takes value 1 otherwise 0.
COMM	If the respondent reported "yes" for any form of formal channels (joint patents with firms, licensing or entrepreneurial activity) it takes value 1 otherwise 0.
KTT Activity	If any one form of 5 KTT activities mentioned above (INFORMAL, RES, ACAD, CONS, COMM) takes value 1 it takes also value 1 otherwise 0.

The analysis of collected data indicates that almost 46 percent of nano-scientists at Turkish universities have an intense relationship with firms (Table 5). The most common form of KTT activity between universities and firms is INFORMAL interactions; nearly 40 percent of nano-scientists mention that they have intensively interacted with the industry through informal and interpersonal linkages. It is followed by RESEARCH-related activities; 12 percent of respondents frequently collaborate with firms in their research activities. However, only 7.18 percent of respondents engage in direct technology transfer channels such as joint patents, licensing and start-ups. The least important form of KTT activity between Turkish NST academics and firms is based on academic activities (ACAD). Only 2.8 percent of academics mention that they intensively collaborate with firm on academic activities.

Table 5 Percentage distribution of respondents across various forms of KTT activity

	0=No relationship	*1=Relationship*
INFORMAL	60.77	39.23
RES	87.85	12.15
CONS	91.16	8.84
COMM	92.82	7.18
ACAD	97.24	2.76
KTT Activity	54.14	45.86

5. Factors influencing the KTT activity

We use probit regression analysis to identify individual and organizational factors that influence nano-scientists to engage in university-industry KTT activity. The basic model to be estimated is as follows:

$$Y_{KTTActivity} = \beta_0 + \beta_1 EXP + \beta_2 NSTPUB + \beta_3 NPATENT + \beta_4 NPUBGRANT + \beta_5 INDFUND + \beta_6 APPL + \beta_7 NTWK + \beta_8 PEER + \beta_9 TOTCIT + \beta_{10} INTCOLLAB + \beta_{11} NSTINST + \beta_{12} UNIVSUPP + \beta_{13} MOTIVECOMM + \beta_{14} ENGINEERING + e$$

where Y indicates the binary dependent variable for KTT activity. The brief definitions of explanatory variables, descriptive statistics and correlation table are provided in Appendix Table A-1 and Table A-2 and Table A-3).

MOTIVECOMM and ENGINEERING in the model is used to control the factors which are not directly related to the individual or organizational resources / capabilities. In order to control the effect of academic disciplines we use a dummy variable “faculty of engineering” (which takes the value of 1 if a university-scientist is employed at the engineering faculty, 0 otherwise). On the other hand, to control the effects of factors motivating university scientist to interact with the industry, the variable MOTIVECOMM is included in the model. There are numerous factors that motivate nano-scientists at Turkish universities to interact with industry. The number of motivations is reduced to three using principal component factor analysis (for details see Appendix Table A-4)

5.1 Results

For three models (Table 5A) a broad range of variables related to individual and organizational resources / capabilities have statistically significant effects. Based on estimation results, it can be argued that, on the individual side, number of NST-related publications and patents, doing applied research, having an intense relationship with other nano-scientists in Turkey and having peers with strong relations with the industry significantly influence the tendency of nano-scientists at Turkish universities to engage in KTT activity. On the other hand, university’s

Table 6A Probit regression results: Determinants of KTT activity

KTT Activity	*Model 1*	*Model 2*	*Model 3*
EXP	-0.009	-0.015	-0.015
[Research experience]	(0.55)	(0.93)	(0.86)
NSTPUB	-0.051	-0.052	-0.055
[NST publications]	(1.84)*	(1.85)*	(1.93)*
NPATENT	0.181	0.187	0.164
[# of patents]	(2.13)**	(2.02)**	(1.88)*
NPUBGRANT	0.484		0.392
[Publicly funded projects]	(2.03)**		(1.64)
INDFUND		4.323	3.975
[Industry funding]		(1.26)	(1.20)
APPL	0.364	0.302	0.328
[Applied research]	(2.80)***	(2.19)**	(2.32)**
NTWK	0.396	0.471	0.434
[Social networks]	(2.53)**	(3.00)***	(2.72)***
PEER	0.250	0.229	0.235
[Peer effect]	(1.68)*	(1.50)	(1.50)
TOTCIT	0.000	0.001	0.001
[Total citations]	(1.44)	(1.91)*	(1.88)*
INTCOLLAB	-1.098	-1.248	-1.382
[International links]	(1.93)*	(2.10)**	(2.28)**
NSTINST	0.713	0.840	0.828
[NST research inst./lab]	(2.45)**	(2.81)***	(2.73)***
UNIVSUPP	0.201	0.227	0.224
[University support]	(1.77)*	(1.86)*	(1.81)*
MOTIVECOMM	0.602	0.701	0.708
[Motiv. Commercialization]	(4.24)***	(4.89)***	(4.89)***
ENGINEERING	0.478	0.334	0.435
[Faculty of Engineering]	(1.41)	(0.97)	(1.20)
Constant	-5.612	-5.517	-5.774
	(5.53)***	(5.40)***	(5.48)***
Observations	135	131	131
Log likelihood	-60.92	-56.64	-55.51
McFadden R^2 (adj.)	0.20	0.22	0.22
Hosmer-Lemeshow χ^2 (8)	8.48	9.49	3.39
(p-value)	(0.39)	(0.30)	(0.91)

Robust z statistics in parentheses
* significant at 10%; ** significant at 5%; *** significant at 1%

Table 6BMarginal effects[5]: KTT activity

KTT Activity *Marginal Effects*	*Model 1*	*Model 2*	*Model 3*
EXP	-0.003	-0.006	-0.006
[Research experience]	(0.55)	(0.93)	(0.86)
NSTPUB	-0.020	-0.021	-0.022
[NST publications]	(1.84)*	(1.85)*	(1.93)*
NPATENT	0.072	0.074	0.065
[# of patents]	(2.13)**	(2.02)**	(1.88)*
NPUBGRANT	0.193		0.156
[Publicly funded projects]	(2.03)**		(1.64)
INDFUND		0.017	0.016
[Industry funding]		(1.26)	(1.20)
APPL	0.145	0.120	0.130
[Applied research]	(2.80)***	(2.19)**	(2.32)**
NTWK	0.158	0.187	0.173
[Social networks]	(2.53)**	(3.00)***	(2.72)***
PEER	0.100	0.091	0.094
[Peer effect]	(1.68)*	(1.50)	(1.50)
TOTCIT	0.000	0.000	0.000
[Total citations]	(1.44)	(1.91)*	(1.88)*
INTCOLLAB	-0.437	-0.497	-0.550
[International links]	(1.93)*	(2.10)**	(2.28)**
NSTINST	0.278	0.325	0.321
[NST research inst./lab]	(2.45)**	(2.81)***	(2.73)***
UNIVSUPP	0.080	0.090	0.089
[University support]	(1.77)*	(1.86)*	(1.81)*
MOTIVECOMM	0.240	0.279	0.282
[Motiv. Commercialization]	(4.24)***	(4.89)***	(4.89)***
ENGINEERING	0.186	0.131	0.169
[Faculty of Engineering]	(1.41)	(0.97)	(1.20)

Robust z statistics in parentheses
* significant at 10%; ** significant at 5%; *** significant at 1%

---

[5] Marginal effects are computed at mean values of explanatory variables (see Section 6.1)

physical resources and organizational capabilities have significant effect over individual scientists' proclivity to interact with industry.

The number of NST-related publications of an individual university-scientist correlates (NSTPUB) negatively and significantly ($p<0.1$) with her/his propensity to engage in KTT activity. Negative but significant coefficients on variable of publication numbers indicates that university scientists with higher number of NST publications have a lower probability of interacting with the industry. Table 6B provides the estimated marginal effects of variables on the probability of being engaged in KTT activity. Marginal effect of the variable NSTPUB indicates that one unit increase in the number of NST-related publications decreases the probability of a scientist to interact with firms by 2 percentage point.

This result is not confirmed by the previous empirical studies; and thus does not support our hypothesis 1. The reason behind the negative impact of the number of publications on the tendency of nano-scientists at Turkish universities to enter in KTT activities might be due to the academic reward system (Dasgupta and David, 1994) which is mainly based on scientific production and academic reputation. In Turkey, among the promotion criteria applied in Turkish universities to university-scientists the number of publications in SCI or SSCI has a considerable importance. Therefore nano-scientists at Turkish universities might prefer allocating their time and effort to carrying out research aimed to increase their international publications rather than for improve their relations with the industry.

Table 6A indicates that the probability of a university nano-scientist's engaging in KTT activity increases with the number of her/his patents (NPATENT). The influence of NPATENT over the propensity of interacting with industry is significant at 5 percent level in Model 1 and Model 2 and at 10 percent level in Model 3. Estimated marginal effects (Table 6B) indicate that the marginal effect of an additional patent or patent application increases the probability of a nano-scientist to engage in KTT activity by nearly 7 percentage point. This result also reinforce the previous studies (i.e. Stuart and Ding, 2006; Baba et al., 2009) supporting the positive impact of patenting attitudes of university scientists on university-industry relations.

Some recent studies by Meyer (2006a; 2006b), Bonaccorsi and Thoma (2007), Guan and Wang (2010) focus on inventor-authors in the field of nanotechnology and provide evidence to support that inventor-authors in the nanotechnology are more successful than their non-inventing peers. Our research results confirm the findings of these studies with providing that inventor-authors are also more successful in university-industry interactions than their non-inventing peers.

The estimation results support that the extent to which a nano-scientist's research outcomes meet the needs of industry (APPL), or in other words the extent to which research outcomes have industrial applications has positive and statistically significant (at 1 percent level in Model 1 and 5 percent level in Model 2 and Model 3) on the formation of KTT linkages between nano-scientists and firms. This indicates that nano-scientists who carry out scientific research with higher industrial applicability have a greater probability to interact with the industry. Marginal effects presented in Table 6B demonstrate that an additional point increase in the extent to which research outcomes meet the needs of industry increases the propensity of a nano-scientist to engage in university-industry KTT activity by 12 - 14.5 percentage point. These results reinforce the findings of previous studies (i.e. Landry et al., 2007; Arvanitis et al., 2008) and also support our hypothesis 4: the greater the extent to which a nano-scientist research outcomes meets the needs of industry is the higher is her/his likelihood to engage in KTT activity.

While the percentage of industrial funding in total research budget of respondents (INDFUND) has no statistically significant impact on the formation of KTT linkages between nano-scientists and firms, a positive and significant relationship between the variable (NPUBGRANT), which indicates the extent of the number of public grants received by respondents, and KTT activity is observed in Model 1. However NPUBGRANT is statistically significant at 5 percent level only when INDFUND variable is excluded. The influence of INDFUND is positive but not significant. On the other hand, Table 6B indicates that the marginal effect of an additional one point increase in the ordered categorical variable indicating the extent to which a nano-scientist engage in publicly funded research projects, increases the probability of engaging in KTT activity by 19.3 percentage point.

The estimation results for industrial funding (INDFUND) do not support the results regarding the strong relationship between industry funding and the formation of KTT linkages which are obtained in previous empirical studies (Bozeman and Gaughan, 2007; Boardman and Ponomariov, 2009; Landry et al., 2007). The reason behind this result might be the low level of industrial funding among nano-scientists at Turkish universities. Descriptive statistics show that nearly 83 percent of respondents have received no industrial fund in the last five-year period. Moreover for 15 percent of the respondents the percentage of industrial funds in the total research budget does not exceed one percent.

On the other hand, the results for the impact of public research grants (NPUBGRANT) over the university-industry interaction reinforce the existing literature (i.e. Bozeman and Gaughan, 2007; Landry et al., 2007). This result might be explained that nano-scientists who are highly engaged in publicly funded research projects deal more with research activities, have access to new networks and hence new knowledge resources; all of these opportunities help nano-scientists to improve their human capital, and hence, their relations with the industry.

Estimation results for the influence of the intensity of personal contacts with other nano-scientists at Turkish universities support our hypothesis 7 which indicates that the higher the intensity of personal relations of a nano-scientist with other nano-scientists at Turkish universities (NTWK) is, the greater is her/his likelihood to engage in KTT activity. Table 6A shows that in all three models NTWK variable has positive and statistically significant (at 5 percent level in Model 1 and 1 percent level in Model 2 and Model 3) coefficients. The estimated marginal effects in Table 6B shows that an additional one point increase in the degree of frequency at which a nano-scientist personally contact with her /his colleagues at other Turkish universities increases the probability of the nano-scientist to engage in KTT activity by 15.8 – 18.7 percentage point.

Although recent studies suggest that peers' attitudes towards industry play a significant role in university scientists' proclivity to engage in KTT activities or entrepreneurship (Bercovitz and Feldman, 2003, 2008; Stuart and Ding, 2006; Tartari et al., 2010) the estimation results in Table 6A provide very weak support for its positive impact on the tendency of nano-scientists employed at Turkish universities to engage in KTT activity. In Model 1, peer effect (PEER) has a positive and significant (at 10 percent level) coefficient. The marginal effect of an additional one degree point increase in PEER increases the probability of a nano-scientist to engage in KTT activity by 10 percent. However when industrial funding is included in Model 2 and Model 3 peer effect becomes statistically insignificant. Although we expect that a university nano-scientist with peers who have stronger industrial ties are expected to engage in KTT activities, the relationship between peer effect and the formation of KTT linkages is not very strong.

Theoretical and empirical studies emphasize the strong dependence of nanotechnology discoveries and innovations on the scientific instrumentation (Darby and Zucker, 2004). Estimation results, as expected, support that the presence of nano-equipped laboratories, research centers at universities (NSTINST) positively and significantly correlates with the tendency of nano-scientists employed at such universities to engage in KTT activity. Estimated marginal effects also state that the presence of nano-equipments at universities increases the tendency of university nano-scientists to interact with firms by 27.8 – 32.5 percent. Hence our research provides strong evidence to support hypothesis which indicates that a nano-scientist employed at a university with nano-equipments (research centers, labs, working groups) is more likely to engage in KTT activity.

As to the variables measuring the impact of universities' human capital resources on the formation of KTT activities, it is captured that while total citations to a university's NST publications (TOTCIT) have statistically weak positive impact on

KTT activity, there is an inverse and significant relationship between international scientific ties of a university (INTCOLLAB) and tendency of nano-scientists to interact with industry. Therefore our results provide a weak evidence for the positive impact of the quality of universities' human capital resources on KTT activity.

Our results are in line with some previous empirical studies finding an inverse relationship between research quality and the formation of university-industry relations (D'Este and Patel, 2007; Ponomariov, 2008). The effect of a high quality research environment may be such that scientists perceive greater incentives to engage in scientific research and consider interactions with industry as distracting their scientific pursuits (Ponomariov, 2008). Furthermore, the valid academic norms in Turkish academia promote engaging more with the scientific research; and the competition among academics is mainly based on the quantity and quality of publications in many universities. Since in the high quality academic environments this competition is expected to be much higher and this may influence the decisions of nano-scientists not to spend their time and efforts to engage in KTT activity instead of scholarly research and publications.

As we hypothesize, there is a strong and positive relationship between university support (UNIVSUPP) to KTT and the tendency of a university nano-scientist to interact with the industry. Table 6B indicates that one point increase in the degree of support provided by a university to nano-scientists during the process of university-industry relations increases the probability of a nano-scientist to engage in KTT activity by 8-9 percent. The estimation results reinforce the previous studies emphasizing the strong influence of university's organizational resources / capabilities, strategies or policies on university-industry KTT (i.e. Thursby and Thursby, 2002; Friedman and Silberman, 2003; Di Gregoria and Shane, 2003; Lockett and Wright, 2005)

Among the control variables, while the motivation of university nano-scientist to commercialize their research outcomes (MOTIVECOMM) has a positive and statistically significant (at 1 percent level) impact on the formation of KTT linkages, no significant impact of academic discipline which is measured by being affiliated to a faculty of engineering (ENGINEERING) is found.

6. Factors influencing INFORMAL-KTT Activity

To analyze the effects of individual and organizational resources / capabilities on the likelihood of a university nano-scientist to engage in INFORMAL KTT (see Table 4) activity we use probit regression analysis. The basic statistical model to be estimated is as follows:

$$Y_{INFORMAL} = \beta_0 + \beta_1 EXP + \beta_2 NSTPUB + \beta_3 NPATENT + \beta_4 NPUBGRANT + \beta_5 INDFUND + \\ \beta_6 APPL + \beta_7 NTWK + \beta_8 PEER + \beta_9 TOTCIT + \beta_{10} INTCOLLAB + \\ \beta_{11} NSTINST + \beta_{12} UNIVSUPP + \beta_{13} MOTIVECOMM + \beta_{14} ENGINEERING + e$$

where Y indicates the binary dependent variable for INFORMAL-KTT activity. The brief definitions of explanatory variables, descriptive statistics and correlation table are provided in Appendix Table A-1 and Table A-2 and Table A-3).

6.1 Results

The estimation results for the impact of human and social capital characteristics of university nano-scientists in Turkey on their engagement in INFORMAL KTT activity exhibit some similarities with those for general KTT activity. For example, the effect of the number of NST publications of a nano-scientist (NSTPUB) is statistically significant (at 5 percent level in Model 1 and 1 percent level in Model 2 and Model 3) but in the opposite direction of that we hypothesized. The results indicate that university scientists with a higher number of NST-related publications have a lower probability of engaging in INFORMAL KTT activity. The marginal effect of an additional number of NST publications on the probability of being engaged in INFORMAL KTT activity equals almost minus 2.5 percentage point (Table 7B).

Our results indicate that the number of a nano-scientist’s patents positively and significantly correlates with her/his propensity to have engaged in INFORMAL KTT activity. This result also confirms that ‘inventor-authors’ of Turkish NST academia tend to interact with industry more than non-inventors. The estimated marginal effects (Table 7B) indicates that one unit increase in the number of patents increases the probability of a university nano-scientist to interact with industry through INFORMAL channels by 4.3 – 5.3 percentage point. The results for both general KTT activity and INFORMAL KTT activity suggest that, at least in the field of nanotechnology, academic inventors with a moderate number of publications play an important role in the formation of linkages between universities and firm.

Additionally, Table 7A indicates that the probability of a university nano-scientist’s having engaged in INFORMAL KTT activity increases with the extent to which a nano-scientist’s research outcomes meet the needs of industry (APPL). This suggests that industrially applicable research increases the probability of a nano-scientist to interact with the industry through INFORMAL channels. The coefficients of the variable APPL are positive and significant at 5 percent level in Model 1 and Model 3. Table 7B for marginal effects shows that one unit increase in the extent to which a nano-scientist’s research outcomes have industrial applications increases the probability of the scientist to engage in INFORMAL KTT activity by 8.8 – 11.5 percentage point.

Although NSTPUB, NPATENT ve APPL variables for both general KTT activity and INFORMAL KTT activity provide similar results, the variables for industry funding (INDFUND) and public funding (NPUBGRANT) vary considerably in terms of their impacts across general and INFORMAL KTT activity. Table 7A shows that while NPUBGRANT, which indicates the extent to which a nano-scientist engage in publicly funded research projects, has no significant impact on the formation of INFORMAL KTT activity between university nano-scientists and firms, share of industrial funding in total research funding (INDFUND) positively and significantly (at 10 percent level) correlates with the INFORMAL KTT activity. Estimated marginal effects in Table 7B indicate that one percentage increase in the share of industry funding in a nano-scientist’s total research budget increases the probability of her/his being engaged in INFORMAL KTT activity by 2.7 percentage point.

These results for industrial funding reinforce the previous empirical studies suggesting that there is a strong relationship between having access to industrial funding and the tendency of university scientists to interact with the industry (i.e. Bozeman and Gaughan, 2007; Boardman and Ponomariov, 2009; Landry et al., 2007). The results also provide support for the hypothesis 5B which indicates that the higher the percentage share of industrial funding in a nano-scientist's total research budget the greater is her/his likelihood to engage in INFORMAL KTT activity.

Similar to the results for general KTT activity, estimation results for INFORMAL KTT activity confirm the strong relationship between the intensity of a nano-scientist's personal contacts with other nano-scientists at Turkish universities (NTWK) and her/his proclivity to interact with firms through INFORMAL channels. Thus, estimation results support our hypothesis 7B which indicates that the higher the intensity of personal relations of a university nano-scientist with others in Turkish academia, the greater is her/his likelihood to engage in INFORMAL KTT activity. The estimated marginal effects in Table 7B shows that one point increase in the degree of frequency at which a nano-scientist personally contact with her/his colleagues at other Turkish universities increases the probability of the nano-scientist to engage in INFORMAL KTT activity by 14.5 – 16.7 percentage point.

Estimation results in Table 7A indicate that research experience of a nano-scientist (EXP) has no significant impact on her/his tendency to interact with industry through INFORMAL forms of interaction. Although experience is widely used in the empirical literature as an indicator of human and social capital endowments of individual university scientists, the Turkish nanotechnology case provides no support for the relationship between experience and the formation of university-industry interactions.

PEER variable is statistically significant at 5 percent significance level when industrial funding variable is excluded. A positive sign on PEER indicates that nano-scientist with peers who have stronger industrial ties tends to engage more in INFORMAL KTT activity. In other words, the extent to which the strenght of a nano-scientist's peers' industrial links increases the propensity of the nano-scientist to interact with industry through INFORMAL KTT channels also increases.

However, Model 2 and Model 3 do not provide support for the relationship between peer effect and the tendency of a nano-scientist to engage in INFORMAL KTT activity.

Estimation results show that there is a strong relationship between the presence of nano-equipped laboratories, research centers at universities (NSTINST) and the propensity of nano-scientists employed at such universities to engage in INFORMAL KTT activity. Estimated marginal effects also state that the presence of nano-equipments at universities increases the tendency of university nano-scientists to interact with firms through INFORMAL KTT channels by almost 30 percentage point

In order to measure the impact of a university's research quality on the formation of INFORMAL KTT activity we use the same variables of the number of total citations to university's NST publications (TOTCIT) and the average number of international links per university's NST publication (INTCOLLAB). Estimation results provide weak evidence for the positive impact of total citations on the formation of INFORMAL KTT activity. However, Model 2 and Model 3 indicate that the number of international links per university's NST publication negatively correlates with the propensity of a nano-scientist to engage in INFORMAL KTT activity at 5 percent significance level. Both of these variables (TOTCIT and INTCOLLAB) suggest that a high quality NST-related research environment negatively affects the propensity of a nano-scientist working in such an environment to engage in INFORMAL KTT activity.

Estimation results indicate that, as hypothesized, there is a strong and positive relationship between university support (UNIVSUPP) and the tendency of a university nano-scientist to interact with industry through INFORMAL KTT channels. Table 7B indicates that one point increase in the degree of support provided by a university to nano-scientists during the process of university-industry relations increases the probability of a nano-scientist to engage in KTT activity by 7.7 - 9 percentage point.

Among the control variables, while the motivation of a nano-scientist to commercialize her/his research outcomes (MOTIVECOMM) has a positive and statistically significant (at 1 percent level) impact on the formation of INFORMAL KTT linkages, no significant impact of academic discipline which is measured by being affiliated to a faculty of engineering (ENGINEERING) is found.

Table 7A Probit regression results: INFORMAL KTT activity

INFORMAL KTT Activity	*Model 1*	*Model 2*	*Model 3*
EXP	0.005	-0.001	-0.001
[Research experience]	(0.35)	(0.06)	(0.08)
NSTPUB	-0.059	-0.065	-0.064
[NST publications]	(2.38)**	(2.60)***	(2.58)***
NPATENT	0.136	0.111	0.119
[# of patents]	(2.46)**	(2.17)**	(2.32)**
NPUBGRANT	0.021	-	-0.116
[Publicly funded projects]	(0.09)	-	(0.54)
INDFUND	-	0.068	0.069
[Industry funding]	-	(1.96)*	(1.94)*
APPL	0.292	0.231	0.225
[Applied research]	(2.33)**	(1.69)*	(1.65)*
NTWK	0.368	0.410	0.426
[Social networks]	(2.49)**	(2.76)***	(2.88)***
PEER	0.270	0.228	0.230
[Peer effect]	(2.02)**	(1.59)	(1.60)
TOTCIT	0.0004	0.0005	0.0005
[Total citations]	(1.30)	(1.70)*	(1.74)*
INTCOLLAB	-0.886	-1.217	-1.192
[International links]	(1.61)	(2.08)**	(2.01)**
NSTINST	0.746	0.857	0.864
[NST research inst./lab]	(2.62)***	(2.88)***	(2.89)***
UNIVSUPP	0.196	0.224	0.228
[University support]	(1.82)*	(1.92)*	(1.93)*
MOTIVECOMM	0.427	0.559	0.561
[Motiv. Commercialization]	(3.18)***	(4.13)***	(4.16)***
ENGINEERING	0.318	0.257	0.229
[Faculty of Engineering]	(1.01)	(0.76)	(0.66)
Constant	-4.820	-4.994	-4.966
	(5.32)***	(5.51)***	(5.52)***
Observations	135	131	131
Log likelihood	-66.9	-60.2	-60.1
McFadden R^2 (adj.)	0.13	0.18	0.17
Hosmer-Lemeshow χ^2 (8)	4.52	10.36	9.52
(p-value)	(0.81)	(0.24)	(0.30)

Robust z statistics in parentheses

* significant at 10%; ** significant at 5%; *** significant at 1%

Table 7B Marginal effects[6]: INFORMAL KTT Activity

INFORMAL KTT Activity *Marginal effects*	*Model 1*	*Model 2*	*Model 3*
EXP [Research experience]	0.002 (0.35)	-0.000 (0.06)	-0.000 (0.08)
NSTPUB [NST publications]	-0.023 (2.38)**	-0.025 (2.60)***	-0.025 (2.58)***
NPATENT [# of patents]	0.053 (2.46)**	0.043 (2.17)**	0.047 (2.32)**
NPUBGRANT [Publicly funded projects]	0.008 (0.09)		-0.046 (0.54)
INDFUND [Industry funding]		0.027 (1.96)*	0.027 (1.94)*
APPL [Applied research]	0.115 (2.33)**	0.090 (1.69)*	0.088 (1.65)*
NTWK [Social networks]	0.145 (2.49)**	0.161 (2.76)***	0.167 (2.88)***
PEER [Peer effect]	0.106 (2.02)**	0.089 (1.59)	0.090 (1.60)
TOTCIT [Total citations]	0.0001 (1.30)	0.0002 (1.70)*	0.0002 (1.74)*
INTCOLLAB [International links]	-0.348 (1.61)	-0.477 (2.08)**	-0.467 (2.01)**
NSTINST [NST research inst./lab]	0.281 (2.62)***	0.319 (2.88)***	0.321 (2.89)***
UNIVSUPP [University support]	0.077 (1.82)*	0.088 (1.92)*	0.090 (1.93)*
MOTIVECOMM [Motiv. Commercialization]	0.168 (3.18)***	0.219 (4.13)***	0.220 (4.16)***
ENGINEERING [Faculty of Engineering]	0.126 (1.01)	0.102 (0.76)	0.090 (0.66)

Robust z statistics in parentheses
* significant at 10%; ** significant at 5%; *** significant at 1%

---

[6] Marginal effects are computed at mean values of explanatory variables (see Section 6.1)

7. Factors influencing RESEARCH-related KTT Activity

To analyze the effects of individual and organizational resources / capabilities on the likelihood of a university nano-scientist to engage in RESEARCH-related KTT activity we use probit regression analysis. The basic statistical model to be estimated is as follows:

$$
\begin{aligned}
&Y_{RES} = \beta_0 + \beta_1 EXP + \beta_2 NSTPUB + \beta_3 NPATENT + \beta_4 NPUBGRANT + \beta_5 INDFUND + \\
&\beta_6 APPL + \beta_7 NTWK + \beta_8 PEER + \beta_9 TOTCIT + \beta_{10} INTCOLLAB + \\
&\beta_{11} NSTINST + \beta_{12} UNIVSUPP + \beta_{13} MOTIVEFIRM + \beta_{14} ENGINEERING + e
\end{aligned}
$$

where Y indicates the binary dependent variable for RESEARCH-related KTT activity. The brief definitions of explanatory variables, descriptive statistics and correlation table are provided in Appendix Table A-1 and Table A-2 and Table A-3).

7.1 Results

Estimation results for the impact of human and social capital characteristics of university nano-scientists on the formation of RESEARCH-related KTT activity exhibit some considerable differences from those calculated for general KTT activity and INFORMAL KTT activity. For example, the number of NST publications (NSTPUB) has no significant impact on the formation of RESEARCH-related KTT activity. It is expected that university nano-scientists with higher number of publications are more experienced in research activities and, therefore, interact with industry through joint research projects, contract research or test and analyses carried out for firms. However, estimation results provide no evidence for a significant association between the number of publications and the propensity of nano-scientists to engage in RESEARCH-related KTT activity.

Likewise, Table 8A indicates that the probability of a university nano-scientist’s having engaged in RESEARCH-related KTT activity is not significantly affected by the extent to which the nano-scientist’s research outcomes meet the needs of industry (APPL). This suggests that industrial applicability of research outcomes has no statistically significant influence over the tendency of a nano-scientist to interact with the industry through research related KTT channels.

On the other hand, the percentage share of industrial funds in the total research budget of a nano-scientist (INDFUND) and the intensity of relations with other nano-scientists in Turkish academia (NTWK) positively and significantly correlates with the propensity of a university nano-scientist to engage in RESEARCH-related KTT activity. Estimation results provide a strong evidence for the impact of INDFUND; marginal effects in Table 8B indicate that one percentage increase in the share of industrial funds in total research budget of a scientist increases the probability of the scientist to engage in RESEARCH-related KTT activity by 1.1 percentage point. Similarly, one point increase in the extent to which a nano-scientist personally contact with other nano-scientists in Turkish universities increases the probability of a nano-scientist to interact with industry through RESEARCH-related channels by 3.1 – 3.8 percentage point.

Furthermore, estimation results provide no evidence for the influence of NPUBGRANT, which indicates the extent to which a nano-scientist engage in publicly funded research projects, and research experience (EXP) on the propensity of university nano-scientists to engage in RESEARCH-related forms of KTT activity.

Estimation results demonstrate that there is a strong positive association between the presence of nano-equipped laboratories, research centers at universities (NSTINST) and the propensity of nano-scientists employed at such universities to engage in RESEARCH-related KTT activity. Estimated marginal effects also state that the presence of nano-equipments at universities increases the tendency of university nano-scientists to interact with firms through RESEARCH-related KTT activity by almost 10 percentage point.

Model 2 and Model 3 which includes INDFUND variable provide evidence for the significant impact of university research quality on a nano-scientist proclivity to engage in RESEARCH-related KTT activity. Estimation results in Table 8A provide a weak evidence for the positive impact of total citations on the formation of RESEARCH-related KTT links with industry. Marginal effects indicate that one unit increase in total citations of university’s NST-related publications increases the propensity of a nano-scientist to interact with the industry through RESEARCH-related channels by almost zero percentage point.

Model 2 and Model 3 provide that the number of international links per university NST publication negatively correlates with the propensity of a nano-scientist to engage in RESEARCH-related KTT activity at 5 percent significance level. These results (TOTCIT and INTCOLLAB) suggest that a high quality research environment affects negatively the propensity of a nano-scientist working in such an environment to engage in RESEARCH-related KTT activity. However, estimation results indicate that there is no significant relationship between university support (UNIVSUPP) and the tendency of a nano-scientist to interact with industry through RESEARCH-related KTT channels.

Among the control variables, while the motivation of a nano-scientist to obtain firm contributions to university research (MOTIVEFIRM) has a positive and statistically significant (at 5 percent level) impact on the formation of RESEARCH-related KTT linkages, no significant impact of academic discipline which is measured by being affiliated to a faculty of engineering (ENGINEERING) is found.

Table 8A Probit regression results: RESEARCH-related KTT activity

RESEARCH-related KTT Activity	*Model 1*	*Model 2*	*Model 3*
EXP	0.009	0.019	0.019
[Research experience]	(0.55)	(0.99)	(1.00)
NSTPUB	0.001	-0.012	-0.012
[NST publications]	(0.03)	(0.43)	(0.45)
NPATENT	0.251	0.170	0.177
[# of patents]	(2.91)***	(2.10)**	(2.04)**
NPUBGRANT	-0.129	-	-0.079
[Publicly funded projects]	(0.37)	-	(0.20)
INDFUND	-	0.136	0.136
[Industry funding]	-	(2.92)***	(2.92)***
APPL	0.200	0.204	0.191
[Applied research]	(1.48)	(1.19)	(1.12)
NTWK	0.334	0.377	0.389
[Social networks]	(1.94)*	(1.80)*	(1.96)*
PEER	0.166	0.157	0.156
[Peer effect]	(1.01)	(0.89)	(0.88)
TOTCIT	0.0004	0.001	0.001
[Total citations]	(1.17)	(1.70)*	(1.70)*
INTCOLLAB	-0.972	-1.677	-1.654
[International links]	(1.55)	(2.29)**	(2.22)**
NSTINST	1.038	1.374	1.374
[NST research inst./lab]	(2.53)**	(3.35)***	(3.33)***
UNIVSUPP	-0.124	-0.138	-0.133
[University support]	(0.84)	(0.87)	(0.83)
MOTIVEFIRM	0.440	0.476	0.474
[Motiv. Firm contribution]	(2.14)**	(2.04)**	(2.02)**
ENGINEERING	-0.373	-0.538	-0.551
[Faculty of Engineering]	(0.92)	(1.29)	(1.28)
Constant	-5.275	-6.022	-5.954
	(3.65)***	(3.64)***	(3.50)***
Observations	135	131	131
Log likelihood	-34.7	-30.2	-30.2
McFadden R^2 (adj.)	0.08	0.16	0.14
Hosmer-Lemeshow χ^2 (8)	3.27	4.97	4.15
(p-value)	(0.92)	(0.76)	(0.84)

Robust z statistics in parentheses

* significant at 10%; ** significant at 5%; *** significant at 1%

Table 8B Marginal effects[7]: RESEARCH-related KTT Activity

RESEARCH-related KTT Activity Marginal effects	*Model 1*	*Model 2*	*Model 3*
EXP	0.001	0.002	0.002
[Research experience]	(0.55)	(0.99)	(1.00)
NSTPUB	0.000	-0.001	-0.001
[NST publications]	(0.03)	(0.43)	(0.45)
NPATENT	0.028	0.014	0.015
[# of patents]	(2.91)***	(2.10)**	(2.04)**
NPUBGRANT	-0.015		-0.007
[Publicly funded projects]	(0.37)		(0.20)
INDFUND		0.011	0.011
[Industry funding]		(2.92)***	(2.92)***
APPL	0.023	0.017	0.016
[Applied research]	(1.48)	(1.19)	(1.12)
NTWK	0.038	0.031	0.032
[Social networks]	(1.94)*	(1.80)*	(1.96)*
PEER	0.019	0.013	0.013
[Peer effect]	(1.01)	(0.89)	(0.88)
TOTCIT	0.00004	0.00005	0.00005
[Total citations]	(1.17)	(1.70)*	(1.70)*
INTCOLLAB	-0.110	-0.138	-0.137
[International links]	(1.55)	(2.29)**	(2.22)**
NSTINST	0.103	0.099	0.100
[NST research inst./lab]	(2.53)**	(3.35)***	(3.33)***
UNIVSUPP	-0.014	-0.011	-0.011
[University support]	(0.84)	(0.87)	(0.83)
MOTIVEFIRM	0.050	0.039	0.039
[Motiv. Firm contribution]	(2.14)**	(2.04)**	(2.02)**
ENGINEERING	-0.037	-0.035	-0.036
[Faculty of Engineering]	(0.92)	(1.29)	(1.28)

Robust z statistics in parentheses
* significant at 10%; ** significant at 5%; *** significant at 1%

---

[7] Marginal effects are computed at mean values of explanatory variables (see Section 6.1)

8. Conclusion

Quantitative investigation of nano-scientists working in Turkish universities and who engage in university-industry KTT activity produce some valuable results for understanding university-industry relations in Turkey.

First and foremost, this study points to the fact that there are various forms of KTT activity and university-scientists engage in knowledge transfer through various channels; and among those channels informal-interpersonal interactions are the most common one. The second most common form of interaction among university nano-scientists to engage in KTT activity is research-related activities. 12 percent of respondents use research-based KTT activities intensively in their relations to industry. Nearly 7 percent of nano-scientists explain that their relation with industry is based on direct commercialization of research results, i.e. joint patenting with private companies; licensing and starting up a new firm.

On the other hand, our data suggests that there are both individual- and organizational-level factors influencing the proclivity of nano-scientists inTurkish universities to interact with firms. One of the most important conclusions of this research is that not “star scientists” of nanotechnology with a higher number of scientific publications but “inventor-authors” who both publish and patent are inclined to engage in university-industry interactions. The number of NST-related scientific publications correlates negatively with the propensity of nano-scientist to interact with firms. Moreover, our data demonstrates that the extent to which a nano-scientist’s research outcomes meet the needs of industry positively influence her/his proclivity to engage in KTT activity. In other words, nano-scientists producing more industrially applicable research outcomes tend more to interact with firms than the others. The nano-scientists who engage in KTT activity also have very intense informal and interpersonal connections with other nano-scientists in Turkish academia. The results also provide that while university’s research quality influences negatively the decision of nano-scientists to engage in KTT activity, university administration’s support for the improvement of university-industry relations and having nano-equipped laboratories inside universities have positive and significant impact on the tendency of a nano-scientist to interact with firms.

Acknowledgements:

We gratefully acknowledge funding by TUBITAK (project no 110K002)

REFERENCES

Adler, P.S., Kwon, SW. (2002). Social capital: prospects for a new concept. *Academy of Management Review, 27(1),* 17-40.

Arvanitis, S., Kubli, U. and Woerter, M. (2008). University-industry knowledge and technology transfer in Switzerland: What university scientists think about co-operation with private enterprises. *Research Policy, 37,* 1865–1883

Azagra-Caro, J.M. (2006). What type of faculty member interacts with what type of firm? Some reasons for the delocalisation of university–industry interaction. *Technovation, 27,* 704–715.

Azoulay, P., Ding, W., Stuart, T. (2009). The impact of academic patenting on the rate, quality and direction of (public) research output. *Journal of Industrial Economics, 57(4),* 637-676.

Baba, Y., Shichijo, N., Sedita, S.R. (2009). How do collaborations with universities affect firms' innovative performance? The role of "Pasteur scientists" in the advanced materials field. *Research Policy, 38,* 756–764.

Bercovitz, J. and Feldman, M. (2003). *Technology transfer and the academic department: who participates and why?* Paper presented at the DRUID Summer Conference on "Creating, Sharing and Transferring Knowledge: The Role of Geography, Institutes and Organizations", Copenhagen, Denmark, 12-14 June.

Bercovitz, J., and Feldman, M. (2008). Academic entrepreneurs: organizational change at the individual level. *Organization Science, 19(1),* pp. 69–89.

Boardman, P.C. (2008). Beyond the stars: the impact of affiliation with university biotechnology centers on the industrial involvement of university scientists. *Technovation, 28,* 291–297.

Boardman, P. C., and Ponomariov, B.L. (2009). University researchers working with private companies. *Technovation, 29,* 142-153Bonaccorsi, A. and Thoma, G. (2007). Institutional complementarity and inventive performance in nano science and technology. *Research Policy, 36,* 813-831.

Bozeman, B., Gaughan, M. (2007). Impacts of grants and contracts on academic researchers' interactions with industry. *Research Policy, 36,* 694–707.

Bozeman, B., Dietz, J., Gaughan, M. (2001). Scientific and technical human capital: an alternative model for research evaluation. *International Journal of Technology Management, 22 (7)*, 636-655

Burt, R.S. (1992). *Structural Holes: The Social Structure of Competition*. Cambridge, MA: Harvard University Press.

Burt, R.S. (1997). The Contingent Value of Social Capital. *Administrative Science Quarterly, 42 (2)*, 339-365.

Coleman, J.S. (1988). Social capital in the creation of human capital. *American Journal of Sociology, 94* (Supplement: Organizations and Institutions), 95-120.

Darby, M. R. and Zucker, L. G. (2004). Grilichesian breakthroughs: inventions of methods of inventing and firm entry in nanotechnology (Working Paper No. 9825). Retrieved from National Bureau of Economic Research website: http://www.nber.org/papers/w9825

De Solla Price, D. J. (1963). *Little Science, Big Science*. New York, NY: Columbia University Press.

D'Este, P. and Patel, P. (2007). University-industry linkages in the UK: what are the factors underlying the variety of interactions with industry? *Research Policy, 36*, 1295-1313.

Di Gregoria, D., Shane, S. (2003). Why do some universities generate more start-ups than others? *Research Policy, 32*, 209–227.

Etzkowitz, H. and Leydesdorff, L. (Eds.), (1997). *Universities in the global economy: A Triple Helix of University–Industry– Government Relations*. London, UK: Cassell Academic.

Etzkowitz, H. and Leydesdorff, L. (2000). The dynamics of innovation: from national systems and Mode 2 to a Triple Helix of university-industry-government relations. *Research Policy, 29*, 109-123.

Etzkowitz, H., Webster, A., Gebhardt, C., and Terra, B.R.C. (2000). The future of the university and the university of the future: evolution of ivory tower to entrepreneurial paradigm. *Research Policy, 29*, 313-330.

Friedman, J., and Silberman, J. (2003). University technology transfer: do incentives, management, and location matter? *Journal of Technology Transfer, 28,* 17–30.

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

Glanzel, W. (2002). Coauthorship patterns and trends in the sciences (1980-1998): a bibliometric study with implications for database indexing and search strategies. *Library Trends, 50 (3)*, 461-473.

Guan, J. and Ma, N. (2007). China's emerging presence in nanoscience and nanotechnology: a comparative bibliometric study of several nanoscience giants. *Research Policy, 36*, 880-886.

Gulbrandsen, M., Smeby, JC. (2005). Industry funding and university professors' research performance. *Research Policy, 34,* 932–950.

Haeussler, C., Colyvas, J.A. (2011). Breaking the ivory tower: academic entrepreneurship in the life sciences in UK and Germany. *Research Policy, 40,* 41–54.

Hudson, J. (1996). Trends in multi-authored papers in economics. *The Journal of Economic Perspectives, 10 (3),* 153-158.

Katz, J. S., and Martin, B. R. (1997). What is research collaboration? *Research Policy, 26,* 1-18.

Kostoff RN, Koytcheff R, Lau CGY (2007) Structure of the global nanoscience and nanotechnology research literature. Retrieved from Defense Technical Information Center website: http://handle.dtic.mil/100.2/ADA461930

Landry, R., Amara, N. and Quimet, M. (2007). Determinants of knowledge transfer: evidence from Canadian university researchers in natural sciences and engineering. *Journal of Technology Transfer, 32*, 561-592.

Leta, J., and Chaimovich, H. (2002). Recognition and international collaboration: the Brazilian case. *Scientometrics, 53 (3),* 325-335.

Leydesdorff, L., and Amsterdamska, O. (1990). Dimensions of citation analysis. *Science, Technology & Human Values, 15 (3),* 305-335.

Link, A. N., Siegel, D. S. and Bozeman, B. (2007). An empirical analysis of the propensity of academics to engage in informal university technology transfer. *Industrial and Corporate Change, 16 (4)*, 641–655.

Lockett, A., and Wright, M. (2005). Resources, capabilities, risk capital and the creation of university spin-out companies. *Research Policy, 34,* 1043–1057.

Lohr, S. L. (1999). *Sampling: Design and Analysis*. Pacific Grove, CA: Duxbury Press.

Lowe, R.A., Gonzalez-Brambila, C. (2007). Faculty entrepreneurs and research productivity. *Journal of Technology Transfer, 32,* 73–194.

Luukkonen, T., Persson, O., Sivertsen, G. (1992). Understanding patterns of international scientific collaboration. *Science Technology & Human Values, 17 (1),* 101-126.

Merz, M., and Biniok, P. (2010). How technology platforms reconfigure science-industry relations: the case of micro- and nanotechnology. *Minerva, 48,* 105-124.

Meyer, M. (2006a). Are patenting scientists the better scholars? An explanatory comparison of inventor-authors with their non-inventing peers in nano-science and technology. *Research Policy, 35,* 1646-1662.

Meyer, M. (2006b). Knowledge integrators or weak links? An exploratory comparison of patenting researchers with their non-inventing peers in nano-science and technology. *Scientometrics, 68 (3),* 545-560.

Murray, F. (2004). The role of academic inventors in entrepreneurial firms: sharing the laboratory life. *Research Policy, 33,* 643–659.

O'Shea, R.P., Allen, T. J., Chevalier, A., and Roche, F. (2005). Entrepreneurial orientation, technology transfer and spinoff performance of US universities. *Research Policy, 34,* 994-1009.

Palmberg, C. (2008). The transfer and commercialisation of nanotechnology: a comparative analysis of university and company researchers. *Journal of Technology Transfer, 33,* 631–652.

Perkmann, M., King, Z., Pavelin, S. (2011). Engaging excellence? Effects of faculty quality on university engagement with industry. *Research Policy, 40,* 539–552.

Ponomariov, B. (2008). Effects of university characteristics on scientists' interactions with the private sector: an exploratory assessment. *Journal of Technology Transfer*, *33,* 485–503.

Porter, A. L. (1977). Citation analysis: queries and caveats. *Social Studies of Science*, *7 (2),* 257-26

Powers, J.B. (2003). Commercializing academic research: resource effects on performance of university technology transfer. *Journal of Higher Education*, *74 (1)*, 26-50.

Powers, J.B., and McDougall, P.P. (2005). University start-up formation and technology licensing with firms that go public: a resource-based view of academic entrepreneurship. *Journal of Business Venturing*, *20,* 291-311.

Schartinger, D., Schibany, A., and Gassler, H. (2001). Interactive relations between universities and firms: empirical evidence from Austria. *Journal of Technology Transfer*, *26,* 255-268.

Shane, S., and Stuart, T. (2002). Organizational Endowments and the Performance of University Start-ups. *Management Science*, *48 (1)*, 154-170.

Stephan, P.E., Gurmu, S., Sumell, A.J., Black, G. (2007). Who's patenting in the university? Evidence from the survey of doctorate recipients. *Economics of Innovation and New Technology*, *16 (2)*, 71-99.

Stuart, T.E., and Ding, W.W. (2006). When do scientists become entrepreneurs?
The social structural antecedents of commercial activity in the academic life sciences. *American Journal of Sociology*, *112 (1)*, 97–144.

Tartari, V., Salter, A., D'Este, P., Perkmann, M. (2010). Come engage with me: the role of behavioral and attitudinal cohort effects on academics' levels of engagement with industry.

Paper presented at the DRUID-DIME Academy Winter PhD Conference, Aalborg, Denmark, 21 – 23 January.

Thursby, J.G., and Thursby, M.C. (2002). Who is selling the ivory tower? Sources of growth in university licensing. *Management Science*, *48 (1)*, 90-104.

Van Looy, B., Ranga, M., Callaert, J., Debackere, K., Zimmermann, E. (2004). Combining entrepreneurial and scientific performance in academia: towards a compounded and reciprocal Matthew-effect? *Research Policy*, *33*, 425-441.

Wang, J., and Shapira, P. (in press). Partnering with universities: a good choice for nanotechnology start-up firms*? Small Business Economics*.
doi: 10.1007/s11187-009-9248-9

Zucker, G., Darby, M. R. And Brewer, M.B. (1998). Intellectual human capital and the birth of U.S. biotechnology enterprises. *American Economic Review, 88 (1)*, 290-306.

APPENDIX

Table A-1 List of explanatory variables and their definitions

Variable	*Description*
EXP	Number of years in research since PhD completion
NSTPUB	Total number of NST publications[1] of the respondent between 2005-2009
NPATENT	Number of NST patents (including patent applications)
NPUBGRANT	It takes value 0 if the researcher has no publicy funded research project; 1 if the researcher's number of publicly funded projects is between 1 and 5; 2 if it is between 6-10; and 3 if it is more than 10.
INDFUND	Percentage of industry funds in total research budget of the respondent
APPL	The extent to which the respondent's research outcomes meet the needs of industry (1: not very much; 5: very much)
NTWK	The extent to which the respondent personally contacts other NST academics at Turkish universities (1: never; 5: very frequently).
PEER	The extent to which the respondent's peers are linked to industry (1: not very strong; 5: very strong)
TOTCIT	Total number of citations to the university's NST-related articles published[1] between 2005 and 2009
INTCOLLAB	Average number of international links[2] per university's NST-related publication[1].
NSTINST	It takes the value of 1 if there is a NST research center, laboratory or research group at the respondent's university, 0 otherwise.
UNIVSUPP	The extent to which the repondent's university supports the formation and sustainability of university-industry relations (1: not ver much; 5: very much)
MOTIVECOMM	Predicted factor loadings for motivations related to commercialization (Table A-3)
MOTIVEFIRM	Predicted factor loadings for motivations related to firm contribution (Table A-3)
ENGINEERING	It takes the value 1 if the respondent is employed at a faculty of engineering, 0 otherwise.

[1] With NST publications we refer to the articles retrieved from SCI with using special keywords provided BY Kostoff et al (1997)

[2] The number of international links is measured by the number of collaborated authors from different foreign institutes. Therefore for some articles the number of links takes a value larger than one if these articles are co-authored with more than one author associated with different foreign institutes.

Table A-2 Descriptive statistics for explanatory variables

Variable	*Variable Type*	*Obs.*	*Mean*	*Std. Dev.*	*Min.*	*Max.*
EXP	Continous	180	15.05	9.69	0	39
NSTPUB	Discrete	181	8.2	6.22	3	37
NPATENT	Discrete	181	0.51	2.01	0	20
NPUBGRANT	Categorical	181	0.87	0.6	0	3
INDFUND	Continous	172	0.01	0.04	0	0.3
APPL	Ordinal	169	3.53	1.07	1	5
NTWK	Ordinal	181	3.03	1.07	1	5
TOTCIT	Discrete	181	492.89	485.87	4	2260
INTCOLLAB	Continous	181	0.37	0.24	0.03	1.23
NSTINST	Dummy	181	0.6	0.49	0	1
UNIVSUPP	Ordered	159	2.99	1.22	1	5
MOTIVECOMM	Continous	173	2.57	0.96	0.08	4.42
MOTIVEFIRM	Continous	173	2.97	0.93	-0.72	4.88
ENGINEERING	Dummy	181	0.25	0.44	0	1
PEER	Ordinal	164	2.44	0.95	1	5

Table A.3 Correlation table

Variables	*(1)*	*(2)*	*(3)*	*(4)*	*(5)*	*(6)*	*(7)*	*(8)*	*(9)*	*(10)*	*(11)*	*(12)*	*(13)*	*(14)*	*(15)*
(1) EXP	1.00														
(2) NSTPUB	0.13	1.00													
(3) NPATENT	0.15	0.17	1.00												
(4) NPUBGRANT	0.08	0.18	0.26	1.00											
(5) INDFUND	-0.02	0.06	0.36	0.08	1.00										
(6) APPL	-0.06	-0.05	0.09	-0.01	0.08	1.00									
(7) NTWK	-0.08	0.10	0.12	0.19	0.07	0.28	1.00								
(8) PEER	-0.17	-0.01	0.05	0.04	0.23	0.03	0.06	1.00							
(9) TOTCIT	0.16	0.18	0.00	0.11	-0.06	0.00	0.03	-0.16	1.00						
(10) INTCOLLAB	-0.04	-0.08	0.05	0.16	0.11	0.06	0.07	0.01	0.20	1.00					
(11) NSTINST	0.05	0.08	0.09	0.17	0.03	-0.03	0.16	0.06	0.22	0.20	1.00				
(12) UNIVSUPP	0.20	0.27	0.10	0.22	0.03	-0.05	0.12	0.01	0.13	0.27	0.27	1.00			
(13) ENGINEERING	-0.02	-0.18	0.06	-0.13	0.14	0.03	0.03	0.20	-0.02	0.17	0.06	0.02	1.00		
(14) MOTIVECOMM	0.06	-0.05	-0.05	-0.03	-0.11	0.04	-0.17	0.05	0.03	-0.15	0.01	-0.15	-0.01	1.00	
(15) MOTIVEFIRM	-0.06	-0.08	0.03	0.06	0.10	0.20	0.10	-0.03	-0.02	0.15	0.06	0.05	0.06	-0.09	1.00

Table A4. Principal component factor analysis of motivations for KTT activity

	Factor 1 *Academic duties* *MOTIVEACAD*	*Factor 2* *Commercialization* *MOTIVECOMM*	*Factor 3* *Industry contribution* *MOTIVEFIRM*
New ideas from the industry for academic research			**0.84**
Additional insights and perspective from the industry to the technology field, product and / or findings			**0.87**
Testing the academic research findings in practice			**0.58**
Patenting academic research findings		**0.88**	
Licensing university patents		**0.85**	
Business opportunities for the commercialization of academic research findings		**0.56**	
Additional resources and funds for academic research	**0.72**		
Providing industrial financial support for graduate students along their research	**0.75**		
Exchange of information and experience with firm researchers	**0.53**		
Increasing job prospects for graduates	**0.67**		
Additional resources for the improvement of labs and technical equipments at universities	**0.81**		
Access to firms’ equipments and technology	**0.69**		
Number of observations	**173**		
Kaiser-Meyer-Olkin (KMO) measure of sampling adequacy	**0.88**[˟]		
Bartlett’s test of sphericity	**1071.97**[∻]		
Variance explained by each component	**6.33**	**1.23**	**0.92**
Proportion of variance explained by each component	**52.75%**	**10.25%**	**7.67%**

[˟] 0.00 to 0.49 unacceptable; 0.50 to 0.59 miserable; 0.60 to 0.69 mediocre; 0.70 to 0.79 middling; 0.80 to 0.89 meritorious; 0.90 to 1.00 marvelous

[∻] p-value= 0.000 ($H_{\circ}$= Variables are not intercorrelated)