WHO INTERACTS WITH WHOM?
INDIVIDUAL AND ORGANIZATIONAL ASPECTS OF UNIVERSITY-INDUSTRY RELATIONS IN NANOTECHNOLOGY:
THE TURKISH CASE

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ABSTRACT

WHO INTERACTS WITH WHOM?
INDIVIDUAL AND ORGANIZATIONAL ASPECTS OF UNIVERSITY-INDUSTRY INTERACTIONS IN NANOTECHNOLOGY:
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The main purpose of this study is to explore individual and organizational level factors which influence the formation of knowledge and technology transfer links between universities and firms. To this end, three sets of data are collected and analyzed. The first one includes bibliometric data of nanotechnology publications, which are authored by scientists affiliated with Turkish universities. The second one is collected through a questionnaire survey from university-scientists dealing with nanoscale research. The third one is from firms doing nanotechnology R&D through in-depth interviews with high level managers.

The analysis of bibliometric data provides an insight to the main actors and characteristics of the nanoscale research in Turkey. This data is also used to identify the population of nano-scientists at Turkish universities. From May 2010 to May 2011, 181 questionnaires were collected from targeted nano-scientists; and 21 firms were interviewed. The collected data was used to investigate the impact of individual and organizational level factors on the proclivity of nanoscientists to engage in knowledge and technology transfer to industry by estimating binary probit models. The results suggest that nano-scientists with relations to industry are those who (i) have high number of patents/patent applications; (ii) do more applied research; (iii) have access to public funds (iv) are well connected to Turkish NST academia; (v) are working in universities which are not the most active ones in nanoscale research; but have nano-equipped laboratories; and support nano-scientists in their relations with industry; and finally (vi) are motivated by commercialization of their research outcomes.

On the other hand, qualitative analysis of our data collected through in-depth interviews conducted with firms suggests that social capital and human capital of firms' nanotechnology professionals play the key role in knowledge and technology transfer from universities. However, absorptive capacity and business culture are the most important firm level factors which influence university-industry relations. Finally, in the last section of this thesis we discuss some managerial and science, technology and innovation policy implications of the research.

Keywords: Nanoscience, nanotechnology, university-industry relations, knowledge and technology transfer

ÖZ

KİM KİMİNLE İLİŞKİ KURAR?
NANOTEKNOLOJİ ALANINDA ÜNİVERSİTE-SANAYİ İLİŞKİLERİNİN
KİŞİSEL VE ÖRGÜTSEL YÖNLERİ:
TÜRKİYE ÖRNEĞİ

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Bu çalışmanın temel amacı, üniversiteler ve firmalar arasında bilgi ve teknoloji transferi ilişkilerinin kurulmasını etkileyen bireysel ve örgütsel düzeydeki faktörlerin araştırılmasıdır. Bu amaçla, üç farklı veri seti oluşturulmuştur. Bunlardan ilki Türkiye'deki bilim insanları tarafından yazılan nanoteknoloji makalelerine ilişkin bibliometrik veriyi içermektedir. İkinci veri seti ise Türkiye'deki üniversitelerde görevli olan ve nanoteknoloji alanında araştırma yapan akademisyenlerden anket yoluyla toplanmıştır. Üçüncüsü ise nanoteknoloji alanında araştırma-geliştirme yapan firmaların üst düzey yöneticileri ile yapılan derinlemesine mülakatlar yoluyla oluşturulmuştur.

Makalelere ilişkin verilerin analizi Türkiye'de yapılan nanobilim ve nanoteknoloji araştırmalarının ana aktörleri ve temel karakteristikleri üzerine derinlemesine bir bakış sağlamaktadır. Veriler Türkiye'deki üniversitelerde görevli olan ve nanoteknoloji alanında araştırma yapan bilim insanlarının belirlenmesinde de kullanılmıştır. Mayıs 2010'dan Mayıs 2011'e kadar geçen dönemde Türkiye'deki üniversitelerde nanoteknoloji alanında çalışan 181 akademisyenle anket yapılmış ve nanoteknoloji alanında AR-GE yapan 21 firmanın üst düzey yöneticileri ile derinlemesine mülakatlar yapılmıştır.

Anket yoluyla toplanan veriler nanobilim ve nanoteknoloji alanında çalışan akademisyenlerin firmalar ile ilişki kurma eğilimlerini etkileyen kişisel ve örgütsel düzeydeki faktörlerin araştırılmasında kullanılmıştır; verilerin analizinde ikili probit analizi kullanılmıştır. Sonuçlar, (i) patent / patent başvurusu sayısı yüksek olan, (ii) sanayinin ihtiyaçlarına daha uygun araştırmalar yapan, (iii) kamu fonlarına erişimi olan, (iv) Türkiye'de nanobilim ve nanoteknoloji alanında araştırma yapan diğer akademisyenlerle iyi ilişkileri olan, (v) nanobilim ve nanoteknoloji araştırmaları konusunda çok aktif olmayan ama nanoteknoloji laboratuvar ve donanımlarının mevcut olduğu üniversitelerde görev yapan ve son olarak (vi) üniversitelerde yaptıkları araştırmaların ticarileştirilmesinin kendileri için önemli bir motivasyon olduğunu düşünen akademisyenlerin sanayi ile ilişki kurma eğiliminin daha yüksek olduğunu göstermektedir.

Diğer yandan, derinlemesine mülakatlar yoluyla toplanan veriler firmalarda çalışan nanobilim ve nanoteknoloji çalışanlarınlarının beşeri ve sosyal sermayelerinin üniversitelerden firmalara bilgi ve teknoloji transferinde anahtar rol oynadığını göstermektedir. Fakat, iş yapma kültürü ve firmaların özümseme kapasitesi de, firma düzeyinde, üniversite-sanayi ilişkilerini etkileyen en önemli faktörlerdir. Bu tezin en son bölümünde ise, yapılan araştırmanın bilim, teknoloji ve inovasyon politikasına ilişkin yansımalarını tartışacağız.

Anahtar kelimeler: Nanobilim, nanoteknoloji, universite-sanayi ilişkileri, bilgi ve teknoloji transferi

To my son Güneş

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LIST OF ABBREVIATIONS

Act:	Bayh-Dole Act
AFM:	Atomic Force Microscopy
AUTM:	Association of University Technology Managerss
EC:	European Commission
EHS:	Environmental, health and safety
EU:	European Union
GPT:	General purpose technology
HEI:	Higher education institute
KBV:	Knowledge-based view
KTT:	Knowledge and technology transfer
METU:	Middle East Technical University
NBIC:	Nano-bio-information science-cognitive science
NNI:	National Nanotechnology Initiative
NPK:	The book titled “The New Production of Knowledge” by Gibbons et al. (1994)
NST:	Nanoscience and nanotechnology
NUTS:	Nomenclatura of territorial units of statistics
PCA:	Principal component analysis
RBV:	Resource based view
STM:	Scanning Tunnelling Microscopy
SPM:	Scanning Probe Microscopy
SPO:	State Planning Organization (Devlet Planlama Teşkilatı)
SRS:	Simple random sampling
STHC:	Scientific and technical human capital
STI:	Science, technology and innovation
TPO:	Turkish Patent Office
TRIPs:	Trade-Related Aspects of Intellectual Property Rights
TT:	Technology transfer
TTO:	Technology Transfer Office
TUBITAK:	The Scientific and Technological Research Council of Turkey
TurkStat:	Turkish Statistical Institute
ULAKBIM:	Turkish Academic Network and Information Center
WoS-SCI:	Web of Science-Science Citation Index
WTO:	World Trade Organization

CHAPTER 1

INTRODUCTION

This thesis deals with university-industry relations in the emerging field of nanotechnology in a developing country context. More specifically, to understand who interacts with whom between academia and industy is the main objective of our research. To this end, first the rise of nanotechnology as the 'next industrial revolution' and, the transformation of universities and university-industry relations are discussed. Second, both university-scientists who engage in nanoscience and nanotechnology (NST) research and firms which develop nanotechnology or use nanotechnology in their product and processes are empirically investigated.

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 economy which is mainly based on new developments in science-based technologies i.e. ICT, biotechnology and nanotechnology.

In Turkey, a mid-size emerging economy, university-industry relations have been traditionally weak; however in the last 15 years there have been some efforts in order to increase KTT between academia and industry. In this period, three important regulations were introduced in this direction: (i) the law of Technology Development Zones (Law no: 6170); (ii) the law about the support of R&D activities (Law no: 5746); and (iii) programme for the establishment of university-industry joint research centers (ÜSAM) by TÜBİTAK. Moreover, in the last Development Program of State Planning Organization (SPO) for the period 2007-

2013, it is emphasized that university-industry collaboration needs to be improved to increase the technology development capabilities of firms (Kiper, 2010).

On the other hand, although NST is a new topic for researchers in the field of social studies of science, it is becoming certainly a challenging topic with its promises for economic development and its potential for radical changes in products and production processes. Moreover, the occurrence and the rise of nanotechnology coincide with the period in which science-technology-innovation connection is reopened to discussion and university-industry relations have increased its pace after 1980. Therefore, science-technology-innovation connection and the links between academia and industry have received a lot of attention not only from academic scholars but also policy makers of developed and developing countries.

Focusing on university-industry relations in the emerging field of nanotechnology in a developing country context, this thesis aims to contribute to the academic literature and to provide some valuable input for STI policy discussions in Turkey.

1.1 Statement of the problem

For developing countries both nanotechnology and university-industry interactions are great challenges to be urgently dealt with not only for catching up with the advanced economies but also for surviving in today's knowledge economy. Therefore, understanding how developing countries can foster university-industry interactions and the commercialization of successful results of nanoscale research conducted in universities is important in a developing country context. Nanotechnology has an important potential to improve current products and the production methods and, therefore, opens a window of opportunity for developing countries to catch up with developed countries.

Turkey is the world's 16th most industrialized economy in terms of GNP (IMF, 2009); however the economy is still based on the low and medium technology industries, the share of high-tech industries in the total value added is just 1.8 percent (Gürlesel, 2009). On the other hand, higher education institutes (HEIs) including universities are responsible for the highest share from the total R&D expenditures. The share performed by HEIs in the total R&D expenditure is 47.4% in 2009. The share of private companies in the R&D expenditure is only 40 percent. While 34 percent of the total R&D expenditure is publicly financed, 41 percent is financed by private firms and 20.3 percent by HEIs[1]. R&D expenditure performed by HEIs is financed mainly from their budget (43%) and through government research grants (33%)[2] . Moreover, universities have a very strong human resources capacity: in 2009, nearly 62 percent of the total R&D staff in the country is employed by the HEIs. Hence, in Turkey, universities are still the main locus of scientific knowledge production; and especially in the recent period with some changes in higher education policies university researchers have gained strong research skills which can be measured by the high quality articles published in the international journals[3].

Nonetheless, despite some recent efforts to build up and improve connections between universities and firms, the interactions are still limited; according to the data collected by Turkish Statistical Institute (TurkStat) in 2009 on innovation capacities of firms only 10.5 percent of the innovative firms collaborate with universities during the innovation process and 38.4 percent of firms declare that they use universities or public research institutes as a source of knowledge (Beyhan and Fındık, 2010). The main reasons are declared to be (i) lack of

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[1] Data is available on the web page for R&D statistics of the Scientific and Technological Research Council of Turkey (TUBITAK) www.tubitak.gov.tr (accessed on May 16, 2011)

[2] Data is available on the web page for R&D statistics of the Turkish Statistical Institute www.tuik.gov.tr (accessed on May 16, 2011)

[3] ULAKBIM (Turkish Academic Network and Information Center) web pages for publication statistics www.ulakbim.gov.tr/cabim/yayin/tr-veri.uhtml (accessed on May 16, 2011)

resources at universities; (ii) lack of resources and skills on the firm side; or (iii) insufficient mechanisms to facilitate knowledge and technology transfer (KTT) between universities and firms.

Nanotechnology is well received in Turkey since the number of NST publications generated in Turkish universities has increased nearly nine fold in the last 10 years; in 2009 Turkey was the 29th among the countries producing high number NST-related research articles (see Chapter 5). The number of research centers, master and PhD programs, and researchers in this emerging field has significantly increased in the recent years; the rising awareness of universities, firms and government bodies also supports academic achievements in nanotechnology; but how KTT between academia and industry can be fostered still stands as an important problem.

In summary, we need to state succinctly the problem of this study as: University-industry interaction in Turkey is rather weak, the mechanisms and channels facilitating KTT are not effective; and there is a need to tackle this issue especially in scientific knowledge-based technologies i.e. nanotechnology; and to develop sound science and technology policies for benefiting from a window of opportunity to catch up with the international level in the emerging field of nanotechnology.

1.2 Aim of the research

The aim of this thesis is to explore university-industry interactions in the field of nanotechnology in Turkey from two sides of these interactions (i) individual nano-scientists at Turkish universities and (ii) firms conducting nanotechnology R&D or using nanotechnology in their products and production processes. The main research question can be stated as follows: How do individual and organizational resource endowments on both sides of the university-industry interactions affect the establishment of channels facilitating knowledge and technology transfer between academia and industry? To this end, two sets of data are collected. First, through a questionnaire survey from academicians dealing with NST-related research and currently holding a position in Turkish universities; and second from firms doing nanotechnology R&D or using nanotechnology in their products and production processes through in-depth interviews with high level managers / founders or R&D professionals.

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; and science and technology policies are mainly based on the encouragement of these few number of channels. However, the number of studies focusing on a larger number of channels has 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 thesis is to focus on this wider spectrum of channels through which nanoscience and nanotechnology researchers at universities interact with industry. Since the channels such as university patenting, licensing, technology transfer offices (TTOs), and academic spin offs and techno-parks are recent phenomena in Turkey the author believes that this special focus on a wider spectrum of channels between university and industry is necessary for the systematic analysis of university-industry interactions in Turkey and for formulating realistic / pertinent policy proposals.

Second, this study aims to investigate the factors influencing the interactions between universities and firms from the different perspectives of university scientists and firms. The argument of this dissertation is that individual capabilities of university and firm researchers along with organizational capabilities are the most important factors in achieving university-industry interactions on both sides of the relationship. Therefore, this study adopts a resource-based view (Penrose 1959; Wernerfelt 1984; Barney 1991) and scientific and technical human capital approach

(Bozeman et al., 2001) to analyze any type of interactions between firms and universities. Resource-based view (RBV) is used as a powerful explanatory approach for the formation of strategic alliances among firms (Das and Teng, 2000; Eisenhardt and Schoonhoven, 1996; Mowery et al., 1998; Tsang, 1998); and between universities and firms (O'Shea et al., 2005; Power, 2003; Santoro and Chakrabarti, 2002; Santoro and Bierly 2006); between individual university researchers and firms (Landry et al., 2007; Rijnsoever et al., 2008). On the other hand, scientific and technical human capital (STHC) approach has recently been popularized among scholars studying the factors influencing university-scientists to engage in KTT (Edler et al., 2011; Boardman 2009; Ponomariov, 2008; Boardman and Ponomariov, 2009; Murray, 2004). Nonetheless, these two approaches utilize a similar perspective (Boardman, 2009; Bozeman and Corley, 2004), especially to explain university-industry KTT activity.

Hence, this dissertation aims to analyze the individual and organizational factors significantly affecting the formation of university-industry interactions in the emerging field of nanotechnology in the context of Turkey; and develop some policy recommendations for the improvement of university-industry interactions. Therefore, the research questions of our thesis are as follows

(i) What are the individual factors that affect the attitudes of nano-scientists at universities in forming linkages with firms?

(ii) What are the organizational factors that affect the attitudes of nano-scientists at universities in forming linkages with firms?

(iii) What are the firm characteristics that influence the formation of linkages with universities?

(iv) How do the individual attitudes, skills and capabilities of R&D managers / responsibles of firms influence the formation of linkages with universities?

(v) How do firms benefit from the linkages they have established with the universities?

The above questions guide the questionnaire prepared for university researchers and the questions in the semi-structured interviews carried out with firm R&D managers.

1.3 Significance of the research

This dissertation generates some significant contributions to the existing literature on university-industry relations. First of all, this study utilizes a multi-level approach to explain the factors influencing the formation of KTT linkages between universities and firms. In other words, both individual and organizational level factors are included in two different analyses of nano-scientists employed at Turkish universities and firms which develop nanotechnology or use any form of this emerging technology in their product and processes. D'Este and Patel (2007) emphasize two neglected issues in the literature exploring the factors that influence university-industry relations: (i) the role of a wide spectrum of channels other than patenting, licensing and spin-offs in KTT; and (ii) the distinctive role of individual. Thus, focusing on these two neglected issues of KTT in the emerging nano-technology field and in a developing country context this research will attempt to contribute to the existing literature and to efforts for formulating realistic / pertinent policy proposals.

On the other hand, while some recent contributions to the KTT literature focus on the factors influencing individual characteristics of university-scientists on KTT activity (D'Este and Patel, 2007; Bekkers and Freitas, 2008; Edler et al., 2011; Boardman 2009; Ponomariov, 2008; Boardman and Ponomariov, 2009), existing studies generally ignore the role of individual firm researchers or scientists in the formation of university-industry linkages. Although Santoro and Bierly (2006) and Santoro and Chakrabarti (2002) provide evidence for the role of individuals (champions) in university-industry relations but focus on the presence of these champions in firms but do not explicitly account for how these champions play a key role in KTT process. Using qualitative techniques to explore the factors influencing firms' attributes to university-industry KTT activity, this dissertation provides evidence for the key role of individual firm researchers in the formation of linkages to academia; and explores how their social and human capital endowments facilitate knowledge transfers and, hence, collaborations between universities and firms. This is the most important expected contribution of this research to the literature.

Third, this research is one of the first attempts in the literature to explore university-industry relations in the emerging field of nanotechnology. Most of the studies focusing on nanotechnology explore patent and publications data to detect the interrelations between academia and industry. However, only Palmberg (2008) and Nikulainen and Palmberg (2010) using a questionnaire survey held among university and firm nano-scientists in Finland empirically explore KTT activity in nanotechnology; and differences in approaches to KTT between firm and university scientists. While these two studies explore the perceived outcomes of KTT for university-scientists and firms, our study focuses on the factors influencing the formation of KTT linkages. According to my knowledge of KTT literature, this thesis is the first study which explores the factors influencing nanotechnology related KTT activity in a developing country context. This is the most important contribution of this thesis to the international KTT literature.

This research is the first attempt in Turkey to explore the factors influencing the formation of KTT linkages between universities and firms; and doing it in a specific technology field (i.e. nanotechnology) with two separate field research carried out with university-scientists and firms. Considering that no previous study employs both quantitative and qualitative research to understand individual and organizational level factors which influence the formation of KTT linkages between universities and firms in Turkey the findings of this thesis will contribute to the science and technology policy studies literature in Turkey.

1.4 Organization of the thesis

The thesis includes nine chapters. Chapter 2 focuses on nanotechnology from a global perspective. This chapter briefly reviews the discussions on the nature of nanotechnology, its history, its political and economic impacts.

Chapter 3 and Chapter 4 focus on universities and KTT between universities and firms. Chapter 3 includes two main sections. Section 3.1 presents the discussions on the changing regime of knowledge production and its effects on the perceived role of universities in the society. Section 3.2 reviews the changing university-industry relations and KTT between universities and firms in the post-1980 period.

On the other hand, Chapter 4 focuses on the literature which explores the determinants of university-industry interactions. In this chapter, first, theoretical frameworks, namely resource-based view (RBV) and scientific and technical human capital (STHC) approach are presented. Second, empirical studies are reviewed.

Chapter 5, on the other hand, deals with NST-related research in Turkey. Using bibliometric data collected from Web of Science – Science Citation Index (WoS- SCI), this chapter scrutinizes main actors and characteristics of nanoscale research in Turkey. This chapter also discusses the science, technology and innovation (STI) policy implications of the research.

Chapter 6 reviews the quantitative and qualitative methodologies used to collect data for this thesis. Two sets of data are collected: one from university-scientists through questionnaire survey and, second, from high level managers of firms through in-depth interviews. This chapter, in Section 6.1, presents a detailed discussion of quantitative methodology used for data collection and data analysis in the research focusing on university-scientists. In Section 6.2, we review qualitative methodology utilized to collect data from firms and its analysis.

Chapter 7 is devoted to a detailed discussion of the results of the quantitative investigation of the proclivity of nano-scientists affiliated with Turkish universities to engage in KTT. This chapter reviews the profile of nano-scientists in Turkish academia and, then, discusses the factors which influence the propensity of a nano-scientist to interact with firms. Finally, we examine some STI policy implications of the research. In Chapter 8, the results of qualitative investigation of Turkish firms which either develop nanotechnology or use any form of nanotechnology in their product and production processes are presented and some implications of the research are discussed.

Chapter 9 concludes the thesis. In this chapter, we present a summary of overall research findings of the thesis. Second, we discuss STI policy implications of the research from a holistic perspective and propose some policy tools for the improvement of university-industry interactions in the field of nanotechnology. Finally, we state the limitations of the thesis and some directions for further research.

CHAPTER 2

A BRIEF INTRODUCTION TO NANOTECHNOLOGY: A GLOBAL PERSPECTIVE

This thesis aims to investigate the factors influencing the formation of university-industry relations in the emerging field of nanotechnology. Therefore, the nature of nanotechnology has a great importance for this study. The purpose of this chapter is to present an extensive overview of nanotechnology and discuss some political and economic aspects of nanotechnology research and development. Section 2.1 reviews various definition of nanoscience and nanotechnology (NST) and Section 2.2 presents the 50-year history of nanotechnology since 1959. In Section 2.3, we discuss the politics of nanotechnology. The following section focuses on the potential economic value generated by nanotechnology innovations and Section 2.5 concludes the chapter.

2.1 What is nanotechnology?

The *nano* prefix comes from a Greek word *nanos* which means dwarf. However this prefix is used by scientists to indicate one billionth of a meter. A single human hair is about 80 thousand nanometer (nm) wide, a red blood cell is approximately 7 thousand nm wide, a DNA molecule 2 to 2.5 nm, a water molecule is 0.24 nm and the wavelength of visible light ranges from approximately 400 nm at the violet end of the spectrum to approximately 700 nm at the red. Thus when we are talking about nanotechnology we are indeed talking about a scale of size or length; in other words, nanoscale is the size scale at which nanotechnology operates (Allhoff et al., 2010). In this emerging technology field, size matters not only for the aim of a simple delineation of the limits of the technology but also because of the changing properties of materials at the nanoscale. For example, at nanoscale, laws of physics change, metals become harder and ceramics become softer, chemical resistance increases, weight reduces, new electrical and novel biological properties occur (Bhat, 2003). While the macro-world is governed by the classical mechanics of Newton the nano-world is governed by the counter-intuitive laws of quantum mechanics. Two unfamiliar and distinctive features of nanoworld are (i) Brownian motion, everything is continually being shaken up and jiggled around; and (ii) stickiness, when surfaces get close they almost always like to stick to each other (Jones, 2004). The laws of quantum mechanics result in some changes to a substance's conductivity, elasticity, reactivity, strength, color, and tolerance to temperature and pressure (ETC Group, 2003). Gold and silver are good examples of observing these changes; while they are normally inert and unreactive, at the nanoscale, gold acts as a highly effective catalyst; and silver displays some bioactive properties (Smith 2004 in Macnaghten et al., 2005). Exploiting such changes is very useful to many industrial sectors (Maclurcan, 2005) because what these properties promise are materials that are stronger, computers that are faster and drugs that are more effective than those we have now (Jones, 2004).

Although size matters for nanotechnology, what nanotechnology makes revolutionary is not merely the size of the substances that nanotechnology deals with. Because, in the manner of size, nanotechnology is not new; humans have been nanotechnologists for millennia. Lycurgus Cup from 4th century in the collection of the British Museum has some unusual optical properties which are caused by a haphazard dispersion of nanometer sized particles of a gold-silver alloy in a glass matrix (Barber and Freestone, 1990, as cited in McCray 2005). The oldest known nanotechnology dates back to the fabrication of the first lustre potteries; some Abbasid lustre ceramics have nano-gratings and in this way objects would change their color depending on the viewing angle (OECD 2009b). Moreover, the long established materials such as Indian ink invented by ancient Egyptians or soap rely on nanotechnology in the broad sense (Jones, 2004). However, what makes us today talking about the revolution of nanotechnology is, fundamentally, the purposeful control and manipulation of the materials and properties at the nanoscale which is enabled by the inventions of scanning tunneling microscopy (STM) and atomic force microscopy (AFM) by IBM researchers.

Today the term nano is in an awkward position; its use increases dramatically and it pervades common language (Loeve, 2010); we are facing a nanofad, nanocraze or nanohype (Bainbridge, 2007) and a fuzzy image of nanotechnology. Thus, it is better to start with the definition of nanotechnology. The official definition of nanotechnology provided by National Nanotechnology Initiative (NNI) in the USA is as follows:

> Nanotechnology is the understanding and control of matter at dimensions between approximately 1 and 100 nanometers, where unique phenomena enable novel applications. Encompassing nanoscale science, engineering, and technology, nanotechnology involves imaging, measuring, modeling, and manipulating matter at this length scale. A nanometer is one-billionth of a meter. A sheet of paper is about 100,000 nanometers thick; a single gold atom is about a third of a nanometer in diameter. Dimensions between approximately 1 and 100 nanometers are known as the nanoscale. Unusual physical, chemical, and biological properties can emerge in materials at the nanoscale. These properties may differ in important ways from the properties of bulk materials and single atoms or molecules[1].

The definition of nanotechnology by the European Commission is similar to that of the NNI in the USA. In “Towards a European Strategy for Nanotechnology”, it is stated that

> Nanotechnology refers science and technology at the nanoscale of atoms and molecules, and to the scientific principles and new properties that can be understood and mastered when operating in this domain. Such properties can then be observed and exploited at the micro- or macro-scale, for example, for the development of materials and devices with novel functions and performance (European Commission, 2004).

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[1] http://www.nano.gov/html/facts/whatIsNano.html last accessed on October 6, 2010.

The British Standards Institution (BSI) define nanotechnology as the "design, characterization, production and application of structures, devices and systems by controlling shape and size in the nanoscale, which covers the size range from approximately 1 nm to 100 nm" (Mini-IGT, 2010). Table 2.1 includes some nanotechnology definitions provided by different institutes and organizations.

At least three common aspects of the nanotechnology definitions in Table 2.1 can be identified. First, all nanotechnology definitions emphasize a particular measurement scale which is nanometer. Hence, nanotechnology is a size-dependent phenomenon. Second, nanotechnology refers to the purposeful control and manipulation of matter at the nanoscale; and this eliminates from the definition any material or process that has come about through accidental nanotechnology. In other words, Lycurgus Cup from 4^{th} century, Indian ink or soap cannot be classified as nanotechnology because they have occurred without purposeful engineering. The third aspect of the definitions is very critical in terms of successful commercialization of nanotechnology innovations. In almost all definitions, it is strongly emphasized that nanotechnology enables "novel applications", "creation of improved / functional materials, devices and systems", "production and application of structures, devices and systems", and "technological innovation in various fields". In this sense, today's nanotechnology blurs the boundaries not only between science and technology but also those between the development of science and technology, and its commercialization.

Table 2.1 Some definitions of nanotechnology

National Nanotechnology Initiative- NNI (USA)	Nanotechnology is the understanding and control of matter at dimensions between approximately 1 and 100 nanometers, where unique phenomena enable novel applications. Encompassing nanoscale science, engineering, and technology, nanotechnology involves imaging, measuring, modeling, and manipulating matter at this length scale.
European Commission (2004)	Nanotechnology refers science and technology at the nanoscale of atoms and molecules, and to the scientific principles and new properties that can be understood and mastered when operating in this domain
ISO Technical Committee 229 on Nanotechnologies	Understanding and control of matter and processes at the nanoscale, typically, but not exclusively, below 100 nonametres in one or more dimensions where the onset of size-dependent phenomena usually enables novel applications. Utilizing the properties of nanoscale materials that differ from the properties of individual atoms, molecules, and bulk matter, to create improved materials, devices, and systems that exploit these new properties[2].
USPTO (U.S. Patent and Trademark Office) Class 977	The disclosures in "Class 977, Nanotechnology" are related to research and technology development at the atomic, molecular or macromolecular levels, in the length of scale of approximately 1-100 nanometer range in at least one dimension, and that provide a fundamental understanding of phenomena and materials at the nanoscale and to create and use structures, devices and systems that have novel properties and functions because of their size[3].
EPO	The term nanotechnology covers entities with a controlled geometrical size of at least one functional component below 100 nm in one or more dimensions susceptible to make physical, chemical or biological effects available which are intrinsic to that size. It covers equipment and methods for controlled analysis, manipulation, processing, fabrication or measurement with a precision below 100 nm (Scheu et al., 2006).
NASA	Nanotechnology is the creation of functional materials, devices and systems through control of matter on the nanometer length scale (1–100 nm), and exploitation of novel phenomena and properties (physical, chemical, biological, mechanical, electrical...) at that length scale[4].

[2]http://www.iso.org/iso/standards_development/technical_committees/list_of_iso_technical_committees/iso_technical_committee.htm?commid=381983 Accessed on October 7, 2010.

[3] http://www.uspto.gov/web/patents/biochempharm/crossref.htm accessed on October 7, 2010

[4] http://www.ipt.arc.nasa.gov/nanotechnology.html accessed on October 7, 2010

Table 2.1 (cont'd) Some definitions of nanotechnology

Royal Society of London	Nanoscience is the study of phenomena and manipulation of materials at atomic, molecular and macromolecular scales, where properties differ significantly from those at a larger scale. Nanotechnologies are the design, characterization, production and application of structures, devices and systems by controlling shape and size at nanometer scale[5].
British Standards Institute (BSI)	Nanotechnology is an emergent area that is developing quickly. It is the branch of science and engineering that studies and exploits the unique behaviour of materials at a scale of approximately 1-100 nanometres[6].
German Federal Ministry of Education and Research	Nanotechnology refers to the creation, investigation and application of structures, molecular materials, internal interfaces or surfaces with at least one critical dimension or with manufacturing tolerances of (typically) less than 100 nm. The decisive factor is that the very nanoscale of the system components results in new functionalities and properties for improving products or developing new products and applications. These novel affects and possibilities result mainly from the ratio of surface atoms to bulk atoms and from the quantum-mechanical behavior of the building blocks of matter[7].
Japan (The Science and Technology Basic Plan 2001-2005)	Nanotechnology is an interdisciplinary S&T that encompasses IT technology, the environmental sciences, life sciences, materials science, etc. It is for controlling and handling atoms and molecules in the order of nano (1/1 000 000 000) meter, enabling discovery of new functions by taking advantage of its material characteristics unique to nano size, so that it can bring technological innovation in various fields[8].

[5] http://www.nanotec.org.uk/report/chapter2.pdf accessed on October 7, 2010

[6] http://shop.bsigroup.com/en/Browse-by-Subject/Nanotechnology/?t=r

[7] http://www.bmbf.de/pub/nanotechnology_conquers_markets.pdf

[8] An unofficial version of the plan is available at http://japan.nsc.gov.tw/public/Data/5831584371.pdf accessed on October 7, 2010.

2.1.1 Nanotechnology as converging technologies

The fuzzy definition of nanotechnology ignites different perspectives about this emerging technology. One of these perspectives argues that what is emerging is not only nanotechnology but converging technologies at the nanoscale. Since nanotechnology is defined as the purposeful control and manipulation of matter at the nanoscale, both nanoscience and nanotechnology "promote the unification of most branches of science and technology, based on the unity of nature at the nanoscale" where the building blocks of matter originate and also the fundamental structures of life arise inside biological cells, e.g. DNA molecule is 2 – 2.5 nm (Bainbridge, 2007). The phrase "convergence at the nanoscale" or "convergent technologies" refers to "the synergistic combination of four major fields of science and technology" (Roco, 2004a) which are (i) nanoscience and nanotechnology; (ii) biotechnology and biomedicine, including genetic engineering; (iii) information technology; and (iv) cognitive science, including cognitive neuroscience. This synergistic combination is also called as NBIC (nano-bio-info-cogno) convergence (Roco and Bainbridge, 2002, 2003, 2007; Roco 2003). According to Roco and Bainbridge (2002, 2003), with proper attention to ethical issues and societal needs the results of NBIC convergence can be a tremendous improvement in human physical and mental capabilities, individual and societal outcomes and quality of life. However, the ethical and social consequences of convergence of these four different fields of science and technology are at the center of most discussions related to social implications of nanotechnology which will be extensively discussed in Section 2.3.

Nanotechnology plays an essential role both in achieving progress in each of these four science and technology field and also in unifying them (Bainbridge, 2007). Loveridge et al. (2008) use nano-artifacts as the synonymous of converging technologies because these artifacts are highly dependent on the various emergent nanoscale technologies which have resulted from a creative collision between chemistry and biology, and engineering and physics, especially where the latter have been related to micromechanical devices and electronics. On the other hand, Schmidt (2008) characterizes nanoscale convergence as “techno-object oriented inter-disciplinarity” which is achieved by addressing problem-oriented issues at the boundaries of NBIC fields through the use of some instruments -such as STM and AFM- and technologies (Porter and Youtie, 2009). The issue of convergence makes the boundaries of nanotechnology blurred but also increases the future expectations and the possibilities created by nanotechnology. Converging technologies are paid equal attention in the USA and Europe. While “NBIC Convergence for Improving Human Performance” is the name of a prominent agenda for converging technologies in the USA “Converging Technologies for the European Knowledge Society (CTEKS)” designates the European approach to converging technologies. CTEKS prioritizes the setting of a particular goal for converging technology research which presents challenges and opportunities for research and governance alike, allowing for an integration of technological potential, recognition of limits, European needs, economic opportunities, and scientific interests (Nordmann, 2004).

2.1.2 Some nanotechnology classifications

Nanotechnology is also defined as an enabling technology (Fiedeler, 2008; Ott and Papilloud, 2007; Alencar et al., 2007; Nordmann 2004). Enabling technologies prepare a ground for a wide variety of applications (Ott and Papilloud, 2007; Nordmann 2004) and they are prerequisites for other technologies, products and processes (Alencar et al., 2007). On the other hand, some argues that nanotechnology is not a single technology; there are many nanotechnologies, some old, some new, some revolutionary, some incremental. What these technologies have in common is the manipulation and control of matter at the nanoscale. Since it is very difficult to talk about a single nanotechnology with some some specific features, some useful classifications for nanotechnology are employed by researchers. For example, in terms of the nature of nanotechnology innovations, three types of nanotechnology are identified; these are incremental, evolutionary and revolutionary nanotechnologies (Wood et al., 2008; 2007; Jones, 2004).

(a) Incremental nanotechnology includes developments which are essentially a continuation of the research directions of the past 50 years. It is focused on materials that have superior or new properties as a result of their controlled nanoscale structure. For example, materials or coats used to produce hydra-phobic or antibacterial layers, textures etc.

(b) Evolutionary nanotechnology refers to the scaling down of existing technologies towards the nanoscale. In this type of nanotechnology, the focus is more on functional devices. This would contain developments in information technology and molecular delivery. For example, more powerful chips downsized to nanoscale in order to achieve smaller but more functional / powerful computers, mobile phones etc.

(c) Radical nanotechnology covers fully functional nanoscale machines and the engineering of systems, not simply materials and devices.

Today, many of the current achievements of nanotechnology are still incremental in nature; these innovations are extensions of developments that were proceeding before the concept of nanotechnology became widespread.

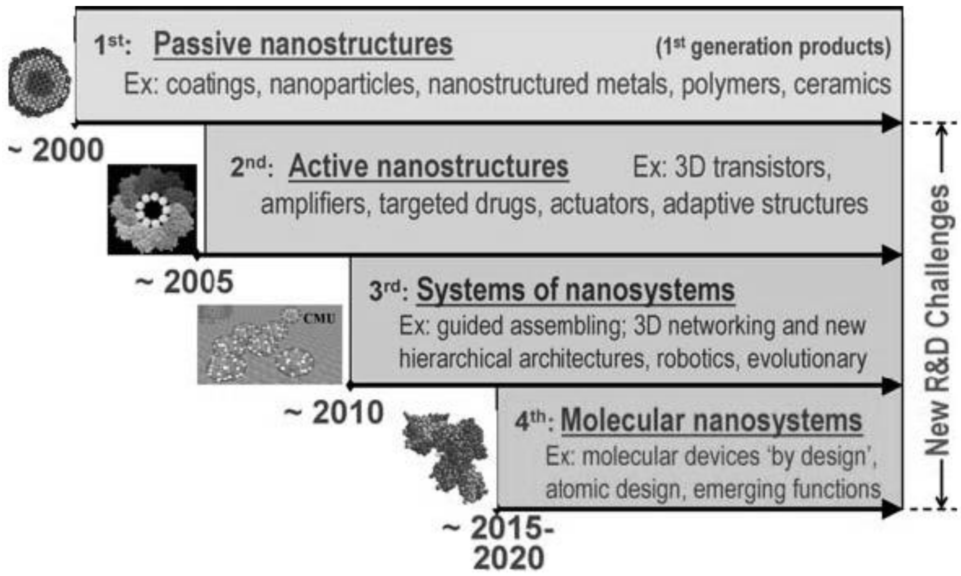
Another classification about nanotechnology is simply based on the techniques leading to the fabrication of nanoproducts: top-down vs. bottom-up approaches.

(a) Bottom-up methods arrange atoms and molecules in nanostructures; in other words nanoscale materials are assembled from smaller molecules and atoms. Here, innovation lies at the precise control of the material’s size and resulting properties (Mazzola, 2003; Mijatovic et al., 2005). Moreover, it is this area of nanotechnology that is the most futuristic and has created the most public interest because it is believed that this technique enables the production of nanorobots (Arnall and Parr, 2005).

(b)Top-down nanotechnology, on the other hand, utilizes lithographic techniques such as semiconductor or MEMS (microelectromechanical systems) lithography to print nanostructures, and is extensively used in what has become known as nanoelectronics (Romig et al., 2007). In other words, it is the creation of nanostructures by using some etching techniques, e.g creating nano fibers by cutting natural fibers in nanometers. However, this technique is not a simple miniaturization because at the nanoscale level the properties of traditional materials change and these new properties dominate the behaviour of the bulk material (Arnall and Parr, 2005; Romig et al., 2007).

A further distinction is also made between bulk nanotechnology andn individually -addressed nanotechnology. Bulk nanotechnology is, by using available nanomaterials, the production of nanoproducts which are used to make existing materials better, and/or faster and/or cheaper. The steel, textile, and various chemical - based industries have been using bulk nanotechnology reactions to assist in the manufacture and improvement of their products. Individually-addressed nano-technology is the atom-by-atom or molecule-by-molecule manufacture of organic or inorganic material (Romig et al., 2007).

On the other hand, Roco (2005) makes a classification based on the development stage of nano-products, or nano-artifacts (Figure 2.1). The first generation nano-products are passive nanostructures which have been already available in the market since 2000s. However, the main transition is toward active nanostructures and nanosystems which were expected to start around the year 2005. Nanoelectromechanical systems (NEMS), nanobiodevices, transistors, amplifiers, targeted drugs and chemicals, actuators, molecular machines, light-driven molecular motors, plasmonics, nanoscale fluidics, laser-emitting devices, adaptive nano-structures, energy storage devices, and sensors changing their state during the measurement are the examples of active nanostructures. Subramanian et al. (2010) perform a bibliometric analysis of articles published from 1995 to 2008 for the aim of detecting any shift from passive to active nanostructures; and their results suggest that there is a sharp rise in active nanostructures publications in 2006 and this rise is maintained in 2007 and 2008. Roco (2005) envisages two further stages of nano-technology evolution which are nanosystems (including 3D networking, hierarchical architectures and robotics) and molecular nanosystems which include



Source: Roco (2005)

Figure 2.1 Four generations of nanoproducts

designed molecular devices, atomic design and emerging functions (Loveridge et al., 2008).

All these classifications, albeit very technical in nature, are important especially in terms of science-technology policy making. For example, nanotechnologies which are identified as incremental, evolutionary, top-down or bulk are not the subject of the main disputes in nanotechnology because their socio-economic consequences are expected to be limited. However, radical nano-technologies and bottom-up approaches, especially the possibility of the self-assembly of nanoproducts and their environmental, health and safety related consequences increase the fear of people and affect the policy making process (for a detailed discussion see Section 2.3).

The rhetoric of nanotechnology allows the possible imagination of nanotechnology as a "next big thing" or "next industrial revolution" (Roco, 1999;

Lux Research, 2004; Loveridge et al., 2008) or “new renaissance of science and technology” (Roco and Bainbridge, 2002). However, beyond all these descriptions the notion of nanotechnology still stays as something fuzzy and its boundaries are obscured. The notion of nanotechnology covers all the research based on the manipulation and control of atoms and molecules; and the established boundaries between different fields of science and technology have diminished at nanoscale. Such a broad definition of this emerging technology leads to some discussion about the nature of the technology itself; some argues that nano has become a scientific marketing term (Loeve, 2010); some argues that nanotechnology is not a definite technology, but an empty signifier which “provides the basis for an encompassing socio-economic project that is kept together only by the signifier itself” (Wullweber, 2008). Before analyzing further economic and political aspects of nanotechnology in the following pages, Section 2.2 presents a brief history of nanotechnology.

2.2 History of nanotechnology

The history of nanotechnology starts with a seminal talk given by Richard Feynman, the Nobel Prize winner physicist, to the American Physical Society on December 29th, 1959 at Californian Institute of Technology (Caltech). In this talk entitled “There is plenty of room at the bottom” (Feynman, 1960), he anticipated that physicists would eventually be able to manipulate matter at the atomic scale (Bennett and Sarewitz, 2006) and presented the initial vision of the innovative nano-research that scientists could do (McCray, 2005). At a time when the mass production of microelectronics was just beginning, Feynman discussed the possibility of writing the entire twenty-four volumes of the Encyclopedia Brittanica on the head of a pin.

> I have estimated how many letters there are in the Encyclopaedia, and I have assumed that each of my 24 million books is as big as an Encyclopaedia volume, and have calculated, then, how many bits of information there are. For each bit I allow 100 atoms. And it turns out that all of the information that man has carefully accumulated in all the books in the world can be written in this form in a cube of material one two-hundredth of an inch wide--- which is the barest piece of dust that can be made out by the human eye. So there is *plenty* of room at the bottom! Don't tell me about microfilm! (Feynman 1960).

Although the initial vision regarding to the nanotechnology was presented in the USA, the term "nanotechnology" was first used by a Japanese researcher Norio Taniguchi in 1974 in a paper (Taniguchi, 1974) on precision engineering which refers to engineering at length scales less than a micrometer (OECD 2009a; Bainbridge, 2007; McCray 2005). However, the rise of the nanotechnology and the nanoscale research in the sense of controlling and manipulating atom and molecules needed to wait until the invention of appropriate tools which are namely scanning tunneling microscopy (STM) and atomic force microscopy (AFM) in the 1980s (Table 2.2).

STM was invented in 1981 by Gerd Binnig and Heinrich Rohrer employed by IBM's Zurich Laboratory; and they won the 1986 Nobel Prize in physics for their invention (Baird and Shew, 2004). This invention was shortly followed by the invention of AFM by Binnig, Quate and Gerber in 1986 (Jones, 2004). The invention of these microscopes is perhaps the most important development in the crystallization of nanoscale science and technology as an emerging field or discipline; in both STM and AFM techniques, images are obtained not only by gathering reflected or refracted waves from a sample but also a very fine tip is scanned across the surface of the sample and interacting with it (Wood et al., 2003). Since in these microscopes the images are get through probing they are also called as scanning probe microscopies (SPM).

SPM relies on an entirely different principle compared to both light and electron microscopes. While electron microscopes detect waves scatterred from the object that researcher is looking in, in SPM there occurs some interaction between the tip of the probe and the surface of the object. Hence, in going from a light or electron microscope to a scanning probe microscope researchers have moved away from looking to touching (Jones, 2004). Moreover, touching or feeling the sample through the probe of the microscope allows purposeful manipulation and control of atoms and molecules where the distinctive feature of nanotechnology lies.

The invention of SPMs is the most important breakthroughs for nano-technology; they are enabling instruments for investigating the nanoscale where objects are visible only with the aid of computer technologies (Mody, 2004a). Darby and Zucker (2004) use the expression of "invention of methods of inventing" due to Zvi Griliches (1957) to analyze the impact of the invention of SPMs on nanoscience and technology research. They detected significant increases in the rate of patenting and publications in nanotechnology between 1985 and 1990 and which is consistent with the history of breakthroughs in SPM as key enabling inventions for nanoscale research.

However why SPMs have been so important for the emergence and development of nanotechnology? The most important advantage of SPMs is that they allow touching and feeling atoms and molecules and, manipulating the nanoworld. With these microscopes, picking up individual molecules from one place and moving them elsewhere, pulling molecules and stretching them, injecting an electron into molecules or carrying out a chemical reaction at the point of the tip are now easily done (Baird and Shew 2004; Shew 2008). Thus this means that today building up a chemical structure atom by atom is literally possible (Jones, 2004); and to prove that, in 1989, Donald Eigler in IBM produced IBM logo by arranging Xenon atoms in a vacuum (UNESCO, 2006) to promote scanning probe microscopies and their capabilities to build something atom by atom. Furthermore, Jones (2004) argues that SPM's ease of use and low cost are very important for the successful commercialization of these microscopes, hence, diffusion of these new technologies/devices. For example, by the late 1990s these instruments could be purchased for as little as USD 50,000 (Amato 1997); and price of instruments used for the educational purposes was as low as USD 15,000 (Baird and Shew, 2004).

In 1985, Richard Smalley, Robert Curl, James Heath, Sean O'Brien, and Harold Kroto at Rice University prepared the first fullerene which is a molecule composed entirely of carbon and takes the form of sphere, ellipsoid or tube (Table 2.2). Since ball-shaped structures of the carbon atoms assembled were like the geodesic domes designed by architect Buckminister Fuller in 1960s, these assemblies of carbon atoms came to be called “buckyballs” or more formally “buckminster-fullerenes” or shortly as “fullerenes” (Bainbridge, 2007). The first and most famous fullerene is also known as C60 which is a spherical structure of 60 carbon atoms. Fullerenes are not found in the nature and their invention rapidly led to the discovery of numerous similar carbon-based molecules characterized by both chemical stability and great strength (Bennett and Sarewitz, 2006). However, the main reason behind the intense research on buckyballs is that their great physical strength and chemical stability increases their industrial applicability over various products (Bennett and Sarewitz, 2006; Bhat, 2003). Thus, Science magazine named the buckyball “the molecule of the year” in 1991 and their discoverers earned 1996 Nobel Prize in chemistry (Bennett and Sarewitz, 2006).

Cylindrical fullerenes or nanotubes were first discovered by Sumio Iijima employed by NEC in Japan (Table 2.2). These carbon nanotubes (CNTs) are usually only a few nanometres wide but they are the strongest and most flexible material yet discovered. Due to its molecular structure, carbon nanotubes have some special features such as electrical and thermal conductivity (UNESCO, 2006). Novel properties of CNTs make them very useful in a wide variety of applications; for example they are currently used as reinforcement material in many applications due to their outstanding mechanical properties (large resistance to stress in relation to their weight); also functionalizing CNTs opens new perspective to engineered carbon-based chemical sensors with enhancement sensitivity; or because of their unique structure they are suitable to be used in production chains for assembling electronic devices, flat displays etc.(Correia et al., 2007).

While scientific and technological developments had been rapidly growing, Eric Drexler’s book entitled “Engines of Creation. The Coming Era of Nanotechnology” (1986) was published (Table 2.2). This book is very important for the popularization of nanotechnology but in a dystopian manner. In this book, Drexler envisions a world in which factories would be shrunk to the size of the cells and equipped with nanoscale machines (nanobots) which are not only able to build other structures by manipulating individual atoms but also able to self-replicate (Jones 2004; Kulinowski 2004). This vision coincides with ‘grey goo’ scenario or dooms day scenario because it describes a future in which “omnivorous” nano-machines become completely autonomous and uncontrolled; they replicate swiftly and spread rapidly all around the world and finally destroy the life on the earth and reduce the biosphere to dust in a matter of days (Kulinowski 2004). Although most scientists, today, do not give credence to Drexler’s representation of nanotechnology (Selin, 2007), Drexlerian vision of nanotechnology or doomsday scenarios related to nanotechnology are still in the center of the nanotechnology debate which will be discussed in Section 2.3.

In terms of science and technology policy, the most prominent breakthrough in the short history of nanotechnology occurred on January 20th, 2000 (Table 2.2); former US President Bill Clinton again chose Caltech where Feynman made his seminal speech regarding to the possibility of nanoscale research and engineering to announce the creation of National Nanotechnology Initiative (NNI) of the USA (Roco 2004b; Kulinowski 2004). The real nanotechnology breakthrough came with the creation of NNI with a huge research funding program launched by the Clinton Administration (Fiedeler, 2008). At the end of his presidency, Bill Clinton proposed the NNI with a $225 million dollar budget for fiscal year 2001, appoximately 83% increase over expenditures on nanotechnology in the previous year (Baird and Shew, 2004). Jones (2006) cynically declares Bill Clinton as nanotechnology’s father figure; because he argues that his support for the NNI converted overnight many industrious physicists, chemists and material scientists into nanotechnologists. He states that “the idea of nanotechnology did not emerge naturally from its parent disciplines, but was imposed on the scientific community from outside”. Approximately three years after Clinton’s support for the NNI, the ‘21st Century Nanotechnology R&D Act’ was signed by the next president Bush on December 3rd, 2003. Through this Act, nanotechnology was recognized by the US Congress as a key challenge for the future of the USA in the 21st century (Roco 2004b).

The vision of controlling and manipulating atoms and molecules; and building structures atom by atom dates back to approximately fifty years ago. However, when it was declared by Feynman there was no appropriate tool or instrument enabling researchers to realize this futuristic vision. The invention of SPMs by IBM researchers in the 1980s was the critical milestone in the history of nanoscale research. With these inventions and their successful development and commercializations a boom both in the number of nanotechnology publications and in the number of nanotechnology related patents had occurred. However, it is widely argued that the most important stimulus for the rapid growth in nanoscience and nanotechnology research came from outside of the science community. Science policy initiatives to promote nanotechnology, innovations and commercialization of these nanoscale research results were first taken by the USA and then followed by other countries; hence, in this emerging field of technology, policy makers have achieved to influence the science community and the growth in publications and patents.

Table 2.2 Some milestones in the history of nanoscience and nanotechnology

1959	Robert Feynman's seminal talk entitled "There's plenty of room at the bottom"
1974	"Nanotechnology" concept was proposed by Norio Taniguchi of the Tokyo University of Science
1981	STM was invented by Gerd Binning and Heinrich Rohrer employed by IBM in Zurich Laboratory
1985	Fullerenes were discovered by Richard Smalley, Robert Curl, James Heath, Sean O'Brien, and Harold Kroto at Rice University in the USA
1986	AFM was invented by Gerd Binning, Calvin Quate and Christoph Gerber employed by IBM
1986	Eric Drexler's book "Engines of Creation: The Coming Era of Nanotechnology" was published
1987	First commercial STM was shipped by Digital Instruments in the US
1989	First commercial AFM was shipped by Digital Instruments in the US
1989	The IBM logo was produced with individual atoms by D. M. Eigler in IBM, USA
1990	The first issue of *Nanotechnology* journal
1991	Carbon nanotubes were discovered at NEC by Sumio Iijima
1991	First nanolabs were established at universities
1997	First DNA-Based nanomechanical device was discovered in the USA
1998	First nanotube transistor was developed
1999	First nanoswitch was developed at Rice University in the USA
2000	The Center for Nanotechnologies at the Chinese Academy of Sciences was opened in Beijing
2000	National Nanotechnology Initiative was launched by the former president Bill Clinton
2002	Nanotechnology Research Network Centre of Japan was established
2002	The European Commission designated nanotechnology a priority area in the Sixth Framework Program
2003	The "21st Century Nanotechnology Research and Development Act" in the US was signed
2006	The EU "Roadmaps at 2015 on Nanotechnology Application" was published
2007	Russia announced USD 8 billion investment in nanotechnology from 2007 to 2015
2008	The US "Technology Roadmap for Productive Nanosystems" was published
2008	Korean "Nanotechnology Roadmap" was published

Source: Bhat (2003); OECD (2009a) and Palmberg and Nikulainen (2006)

2.3 Politics of nanotechnology

The standard history of nanotechnology is narrated more or less in the same manner -as we did in the previous part- starting with Feynman's speech in 1959 and continues with the inventions that open up nanotechnology's own way as an emerging technology. However, Baird (2003, as cited in Shew, 2008) argues that this standart story of nanotechnology plays an important role for the creation of the mythology of nanotechnology with its purpose being to direct people's attention to a new way of thinking about science and technology which is based on manipulation and control, technology transfer and commercialization; not on observation, representation and the articulation of truth. This myth created around the possibilities that would be opened up with the development of nanotechnology has brought many disputes and radical contestations. The radical representations of nanotechnology; and more evolutionary perspectives that have recently emerged and gained power are the fundamentals of nanotechnology policies or the politics of nanotechnology. In this section, first the main perspectives in nanotechnology debate are briefly stated and, then nanotechnology dispute on the issue of development is discussed.

2.3.1 Crystallizing nanotechnology debate

Understanding the politics of nanotechnology needs the crystallization of nanotechnology debate. One dispute is about the nature of nanotechnology; whether it is revolutionary or evolutionary (Romig et al., 2007). Proponents of evolutionary nature of nanotechnology are also called as nano-realists (Wilsdon, 2004) who are not interested in radical or hypothetical possibilities of nanotechnology but focused on incremental innovations that will have near term practical applications and short-term economic returns. On the other hand, those who assume that nanotechnology is a radical, path breaking and disruptive technological change gathered into positive and negative sides of the nanotechnology debate (Wood et al., 2008).

Radical conceptions of nanotechnology went back to the publication of Drexler's book "Engines of Creation: The Coming Era of Nanotechnology" (1986). In this book Drexler deals with the possibility of molecular manufacturing, in other words the manufacturing of products and nanomachines with atom-by-atom control; he envisions a world in which tiny machines and assemblers are able to build other nanomachines and other nanostructures by manipulating individual atoms (Kulinowski, 2004) (e.g. self-replicating nanomachines or nanorobots). He argues that molecular manufacturing is what Feynman proposed in his prolific talk in 1959; therefore, he calls this radical conception of manufacturing as Feynman vision of nanotechnology (Drexler, 2004; Wood et al., 2008). Another radical conception of nanotechnology was heralded by Roco and Bainbridge in the beginning of the 2000s as the convergence of technologies at the nanoscale in other words, NBIC convergence. They argue that if it is achieved with proper attention to ethical and societal issues the result of this convergence will be "a tremendous improvement in human physical and mental capabilities, individual, and societal outcomes, and quality of life" (Roco and Bainbridge, 2003).

Radical conceptions of nanotechnology bring both utopian and dystopian views of nanotechnology. Some scholars who are focusing on utopian visions imagine a superworld where nanorobots eliminate diseases (Munshi et al., 2007) or solve food scarcity and environmental problems. Those people imagine that nanorobots will travel in our bodies, find the exact organ or tissue to be fixed, eradicate problems while generating cellular growth to build new healthy tissue or body parts, so no more aging and long lives for humanbeings; or we will be able to manufacture steak without raising cattle by utilizing the atomic components of oxigen, carbon, etc., so food can be easily manufactured, starvation and hunger will be eliminated from the globe; or nanotechnolgy will clean up the environment by eliminating polluting atoms or molecules; nanorobots will be able to clean up any toxic site or oil spill and since all these reactions occur at the atomic level the ecosystem will not be negatively affected (Dunkley, 2004); we will have super-brains; nanorobots will expand our minds through the merger of biological and nonbiological, or machine intelligence; we will learn how to augment our 100 trillion very slow interneuronal connections with highspeed virtual connections via nanorobots; the technology will allow wireless communication from one brain to another (Kurzweil, 2006).

In the opposite of these utopian scenarios of nanotechnology, there are dystopian views of nanotechnology dealing with"grey goo" problem and dooms day scenarios. Drexler (1986) first wrote about the possibility of radical dystopian outcomes of nanotechnology but it was Bill Joy, CEO of Sun Microsystems and a prominent scientist, who raised the alarm bells (Wood et al., 2007). In 2000, Bill Joy published an article in Wired entitled "Why the Future Doesn't Need Us?" in which he wrote about "grey goo" and nanotechnology's potential to induce human extinction (Joy, 2000).

The idea of grey goo –as "omnivorous" nanomachines which are completely autonomous and uncontrolled; do replicate swiftly and spread rapidly all around the world (Mody 2004b; Kulinowski 2004)- has captured the attention of moviegoers and science fiction writers. The first well-known science fiction was Michael Crichton's Prey (2002) and then turned into a movie (Sheetz et al., 2005). This book describes the horrific consequences of out-of-control nanorobots that escape from the laboratory (Selin, 2007). But this is not a unique appearance of nanotechnology in the popular culture; it is also mentioned in the movies Minority Report, The Hulk, in the three Matrix movies and both Spiderman movies; and in all these examples nanotechnology is associated with the villain, not the hero (Sheetz et al., 2005).

However, the aforementioned debate on the implications of nanotechnology has fundamentally focused on the longer term possibilities of radical nanotechnology or molecular manufacturing not on the relatively mundane applications that have already arrived or are in the R&D process to arrive in the market in the very near future (Wood et al., 2003). Lopez (2005) emphasizes, just like in the science fiction, how a single element – e.g. molecular manufacturing-, in nanotechnology narrations, is used as an axis around which a future alternative world is spun; and argues that utopian visions brought by nanotechnology only leave room for similarly constructed counter-visions; the generation of dystopian futures linked to nanotechnology may have much less to do with technophobia than with the fact that pro-nanotechnology futures are so impenetrable to critique; and the only way to criticize them is to introduce a dystopian conception of the nanotechnology future. The disappearing boundaries between science and science fiction in nanotechnology (Hodge et al., 2007; Lopez 2005); and radical and dystopian visions related to molecular manufacturing against more realistic conceptions generate a potential backlash against nanotechnology (Hodge et al., 2007; Wood et al., 2003; 2007) which should be avoided through the governance of nanotechnology in proactive, constructive and transparent engagement with the public (Hodge et al., 2007).

The Economic and Social Research Council (of the UK)'s report (Wood et al., 2007) notes that since the initial report (Wood et al., 2003) the nanotechnology debate has become less dominated by the radical visions. In this change, one important factor is the rejection of radical conceptions of nanotechnology and the possibility of molecular manufacturing by the scientists. Berube (2006) mentions that the majority of scientists in this emerging field rejects radical manufacturing as a vision and opts for a more evolutionary view that is grounded in applied science. Selin (2007) quotes from a personal telephone interview conducted with Meyya Meyyapan, the Director of NASA's nanotechnology program: "Real scientists" doing "real work in the laboratory" do not have time or patience for the longer term vision of Drexler's nanobots (as quated by Selin 2007).

The discussion about the possibility of radical visions or molecular manufacturing also confronted Drexler and the Nobel Laureate Physician Robert Smalley who is also one of the discoverers of nano fullerenes (Smalley 2001; Drexler and Smalley, 2003; Drexler 2004). Smalley (2001) simply argues that nanorobots in the Drexlerian sense are physically impossible. Smalley (2001) raises two issues which are fundamental to the possibility of nanorobots; these are fat and stick finger of an assembler's arm: (i) the fingers are fat because it takes many atoms to build a structure complex enough to make a nanorobot, up in a scale of several nanometers, but the individual atoms they are supposed to manipulate are much smaller than a nanometer; and (ii) the sticky finger problem arises because of unfamiliar and distinctive features of nanoworld which is stickiness, in other words when surfaces of atoms get closer they almost always like to stick to each other. Therefore, it will be impossible to release these atoms and molecules in a precisely right spot (Smalley 2001; Jones 2004; Bainbridge 2007). On the other hand, Drexler (2004) argues that all these attempts aiming to prove the impossibility of nanorobots are to calm public fears about nanotechnology; the budget allocated for nanoscale research is huge and any suspicion about molecular manufacturing probably raises objections. On the other hand, Whitesides (2005) proposes to dismiss this type of concerns related to nanorobots at least until scientific inventions in self-replication; and he warns about that "the most serious risk of nanotechnology comes, not from hypothetical revolutionary materials or systems, but from the uses of evolutionary nano-technologies that are already developing rapidly". The risks of using evolutionary nanotechnologies are discussed below.

Privacy, health and environmental risks; economic and political risks related to the increasing gap between the rich and poor are among the issues, currently needed to be held and discussed in the field of nanotechnology. The idea that "nanotechnology may lead to the loss of personal privacy because of tiny surveillance devices" is the most frequently mentioned potential risk related to this technology by lay people (Cobb and Macoubrie 2004; Scheufele and Lewenstein, 2005). Moreover, nanotechnology is expected to lead to smaller, faster and cheaper computers which will make it easier to collect, store and sort enourmous quantities of data about people (Whitesides 2005; Lewenstein, 2005). Controlling and regulation of access to such databases will become an important issue in the near future to keep privacy of people.

Health and environmental risks are another challenge for the governance of nanotechnology because, for now, most of these risks are yet unknown. Although it is argued that nanotechnology has potential enourmous risks for human health and environment, the data to prove these risks is very scarce (ETC, 2004). Furthermore, the methods or test used today for the measurement of toxicological effects of nanomaterials is not sufficient and appropriate; new methodologies and tests are needed to be developed for the understanding of mammalian and ecotoxicological profiles of nanomaterials (Santamaria and Sayes, 2010). On the other hand, Maynard (2007) emphasizes the importance of ensuring safe nano-workplaces. It can be foreseen that some engineered materials will present some new and unusual risks and the worker in the plants using these nanomaterials will be subjected to these risks; therefore, safety regulations and practices for nano-workplaces are needed. The third group of risks related to the inequalities in accessing to nanoscience and technology knowledge, and nano patents will be extensively discussed in the following part.

On the other hand, how these risks are treated depends on how nanotechnology is defined i.e. a novelty or a continuity. If it is a novelty a new policy framework and new regulations are needed but if not some incremental tweaks will e sufficient (Wilsdon, 2004). The fact that nanotechnology is a buzzword and its definition differs from one agent to another; therefore, "there are multiple ways of defining the nanotechnology problem - or indeed attempting to define whether there is indeed a problem there at all" (Hodge et al., 2007). This is a crucial challenge for nanotechnology policy making and new regulations which are needed both to make people confortable about the ethical, environmental and safety problems possibly created by the use of nanotechnology and also to promote nanotechnology innovations and their diffusion along the different industries. While governments have invested heavily in R&D programs they have been unenthusiastic about implementing new regulatory frameworks for risk minimisation – i.e. the USA, Japan and many other countries have chosen to regulate nanotechnology through existing regulatory arrangements instead of implementing nano-specific ones (Bowman and Hodge, 2006). On the other hand, even if nanotechnology is continuity not a novelty, the radical representations of nanotechnology ignite the fear of people about the unknown risks of the technology; and they become hesitant to nanoproducts or the usage of nanotechnology. Some scholars (Mehta 2004; Wildson 2004; Einsiedel and Goldenberg 2004; Wood et al., 2007) emphasize on the analogy between genetically modified (GM) foods and nanotechnology to prevent the risk of non-acceptability of nanotechnology innovations by customers. The precautinary principle plays an important role in nanotechnology debate as in the debate about the safety of GM organisms. Precautionary principle is based on the motto ‘better-safe-than-sorry’ and shifts the burden of proof to the proponents of a technology to prove its safe. Advocates of the precautionary principle require strict limitations on nanotechnology until nano-materials are proven not to be hazardous (Marchant and Slyvester, 2006).

Another important challenge for nanotechnology regulations is achieving public engagement which involves allowing the public to express their concerns and also transparency in policies and regulations; i.e. explaining what the technologies are, the potential they hold, how their risks will be managed and how they will be regulated (Sandler and Kay, 2006). The upstream engagement and public discourse should be achieved by science/technology policy makers in this field of scientific development; otherwise paranoia about the unknown risks of nanotechnology makes the governance of nanotechnology more challenging (Hodge et al., 2007).

2.3.2 Nanotechnology dispute and development

Nanotechnology is seen and supported as something that will eventually solve current problems related to energy, clean water, food scarcity, environment, or health; and improve globally the quality of human life. In this sense, it is argued that nanotechnology provides a viable alternative for attaining most of the Millennium Development Goals of The United Nations which were agreed to in

2000 and refined at the 2002 World Summit on Sustainable Development[9] (Salamanca-Buentello et al., 2005; Meridian Institute, 2005; Hassan 2005; Maclurcan, 2005; Invernizzi and Foladori, 2005). On the other hand, some scholars working on the societal impacts of nanotechnology insist on the argument that with nanotechnology the gap between the rich and the poor will be widened; and this new technology will increase the inequalities and bring a nanodivide (ETC 2004a; Sheetz et al., 2005; Invernizzi and Foladori 2005; Schummer 2007a; Invernizzi et al., 2008).

Invernizzi et al. (2008) identify two different positions on the role of nanotechnology in promoting development and alleviating poverty: (i) instrumental position; and (ii) contextual position.

(i) Instrumental position emphasizes the technical capacity even superiority of nanotechnology to solve problems in poor countries related to poverty, and promote development. The proponents of this position tend to see nanotechnology as neutral artifacts that can be easily transferred from one context to another (Invernizzi et al., 2008). It is simply technological determinism in the sense that technology is autonomous; and technological change occurs as free from the context in which it is created; and this change cannot be shapen by the society (MacKenzie and Wajcman, 1999; Bimber, 1994). Furthermore, in this perspective, what is offered is a 'technological fix', i.e. using technology in order to solve problems that are nontechnical in nature (Volti, 1995). This position represents a technocratic idea of progress which is a belief in the sufficiency of scientific and technological innovation as the basis for general progress (Marx, 1993).

Instrumental approaches conceive poverty as being a consequence of lack of access to technologies and do not consider its social causes. In these approaches, poverty issues and contexts are homogeneised, "one-size-fit-all" technological solutions are offered to very different ecological, social and cultural contexts. This

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[9] United Nations. *Millennium Development Goals.* Available at: http://www.un.org/millenniumgoals accessed on Oct 25, 2010. These goals are (1) eradicate extreme poverty and hunger; (2) achieve universal primary education; (3) promote gender equality and enpower women; (4) reduce child mortality; (5) improve maternal health; (6) combat HIV/AIDS, malaria and other diseases; (7) ensure environmental sustainability; and (8) develop a global partnership for development.

does not mean that all proponents of nanotechnology arguing that this new technology will help solving the problems of the poor are strictly technological determinists. However, the dangers of neglecting the impact of social, political and economic factors on poverty need to be considered especially for designing nanotechnology-related technology policies in developing countries. Schummer (2007a) gives the example of nano carbon filters for water purification which are promoted as an effective solution to the problem of clean water scarcity in the poor countries. Schummer (2007a) emphasizes that these filters are very expensive for the poor countries because they are designed and manufactured in developed nations; and the existing old fashioned filters also work very well to purify the water; and most importantly clean water problem is not about the filters; in other words, the main problem is not of technological in nature per se but a lack of basic infrastructure, facilities, and hygene education. Nano-artifacts are not mostly developed or designed to solve the problems of the poor but designed in laboratories in the developed countries and funded by the governments or firms of these countries; therefore, they cannot be easily transferred to the context of developing or poor countries. As stated by Schummer the use of expensive carbon nanotubes in water filters is a project by the US military that aims to provide pure water to use for medical purposes on the battlefield rather than helping developing countries. However, the exaggerated opportunities of nanotechnology to solve the problems of food and clean water scarcity, environmental pollutions and some other problems related to poverty support the myth of nanotechnology and moreover rationalize the huge amounts of public funds allocated to nanoscale research.

(ii) Contextual position, on the other hand, emphasizes the social context wherein technology is produced, used and adopted. According to this approach, technologies are not neutral artifacts but ones that embody social relations, political power, values, interests, etc. (Invernizzi et al., 2008). However, there are significant differences among arguments grouped under contextual position. The following arguments within this perspective should be considered in designing nanotechnology policies in developing countries.

1) Excessive patenting in nanotechnology: Legal changes (i.e. Bayh-Dole Act in the USA) in IPR protection since 1980s have moved some types of knowledge which were formerly in the public domain into the realm of commodities. Bayh-Dole Act brings a requirement that university employees report their inventions of possible commercial value to the university administration before possible publication. After Bayh-Dole, license revenues of universities increased from 200 million USD in 1991 to 1.4 billion USD in 2004. The commercial success of Bayh-Dole Act has encouraged other countries to issue similar acts. On the other hand, in some developed countries, now patenting of life form is legal; and this legal change is another factor increasing the number of patents issued and patent applications. These patents are acquired by multinational companies with huge patent portfolios or by the universities in the developed countries. This situation brings knowledge monopolies. Since developing countries are located at the periphery of R&D networks, have very limited resources in their firms and universities to carry out cutting edge innovations which can be patented, developing countries suffer most from these changes in IPR protections. Finally, the impact of WTO (World Trade Organization)'s TRIPs (Trade-related Intellectual Property Rights) and bilateral/regional trade agreements among countries are expected to negatively influence nanotechnology innovations in the less developed countries with little innovation but some imitation potential (Schummer 2007a; Invernizzi et al., 2008; Invernizzi and Foladori 2005; ETC 2004a, 2004b, 2005; UNESCO 2006). However, with these changes imitation of innovations would be very difficult for firms in such countries.

2) Decreasing demand for raw materials: Nanotechnologies are expected to have a major impact on the materials demanded in the production process in a wide range of industries; the amount of raw materials used in the production will decrease; newly developed nano materials will substitute the traditional materials. Since the developing countries or other poor countries are the main exporters of these raw materials, any change in the demand of materials on the world market affects the economies of these countries. Therefore, widespread usage of nanotechnologies in products and processes, at least in the short term, is expected to

negatively affect the economies of less developed countries, the international division of labor and the industrial structure (ETC 2005; Schummer 2007a; Invernizzi et al., 2008).

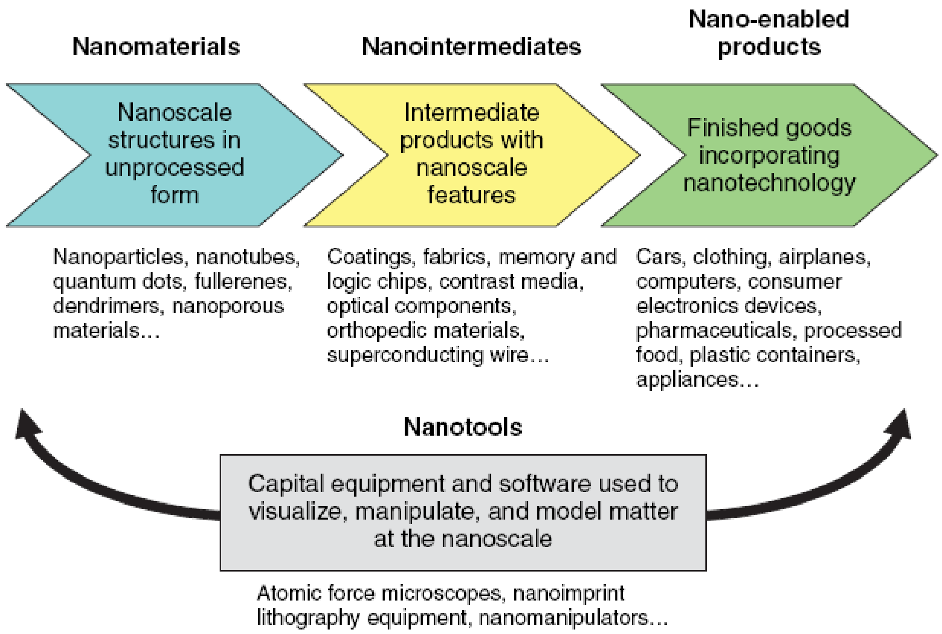
3) Governance of nanotechnology: Several developed countries encourage different ways of public participation to assess nanotechnology development; however this is very rare in developing countries (Invernizzi et al., 2008). This also brings the problem that risks cannot be handled by the governments of developing countries. As a conclusion, these countries may be adversely affected by the pollution or health problems created by nanoparticles and other nanomaterials because they are late to implement legal changes to prevent the possible dangerous effects of nanoparticles and nanomaterials.

The dispute on nanotechnology becomes more crystallized when its impact on developing countries are discussed. Some scholars and institutes emphasize that nanotechnology will solve the current problems that the less developed of the world suffer most, i.e. clean water, food scarcity, health related issues, energy, etc. and help to achieve millennium goals refined by the UN (Salamanca-Buentello et al., 2005; Meridian Institute, 2005; Hassan 2005). However, nanotechnology has come into a world in which wealth is highly concentrated and inequalities are alarming. Therefore, it is not expected from nanotechnology to alleviate these problems but give rise to new, more comprehensive problems (Invernizzi et al., 2008); magnifying global inequalities by fostering a nanodivide (Mehta 2008; Sheetz et al., 2005; Maclurcan 2005).

2.4 Economics of nanotechnology

According to Lux Research, nanotechnology impacted 254 billion USD worth of products (in other words, the worth of all products using any form of nanotechnology) in 2009 (Forfas, 2010). Today, nanotechnology is widely used in textile, cosmetics, sunglasses, and sport equipments. Some of the well known applications of nanotechnology are: glass coated with titanium oxide nanoparticles that react to sunlight to break down dirt; nanotechnologies used to reinforce certain properties of car bumpers; sunglasses using protective and antireflexive ultrathin polymer coatings; textiles improved with nanotechnology for waterproofing, windproofing, UV protection, antibacterial or guarding against electrostatic discharges; sunscreens with nanoparticles such as titanium dioxide; anti-wrinkle creams with polymer capsules to transport active agents to under skin; or televisions, LCD screens (OECD 2009b). However, in the medium term, new products powered by nanotechnology are foreseen, such as much smaller but powerful computers; nanostructured drugs, drug delivery systems targeted to specific organs, sensors for labs-on-chip, bio-compatible replacements, cancer research; bio-sensors; or new types of batteries, quantum well solar cells, safe storage of hydrogen for use as a clean fuel. These foreseen nanoproducts seem to provide solutions to our most current problems related to energy efficiency, environmental and health related issues, improving the quality of life, etc.

Lux Research view nanotechnology as a value chain of materials, intermediaries and end products which are supported by nano tools, i.e. STM and AFM (Figure 2.2). Indeed, since there is no single nanotechnology industry but instead nanotechnology developers applying new products and know-how that add value to a wide range of existing industries, such a value chain framework can be used to visualize the role that nanotechnology applications play from raw materials through to the final goods (Forfas, 2010). Within the value chain of nanotechnology while some firms working on producing nanomaterials some others working on the applications in more complex structures such as targeted drugs, energy storage devices or nano-bio devices. More importantly, Shapira et al. (in press) posit that the entry of corporations into nanotechnology commercialization will reflect some general characteristics of the national innovation systems of their countries. This reflects that nanotechnology firms from developing countries would be at the lower end of this value chain.



Source: Bünger (2008)

Figure 2.2 Nanotechnology value chain by Lux Research

Nanomaterials are purposely engineered materials or structures with at least one dimension of less than 100 nm. Among nanomaterials, carbon nanotubes, fullerenes, metal and oxide nanoparticles, or dendrimers can be spoken out. On the other hand, nanointermediaries are neither raw materials nor goods that represent final consumption, but they have been constructed as something new with nanoscale features; e.g. headwaters' nanocatalysts which are used to convert heavy oils into usable fuels[10]; or memory chips, coatings, optical components, superconducting wire (Bürgen, 2008). Nanoenabled products are finished goods such as clothings, pharmaceuticals, computers, processed food etc which incorporate nanomaterials and nanointermediaries. While the nanointermediaries segment is the most dynamic

[10] Lux Research Nanotech Index. Available at http://www.luxresearchinc.com/pxn.php accessed on Oct 25, 2010.

in present and it is populated by start-ups; end-products segment is mainly populated by large and established firms (Palmberg and Nikulainen, 2006).

In this section, some important points related to the economics of nanotechnology will be reviewed. Expectations and forecasts about the economic impact of nanotechnology, investment and funding for nanoscale research, patenting, the nature of nanotechnology innovations, barriers to the commercialization of nanotechnology and university-industry technology transfer in the field of nanotechnology are the main headlines which will be included in this part.

2.4.1 Future expectations and worldwide nanotechnology investments

The proposition that nanotechnology provides a great opportunity to address global challenges has increased the expectations related to the future of nanotechnology and also R&D investments in terms of public and corporate fundings. In spite of the aforementioned controversies regarding to how radical nanotechnology is and how radical its effects are going to be, estimations on the impact of nanotechnology on product and labor markets are very optimistic. Among those estimations the best known is the one made by National Science Foundation (NSF) of the USA in 2001; NSF estimated a world market for nanotechnological products of 1 trillion USD for 2015 (Roco 2001; 2005; Hullman 2007; EC 2006) and a need for two million workers in nanotechnology and about three times as many jobs in supporting activities (Roco 2001, 2005).

Due to some differences regarding to the definition of nanotechnology and its contribution to the added value of the final products, estimations vary between a moderate level of 150 billion USD in 2010 (Mitsubishi Institute, 2002, as cited in Hullman, 2007) and a very optimistic level of 2.6 trillion USD in 2014 (Lux Research, 2004). In 2008, Lux Research has increased the forecast for the global nanotechnology market in 2015 up to 3.1 trillion USD[11] but after the economic downturn in 2009 again decreased to 2.5 trillion USD[12]. An Indian based market research company RNCOS expects that nanotechnology incorporated manufactured goods will worth 1.6 trillion USD in 2013[13]. Cientifica, a consultancy company based in London, predicts a global nanotechnology market in 2015 of 1.5 trillion USD excluding semiconductors and 2.95 trillion USD including semiconductors [14].

In the market forecasts, reference is made to the whole set of products along the value chain that are believed to become affected by nanotechnology. However, the critical issue in interpreting these market forecasts is the definition of nanotechnology products. In other words, the most optimistic market forecasts refer to the total market value of all end-products that embody a nanotechnology component, rather than the value the component. They calculate the market value of the end product not the value of the "nano-contribution". For example, if a tenth of a gram of a nanocoating, which costs 10 Euro cent, is present in a dose of a drug costing 100 Euro then the value of this 'nanotechnology product' would be calculated as 100 Euro not as 10 Euro cent (OECD 2009a).

On the other hand, there are more modest reports focusing on the specific impact of nanotechnology on product values. BCC Research, in the nanotechnology report entitled "Nanotechnology: A Realistic Market Assessment" states that

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[11] "Nanotechnology boom expected by 2015" article published by Industry Week. Available at http://www.industryweek.com/articles/nanotechnology_boom_expected_by_2015_16884.aspx?SectionID=35 and http://www.luxresearchinc.com/press/RELEASE_Nano-SMR_7_22_08.pdf accessed on Oct 14, 2010

[12] "The Recession's Ripple Effect on Nanotech" report by Lux Research available at https://portal.luxresearchinc.com/research/document_excerpt/4995, accessed on Oct 16, 2010

[13] Nanotechnology Market Forecast to 2013 by RNCOS (March 2010). Available at http://www.rncos.com/Market-Analysis-Reports/Nanotechnology-Market-Forecast-to-2013-IM185.htm , accessed Oct 14, 2010

[14] "Debunking the trillion nanotechnology market size hype" article available at http://www.nanowerk.com/spotlight/spotid=1792.php accessed on Oct 15, 2010

worldwide sales revenues for nanotechnology were around 11.6 billion USD in 2009 and are expected to increase to more than 26 billion USD in 2015[15]. This report seems to provide a more realistic assessment of the growth in sectors with the stimulus of nanotechnology. The report states that the largest nanotechnology segments in 2009 were nanomaterials, with sales reaching 9 billion USD and this segments is expected to grow to more than 19 billion USD in 2015. Sales of nanotools, meanwhile, will experience high growth. From a total market revenue of 2.6 billion USD in 2009, the nanotools segment will reach a value of 6.8 billion USD in 2015. Sales of nanodevices, on the other hand, will experience moderate growth from 31 million USD in 2009 to nearly 234 million in 2015[16]. A spin-out company of Institute of Nanotechnology (in the UK), Nanoposts, worked on the impact of nanoscale technologies within existing market sectors and and reported that total revenue of 2.66 billion USD from nanotechnology usage in 2007 is expected to grow to 85.7 billion USD by 2015 (Mini-IGT 2010). Although it is expected that nanotechnology will affect a range of industries and sector, its impact on these industries will not be the same. For example, nanotechnologies impact on ICT is expected to be tremendous compared to other sectors. Table 2.3(a) ve Table 2.3(b) provides the expected impact of nanotechnologies on different sectors and technology fields. Table 2.3(a) provides the potential impact of nanotechnology on some fields with higher importance as based on the forecast made by NSF (1 trillion USD nanotechnology market in 2015); and Table 2.3(b) reports Nanoposts' forecast regarding the nanoscale impact on different sectors.

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[15] Nanotechnology: A Realistic Market Assessment by BCC Research (July 2010). Available at http://www.bccresearch.com/report/NAN031D.html, accessed on Oct 13, 2010.

[16] "Nanotechnology market forecasts - what a difference a trillion makes" article available at http://www.nanowerk.com/news/newsid=17582.php accessed on Oct 14, 2010

Table 2.3(a) Potential impact of nanotechnology on some technology fields

	Total market value of products using any form of nanotechnology 2015 (Million USD)
Electronics	300,000
Materials and chemicals	440,000
Biology and medicine	210,000
Energy, environment, transportation	235,000
Total	~1,000,000

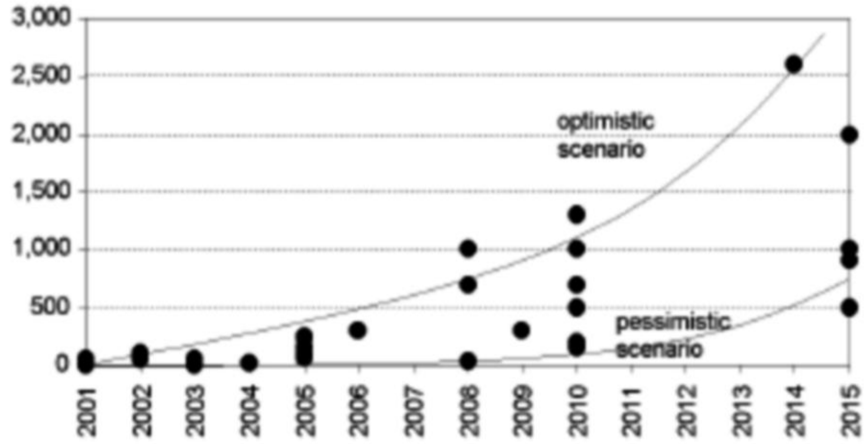
Source: Tolles and Rath (2003)

Table 2.3(b) Potential impact of nanotechnology on some sectors (Nanoposts)

	Contribution of nanotechnology to the values of products in 2007 (Million USD)	*Predicted contribution of nanotechnology to the values of products in 2015 (Million USD)*
ICT	585	41,402
Automotive	404	7,134
Shipbuilding	357	4,295
Aerospace and defense	323	3,768
Food and drink	265	3,210
Consumer goods	188	6,225
Life sciences	145	5,670
Textiles	122	2,170
Energy	90	3,615
Environment and water	86	3,885
Construction	66	1,672
Brand and product security	30	2,650
Total	2,661	85,696

Source: Mini-IGT (2010)

One interesting point regarding aforementioned forecasts (Figure 2.3) is that all “predict a substantial increase of the market for nanotechnological products with a take off somewhere in the early 2010s” (Hullman, 2007; EC, 2006). The same argument can also be observed in data provided by UK nanotechnology report (Mini-IGT 2010).



Source: Hullman (2007)

Figure 2.3 Representation of different scenarios for nanotechnology market upto 2015

It is very difficult to decide whether these scenarios about the possible impact of nanotechnology on the global economy are overoptimistic and just expressions of a wish or reflections of a real opportunity. Lux Research calculates nearly a ten-fold increase in the worth of nanotechnology incorporated products in the next five years until 2015[17]. This idea is simply based on the expectation that between 2010 and 2014 a commercialization boom will occur. This expectation is

[17] "The Recession's Ripple Effect on Nanotech" report by Lux Research available at https://portal.luxresearchinc.com/research/document_excerpt/4995, accessed on Oct 16, 2010.

the main rationale behind the rapidly growing public funding for nanotechnology R&D at the global scale.

Roco (2005) reports that the worldwide investment in nanotechnology R&D reported by national governmental organizations and European Commission has increased approximately 9 fold –from 432 million USD in 1997 to 4.1 billion USD in 2005. On the other hand, Lux Research estimated a 9.6 billion USD spending made on nanotechnology R&D worldwide in 2005 and 13.5 billion USD in 2007[18]. According to the nanotechnology report prepared by Lux Research (2006), in 2005, 1.7 billion USD of nanotechnology investments was made in North America (mostly in the USA), another 1.7 billion was invested in Asia (dominated by Japan) and 1.1 billion was in Western Europe. The rest of the world invested only 100 million USD on nanotechnology R&D. The global spending on nanotechnology R&D had doubled in three years and reached 18.2 billion USD in 2008 at the global scale. In this amount of spending the amount of government funding ballooned to 8.4 billion USD, corporate spending edged to $8.6 billion, and venture capitals (VCs) provided 1.2 billion USD[19]. The amount of investment in nanotechnology has been still radiply increasing; i.e. the US government's 2011 budget provides 1.8 billion USD merely for the NNI which is the broadest financial support provided for this initiative since the beginning. This budget document[20] clearly states the rationale behind this support is "nanotechnology's potential to vastly improve our understanding and control of matter at the nanoscale, ultimately leading a revolution in technology and industry for the benefit of the society".

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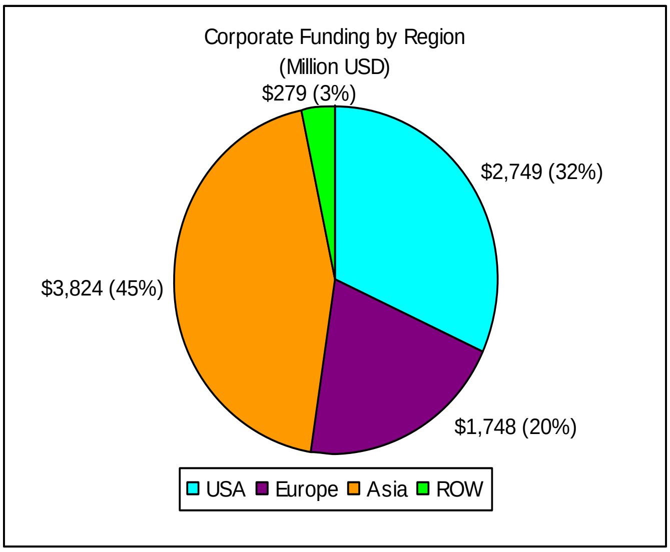
[18] http://www.luxresearchinc.com/press/RELEASE_Nano-SMR_7_22_08.pdf accessed on Oct. 17, 2010.

[19] "Cleantech's Dollar Investments, Penny Returns" Lux Report in the article "Nanotechnology Intermediates Generate Twice the Profit Margins of Nanomaterials and Nano-Enabled Products" available at http://www.nanowerk.com/news/newsid=8975.php, accessed on Oct 16, 2010.

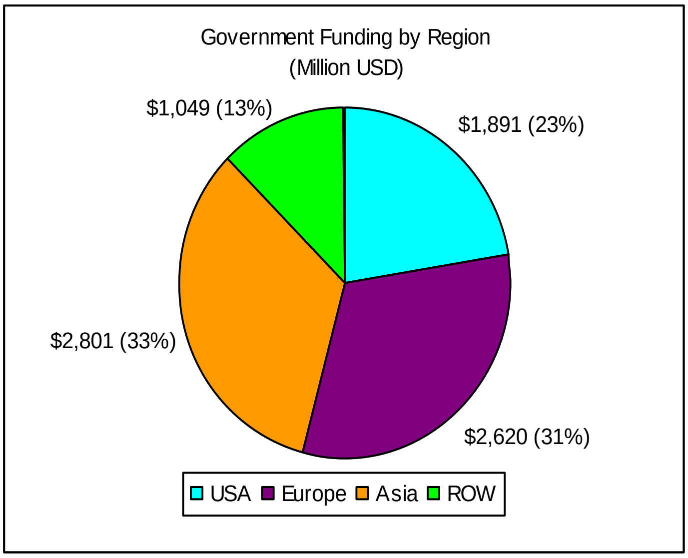
[20] http://www.nano.gov/NNI_2011_budget_supplement.pdf accessed on Oct. 14, 2010. The report entitled "Supplement to the President's 2011 Budget" is prepared by National Science and Technology Council.

However, the amount spent for nanotechnology research is concentrated certain regions (Figure 2.4(a) and Figure 2.4(b)); these are namely USA, Europe and Asia (especially three countries Japan, China and South Korea). The rest of the world spent only 13 percent of the total nanotechnology government funding and only 3 percent of the total corporate funding. Asian countries have the highest share in the total amount of corporate funding; on the other hand USA is appeared as the leading country in nanotechnology R&D investments (Forfas, 2010).



Source: Forfas (2010)

Figure 2.4(a) Global corporate spending by region, 2008



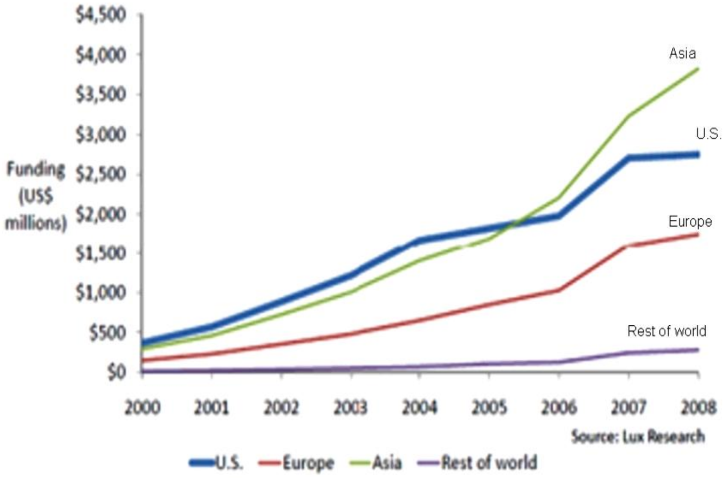
Source: Forfas (2010)

Figure 2.4(b) Global government spending by region, 2008

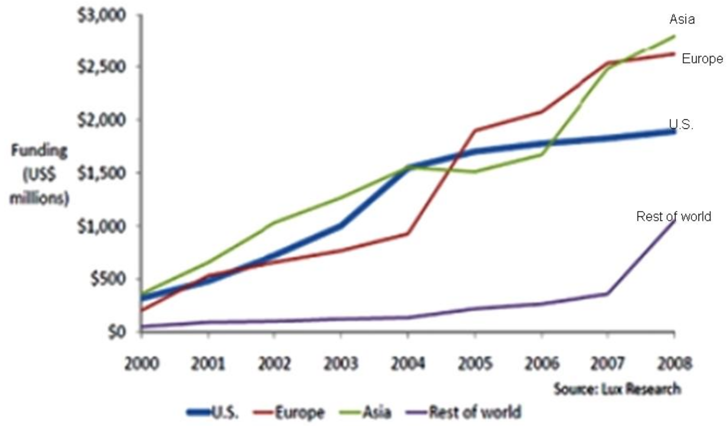
Figure 2.5 indicates the declining leading role of the USA in nanotechnology research. In the USA one certain concern is the dramatically increased economic competition from other countries. While the USA was a global leader in government and total funding provided for nanoscience and technology R&D, after 2005 the USA fell behind the regions, Asia and Europe. Figure 2.5 shows the changes in the government and total funding dedicated to nanotechnology research in years and regions[21].

[21] National Nanotechnology Initiative Review: Assessments and Recommendations March 12, 2010. Available at http://www.whitehouse.gov/sites/default/files/microsites/ostp/pcast-nano.pdf accessed on Oct 17, 2010.

Total funding from all sources (government, firms, venture capital)



Total funding from government



Source: National Nanotechnology Initiative Review: Assessments and Recommendations [24]

Figure 2.5 Changes in the nanotechnology funding by years and regions

Another interesting point about nanotechnology R&D investments is that the structure of the nanotechnology spending differs in regions. While in Asian countries and the USA the corporate spending on nanotechnology is as high as government funding, in the EU region the government funding is the most important source of the rapid growth of nanotechnology research. In the EU 70 percent of nanotechnology research was funded by either national governments or EU funds (European Commission, 2005). In EU region, public funding may help European countries for catching up with the USA and Japan in the field of nanotechnology.

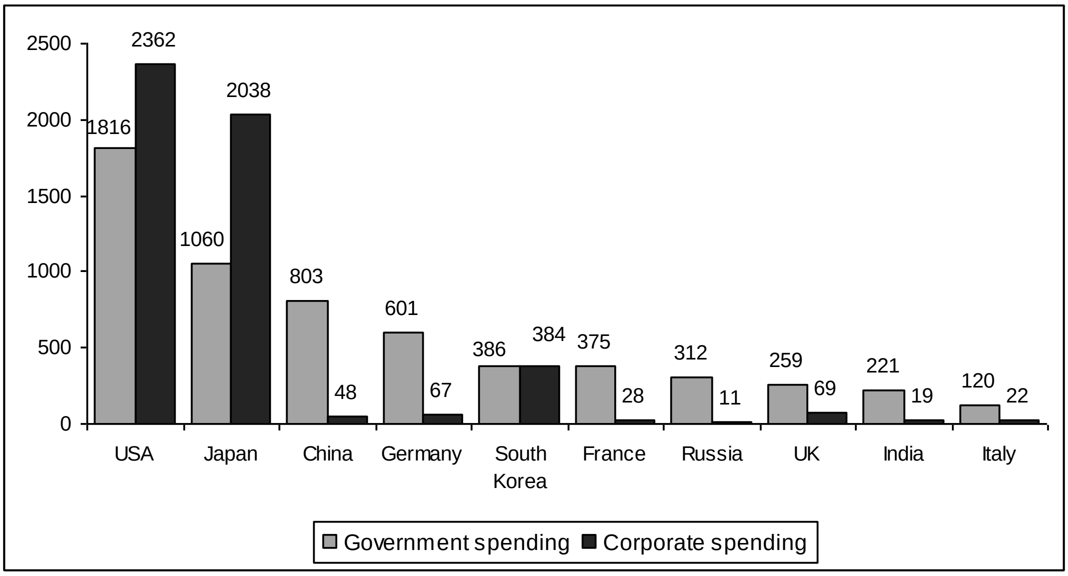
In EU area, Research Framework Programmes (FP6 and FP7) have an important role in funding nanoscale research. FP6 includes nanotechnologies and nano-sciences, knowledge-based multifunctional materials and new production processes and devices among its priority areas and one billion Euro is allocated for the period 2002-2006; and over the duration of FP7 the EU have earmarked a total 3.5 billion Euro for funding the theme entitled "Nanosciences, nanotechnologies, materials & new production technologies (NMP)"[22]. Among the countries associated to the EU Framework Programme, the most prolific countries in terms of the public funding of nanotechnology R&D are Germany (320.3 million Euro), France (246.7 million Euro) and the UK (130.1 million Euro) (European Commission, 2005).

In Asia, Japan is the leading country in nanotechnology R&D. In 2004, 28 percent of total nanoscale research spending (public and private) in the region was made in Japan. On the other hand, Japan differs from other regions and countries with a low level of government funding. While only 19% of worldwide public funds was provided in that country 37% of corporate spendings on nanotechnology research was made by Japanese firms (European Commission, 2005).

The public and private funding figures of the last five-year period between 2005 and 2010 confirm the dominance of certain countries, namely the USA, Japan, Germany, France and the UK. However new players have entered into the global nanotechnology race. For example, the Netherlands, Ireland, Belgium and South Korea have invested relatively higher share of their total public R&D investments in nanotechnology compared with, for instance Japan and USA. The share of total R&D investments in nanotechnology of some other countries, such as Denmark,

[22] The data is available at http://cordis.europa.eu/fp7/cooperation/nanotechnology_en.html accessed on Oct 17, 2010

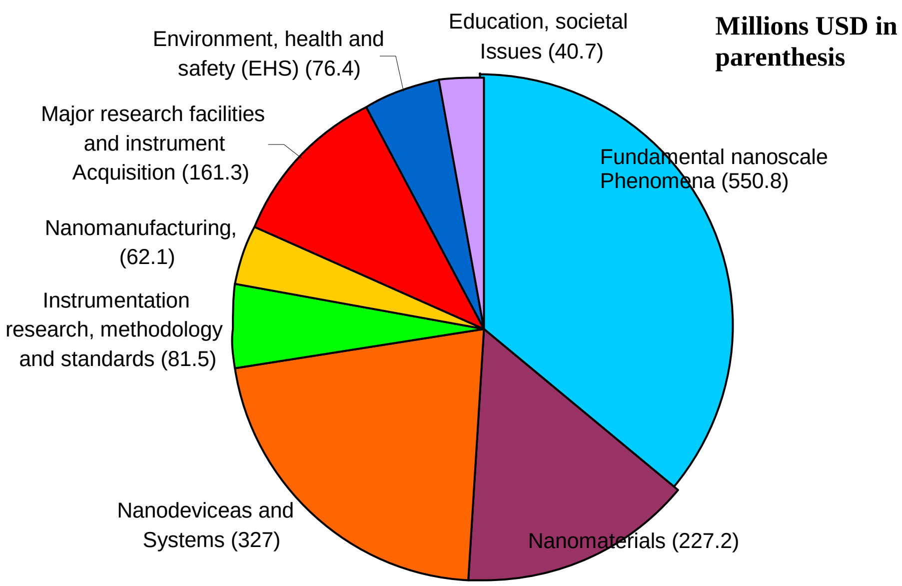
Austria, Finland and Norway, are on similar levels to Japan and USA (OECD 2009a). Some developing countries have spent much on nanotechnology research not to fall behind their competitiors in the nanotechnology race. China's nanotechnology R&D investment is estimated to be about 250 million USD in 2008 (Guan and Ma, 2007). In Taiwan, the public funding made for nanotechnology has reached to 120 million USD in 2008 (Mini-IGT 2010). Finally, it has recently been announced that a nanotechnology funding programme in Russia has been approved, making it the largest one in the world, with 3.95 billion USD earmarked until 2015 (Mini-IGT 2010, OECD 2009a). Figure 2.6 provides the difference among countries in terms of public and private nanotechnology funding (Huang and Wu, 2010).



Source: Huang and Wu (2010)

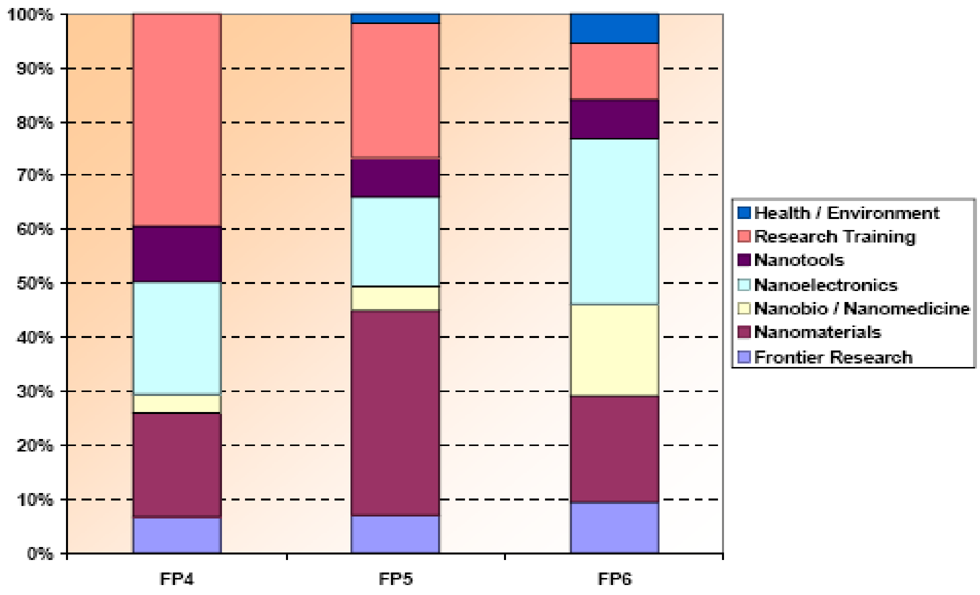
Figure 2.6 Government and corporate spending PPP (Millions USD) 2005-2007 estimations

The program component areas funded by NNI indicates that public fundings in the USA mainly allowed for the research on fundamental nanoscale phenomena (36 percent) or in other words for basic research at nanoscale. Other major research areas are nanodevices (21 percent) and nanomaterials (15 percent). On the other hand, only 5 percent of the NNI fundings are allocated to 'environment, health and safety (EHS)' issues; and 3 percent to 'education and societal issues' (Figure 2.7). In the European region, 'nanomaterials', 'nanoelectronics' and 'nanobio/nanomedicine' have appeared as the main nanotechnology R&D areas supported by framework programmes (Figure 2.8).



Source: PCAST 2008

Figure 2.7 NNI funding of the USA by program component area, 2009



Source: European Commission (2005)

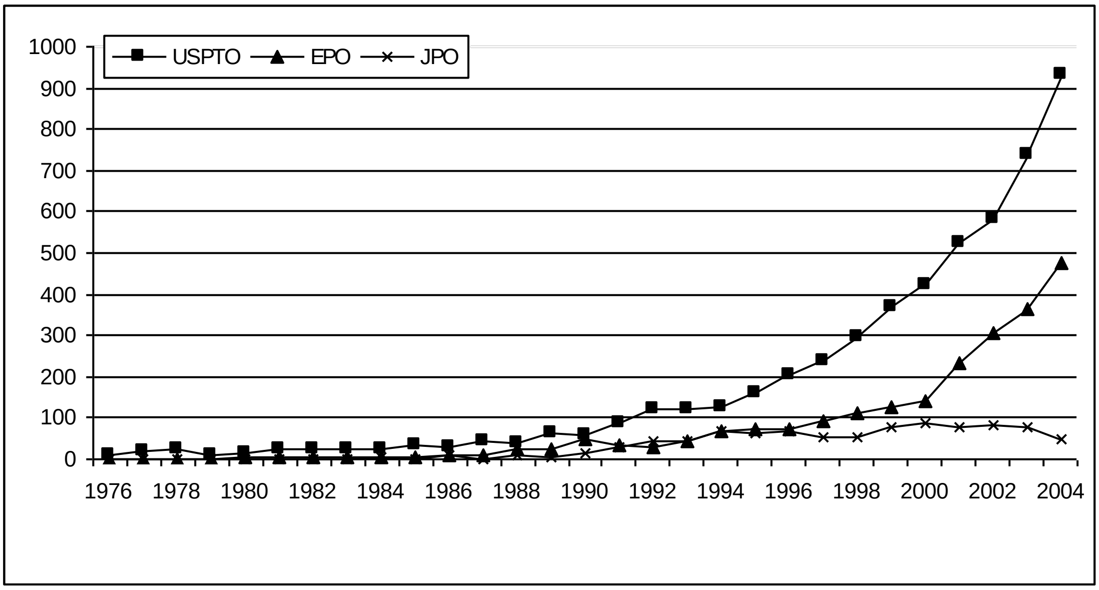
Figure 2.8 Nanotechnology R&D areas supported by EU Framework Programmes

The future market expectations of nanotechnology and funding for nanoscale research ignite each other. Enthusiastic explanations about nanotechnology, such as nanotechnology will be the next industrial revolution, the 6th Kondratieff Cycle (Wonglampiyarat, 2005) and will change the industrial and market structure increases market expectations; these expectations justify both public and private fundings for nanoscale research; and increase the share of budget allocated to nanotechnology; and vice versa. In conclusion, both funding schemes for nanotechnology and future expectations about nanotechnology's impact on product markets support and are supported by the myth of nanotechnology.

2.4.2 Growth in nanotechnology patents

Patents are often used as indicators of technological innovations. In the field of nanotechnology, patent analysis is a widely used method for examining the growth in nanotechnological innovations, the geographical concentration of these innovations, and investigating trajectories in nanotechnology (Huang et al., 2003; 2004; Li et al., 2007a, 2007b; Dang et al., 2010; Alencar et al., 2007; Meyer, 2007). Although all these studies use different methodologies for the detection of nanotechnology-related patents (i.e. searching for some nanotechnology related keywords in the title, abstract or full text of the patent documents) they all confirm that the number of nanotechnology patents and patent applications has been continuously growing.

Li et al. (2007a) provide evidence that the number of nanotechnology patents registered in USPTO and EPO has rapidly grown especially since the beginning of the 1990s (Figure 2.9). Furthermore, the worldwide annual growth rate of the number of nanotechnology patent applications in the period from 2000 to 2008 is nearly 34.5% and it is higher than the rate of increase in the number of Science Citation Index nanotechnology articles which is around 25% (Dang et al., 2010) (Table 2.4). In this table, China takes the second rank with a huge number of nano-patent applications just after the USA. Alencar et al. (2007) note a six fold increase in China’s nanopatents in the period between 2002 and 2005.



Source: Li et al. (2007a)

Figure 2.9 Number of nanotechnology patents granted in USPTO, EPO and JPO (1976-2004) (title-abstract research23)

[23] It indicates that title and abstracts of patent documents are research for some predetermined keywords used to delineate the field of nanotechnology.

Table 2.4 Nanotechnology patent applications published in the top 15 countries /regions' patent offices in the interval 1991 to 2008

Rank	*Patent office (repository)*	*No. of nanotechnology patent applications (1991-2008)*	*Year 2000*	*Year 2008*
1	USA	19,665	405	3,729
2	China	18,438	105	5,030
3	Japan	10,763	328	1,744
4	South Korea	5,963	74	1,249
5	Canada	1,539	41	255
6	Taiwan	1,363	28	3
7	Germany	1,312	62	70
8	Australia	1,296	76	136
9	Russia	859	45	162
10	Mexico	471	0	88
11	UK	412	14	68
12	France	390	8	38
13	Brazil	315	0	103
14	Ukra55 ine	243	0	83
15	New Zealand	140	11	18

Source: Dang et al. (2010).

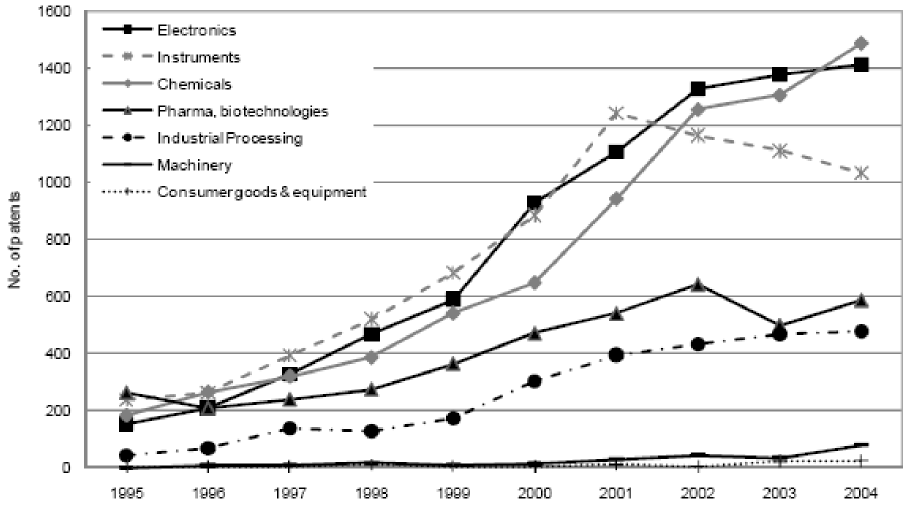
The investigation of assignee countries in the field of nanotechnology shows that a few countries are the main actors in the nanotechnology innovations. The top five assignee countries in USPTO and EPO are the same, namely the USA, Japan, Germany, France and South Korea (Table 2.5). In the USPTO, for the interval 1976-2004, the institute with the highest number of patents is IBM; it is followed by The Regents of the University of California, the Secretary of the Navy of the USA, Eastman Kodak Co. and 3M. The top assignee institutions had long histories in nanotechnology research which are indicated by a five year patent age (i.e. the number of years passed after a patent is granted) on average. On the other hand, in EPO, L'oreal from France has the highest number of patents; and it is followed by three companies from the USA, namely IBM, Rohm & Haas, and Eastman Kodak Co. and from Korea Samsung Electronics Co. Ltd. In general, the average age of the top 20 EPO assignee institutes' patents is four years (Li et al., 2007a).

Table 2.5 Top 10 assignee countries in USPTO and EPO

USPTO, 1976-2004			**EPO, 1978-2004**		
Rank	*Assignee country*	*Number of patents*	*Rank*	*Assignee country*	*Number of patents*
1	United States	3,450	1	United States	925
2	Japan	517	2	Germany	343
3	Germany	204	3	Japan	323
4	France	156	4	France	201
5	Rep.of Korea	131	5	Rep.of Korea	98
6	Canada	104	6	Switzerland	77
7	China (Taiwan)	71	7	U. K.	72
8	U. K.	60	8	Netherlands	51
9	Netherlands	54	9	Belgium	42
10	Switzerland	41	10	Italy	34

Source: Li et al. (2007a)

The examination of nanotechnology patents by application fields in Figure 2.10 points to the rapid growth in nanotechnology patents in two application areas; namely electronics and chemicals. Although patenting in nanoinstruments had rapidly grown until 2001 after that year the growth rate of nanoinstrument patenting has slowed down in comparison to nano-patents related to electronics and chemicals. These three application area are followed by pharma/biotechnology and industrial processing.



Source: OECD (2009a).

Figure 2.10 Number of nanotechnology patents by application area

One special feature that needs to be emphasized about nanotechnology patents is the strong impact of scientific literature which is measured by citations made to academic articles in patent documents. Meyer (2000a; 2000b) and Hu et al. (2007) are among the studies investigating the relationship between science and technology using patent citations. Hu et al. (2007) analyze nanotechnology-related patents from 1976 to 2004 at USPTO and find that the number of patents and article citations in patent documents has increased faster in this interval for nanotechnology field as compared to other technology fields. The results of this study show that about 60 percent of nanotechnology related patents have on average approximately 18 academic citations. Moreover, authors identify two major technology fields in nanotechnology based on citation patterns: (i) chemical/pharmaceutical fields with an average patent citing about 40 articles; and (ii) the materials/semiconductor fields with an average patent citing about 10 articles. Furthermore, USPTO patent data indicates that the share of universities as assignee institutes has recently grown. Wang (2007) points out that the average annual growth rate between 1990 and 2005 was 12 percent for industry patents and 30 percent for university patents. While the share of industry patents decreased from 88 percent in 1990 to 68 percent in 2005 the share of university patents among USPTO nanotechnology patents reached 22 percent in 2005 from 6 percent in 1990.

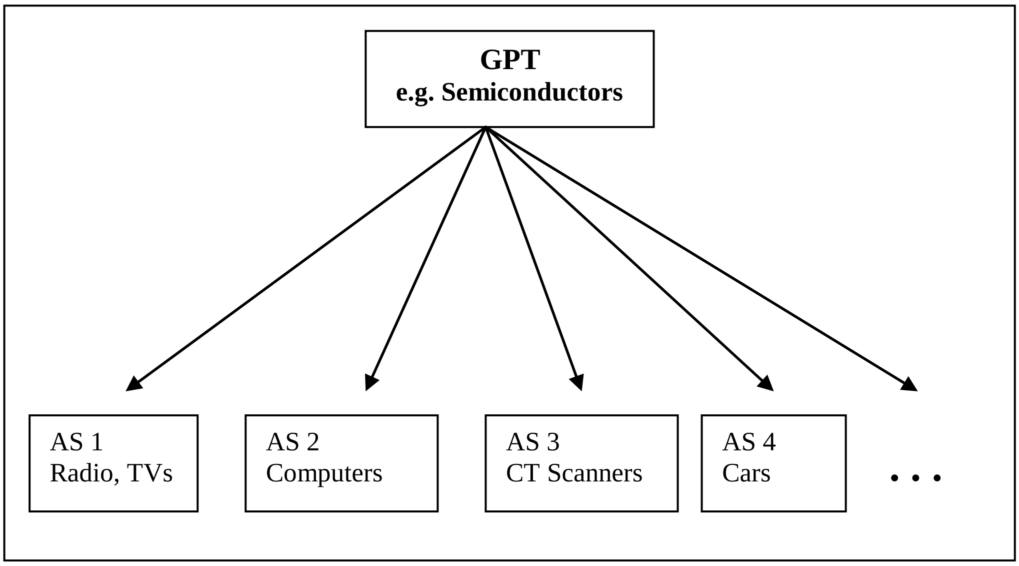
2.4.3 Nature of nanotechnology innovations

2.4.3.1 Nanotechnology as a general purpose technology

Some scholars working on nanotechnology emphasize that nanotechnology is a general purpose technology (GPT); some others argue that it might be a GPT in the near future, however, it is very difficult to confirm this argument in this very early period of the technology (Shea, 2005; Youtie et al., 2008; OECD, 2009a; Ott and Papilloud, 2007; Palmberg and Nikulainen, 2006). In this section, the discussions on whether nanotechnology is a GPT and the possible impacts of its being a GPT will be briefly examined.

Economists have acknowledged technical change as an important force driving economic growth at least since the second half of the nineteenth century (Kuznets, 1966; Abramovitz, 1956; Solow, 1957); and the role of some specific key technologies, i.e. steam engine, factory system, electricity, semiconductors in the process of growth are investigated by some scholars (Landes, 1969; Rosenberg, 1982; Freeman and Perez, 1988; Mokry, 1990; Freeman and Louçã, 2001). Mokry (1990) calls macro inventions those “in which a radical new idea, without clear precedent, emerges more or less ab nihilo”; Lipsey and Bekar (1995) call “enabling technologies” which are defined by their extensive range of use; David (1990) calls general purpose engines around which techno-economic regimes formed; and finally Freeman and Perez (1988) call for the concept of a "techno-economic paradigm" which is systematically related to changes comes from a key technology.

Bresnahan and Trajtenberg, in their prolific work entitled "General purpose technologies: engines of growth" (1995) take a step further and investigate what is it about the nature of these technologies which plays an important role in economic growth. As can be seen in Figure 2.11, they define technologies in a tree-like structure with a few primemovers located at the top which are identified as GPTs and all other technologies applied in different sectors at the bottom (Lipsey et al., 1998).



Source: Bresnahan and Trajtenberg (1995)

Figure 2.11 Treelike structure of a GPT

GPTs are “enabling technologies” opening up new opportunities rather than offering complete, final solutions (Bresnahan and Trajtenberg, 1995). Rosenberg (1998) identifies chemical engineering as a GPT and, hence, defines GPT not as necessarily confined with hardware i.e. computers but rather a discipline that provides the concepts and methodologies to generate new or improved technologies over a wide range of downstream economic activity.

Three primary characteristics of GPT can be identified in Brenahan and Trajtenberg’s (1995) (see also Jovanovic and Rousseau 2003, Youtie et al., 2008):

(i) Pervasiveness: a GPT should be applied in several areas of production

(ii) Innovation spawning: a GPT should make it easier to invent or produce new products and processes; in other words, lead to the development of complementary technologies.

(iii) Scope for improvement: a GPT should get better over time, reach a certain level of efficiency and decrease the costs for its users; hence, its adoption becomes convenient.

Youtie et al. (2008) and Palmberg and Nikulainen (2006), by considering aforementioned characteristics of a GPT, examine whether nanotechnology is a GPT or not. Both of these studies use patent data to investigate the GPT characteristics of nanotechnology. However, these studies are not the only ones arguing that nanotechnology is a GPT; before them Shea (2005) suggests that nanotechnology is a GPT because it is disruptive and radical. However, being radical and disruptive are neither necessary nor sufficient for a GPT (Youtie et al., 2008).

These efforts to define the main characteristics of a GPT are not only used for the ex-post identification of GPTs but also allow ex-ante identification of some technologies which have the potential to become GPT (Lipsey et al., 1998). As noted by Youtie et al. (2008), identification of GPTs is important in terms of

(i) R&D policy: These policies aim to spur innovation; and the improvements in a GPT stimulate innovations in various sectors of the economy. Therefore, creating incentives for innovators related to GPT can possibly foster the diffusion of innovations due to vertical and horizontal externatilies.

(ii) Economic growth: Investigating whether a technology is a GPT is important to understand the source of economic expansions and slowdowns. In the first phase after the introduction of a GPT, a decrease in the productivity is expected because this technology is not effective or adopters do not possess the necessary skills and knowledge to use them efficiently. Solow in 1987 summarizes this problem in one sentence for ICT: "you can see computers everywhere except in productivity figures"

(iii) Social synchronization: For the adoption of GPTs and coordination between inventors and users in application sectors, the expectations about the usefulness of the emerging technology are important. These expectations play a key role in decisions to invest in the main and complementary technologies. Therefore, GPTs require a high level of synchronization in society; and the identification of a GPT can be beneficial in allowing society to plan for a needed synchronization.

Although nanotechnology as a GPT has been widely pronounced by some scholars, some others emphasize that there is no one nanotechnology but nanotechnologies; hence, some would be a GPT, some would be part of a new GPT, but many others would emerge without having any transformative effect (Valdivia, 2008).

2.4.3.2 Nanotechnology as a new techno-economic paradigm

A number of GPTs along the history of technology can be identified in different fields such as railways and motor vehicles in transportation; or steam and electricity in power delivery systems; or ICT, internet, lasers, factory system, flexible manufacturing, mass production (Lipsey et al., 1998) or chemical engineering (Rosenberg, 1998). All these have certain externalities and have an impact on economic growth. The concept of GPT aims to understand what it is in the nature of a technology which plays a key role in economic development but is not specifically concerned about other social, economic and political factors surrounding this key technology. Hence, because of the radical and possibly disruptive nature of nanotechnology, some scholars emphasize that it is likely the paradigm leading technology of the sixth Kondratieff cycle (Wonglimpiyarat, 2005; Drechsler, 2009, Islam and Miyazi 2010). A list of Kondtratieff cycles is provided in Table 2.6.

Dosi (1988) makes an analogy with scientific paradigms and defines a technological paradigm as a “pattern of solution of selected techno-economic problems”. Like scientific paradigms, technological paradigms embody an outlook, a definition of the relevant problems, and a pattern of enquiry. On the other hand, Freeman and Perez (1988) call for another concept of “techno-economic paradigm” which considers the pervasive effects of a technological change throughout the economy. These types of technological changes not only lead to the emergence of a new range of products, services or systems and industries but also affect - more or less, directly or indirectly- different branches of the economy. Hence, techno-economic paradigms go beyond the concept of “technological paradigms” of Dosi (1988) which is limited to engineering trajectories. According to Freeman and Perez (1988) key technologies create new investment opportunities and potential for increasing productivity and profits; hence, once the new technology is widely adopted, the change is generally irreversible due to pervasive economic and technological advantages created and complementarities. On the other hand, wider societal problems might occur in the transition from one techno-economic paradigm to another, i.e. the structural crisis of the 1980s as a consequence of a transition to the techno-economic paradigm of information and communication technology.

Table 2.6 Schumpeterian long waves

Kondratieff Cycles	*Period*	*Description*	*Key factor of economic development*
First Kondratieff	1780s-1840s	Early mechanization, especially textiles	Cotton
Second Kondratieff	1840s - 1890s	Age of stream power and railways	Coal
Third Kondratieff	1890s-1940s	Age of electrical and heavy engineering	Steel
Fourth Kondratieff	1940s-1990s	Age of Fordist mass production	Energy (esp. oil)
Fifth Kondtratieff	Late 1990s	Age of information, communication and computer networks	Chips, micro-electronics
Sixth Kondratieff	2000s -	Age of nanoengineering and manufacturing	Nanotechnology

Source: Freeman and Perez (1988) and Wonglimpiyarat (2005)

Both GPT and techno-economic paradigms appreciate the role of some key technologies having some common features in nature on economic growth and development. The common presumption among the scholars working on nanotechnology is that it is an enabling technology which would affect many industries in a disruptive way; applied in product and processes in different sectors; adopted by a range of firms; and would radically transform economy and society. Hence, in spite of the fact that nanotechnology is in the very early days of its development and still there are some concerns about engineering trajectories of nanotechnology “many see nanotechnology as the technology that will underlie the next Schumpeterian wave creating new opportunites for wealth and job creation” (Linton and Walsh, 2008).

2.4.4 Barriers to commercialization of nanotechnology

Nanotechnology holds the promise of both incremental and radical innovations; and the potential to transform the existing industries and create new ones. However, higher expectations about nanotechnology and its forecasted impact on the global economy are shadowed by some challenges regarding to the commercialization of nanotechnology products and processes. The barriers pronounced with respect to the commercialization of nanotechnology are (i) lack of standards; (ii) unknown risks, questions about health, environment and safety implications of nanotechnology; (iii) limited/restricted venture capital and, (iv) insufficient education and workforce preparation (PCAST, 2008). On the other hand, the report prepared for The US Department of Commerce[24] is concerned more about the commercialization of university and public lab research results; and the most significant barriers are identified as funding which favors research over development and commercialization; the need for long term funding for start-up nano companies; intellectual property issues; the science culture which is not application-based; and lack of prototyping facilities.

National Center for Manufacturing Sciences in the USA carries out periodic research to measure the impact of nanotechnology on the US manufacturing industry. These studies are based on questionnaire surveys distributed among the manufacturing firms. The last survey was carried out in 2009; and the identified barriers to nanomanufacturing and commercializations were not different from those mentioned in 2003 and 2005 surveys. Among 270 respondents of 2009 survey there was a consensus on the top 10 barriers to nanotechnology commercialization and manufacturing (NCMS, 2010).

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[24] "Barriers to nanotechnology commercialization" Final Report to the US Department of Commerce Technology Administration (September 2007). Available online http://www.ntis.gov/pdf/Report-BarriersNanotechnologyCommercialization.pdf, accessed on Oct. 23, 2010.

(i) Insufficient investment capital to finance nanotechnology developments for the marketplace
(ii) Long time needed for commercialization of research outcomes requiring patient capital
(iii) High cost of processing nanomaterials
(iv) Lack of process scalability to achieve economical high-volume manufacturing (i.e. for now, nano-materials are mostly produced in very small amounts in laboratories; producing them in high-volumes bring some problems or some nano-properties cannot be achieved in high-volume production; hence, high-volume manufacturing in nanotechnology needs further research and development)
(v) Intellectual property issues
(vi) Regulatory concerns and uncertainty of federal policies
(vii) Environmental, health and safety (EHS) issues
(viii) Materials/process variability result in poor reliability (i.e. the dominant design in most nanotechnologies cannot be achieved yet; therefore, there are various nanotechnologies to solve the same problem; for example there are various different nano-materials for enabling anti-bacterial products)
(ix) Shortage of qualified manpower in nanotechnology
(x) Multidisciplinary issues (i.e. nano-technology production needs collaborations of engineers or technicians from different disciplines).

The available surveys carried out in other countries point to similar challenges for the firms doing nanotechnology R&D. The German nanotechnology survey indicates investment costs, funding, and financial support as the main barriers to nanotechnology commercialization. These finance-related barriers are followed by those related to finding skilled workers and cooperation partners (Malanowski et al., 2006). On the other hand, the survey made among Finnish firms identifies “difficulties in achieving mass production” and “shortage of funding” as the first and second most important barriers to commercialization of nanotechnology research results. These are followed by the challenges related to "identification of commercial applications at universities", "consumer acceptance" and "lack of standards" (OECD, 2009a).

In Australia, the Department of Industry, Tourism and Resources (DTIR) commissioned two surveys in 2005 and 2006 entitled "Nanotechnology business surveys". These surveys scrutinized factors preventing investments in nanotechnology rather than barriers or challenges related to nanomanufacturing and commercialization. "The lack of consumers who demand nanotechnology products" was rated as the primary barrier to investing in nanotechnology. It is followed by "difficulty in securing the right skills in-house to manage developments"; "difficulty in negotiating intellectual property agreements with research partners"; "lack of access to the right research partners" and "lack of access to the right infrastructure" (OECD, 2009a).

Furthermore, Bozeman et al. (2009) collect data to evaluate the main barriers to the diffusion of nanotechnology. At the end of 2005, they collected questionnaires from nanotechnology-based or nanotechnology related companies in North Carolina (USA); and they found that the most important barriers to nanotechnology growth are, from most to least important, (1) access to early stage capital; (2) access to equipment; (3) access to qualified labor force and (4) access to university.

The number of nanotechnology publications and patents has been rapidly grown, however, still in the market, nanotechnology products are very limited. The commercialization of nanotechnology research results obtained in the university or firm labs has not been successfully achieved yet. The main reasons, as showed by the research carried out in different countries, are insufficient investment; lack of process scalability to achieve high-volume manufacturing; lack of regulations including standards and IP; and finally unknown risks of nanotechnology and related EHS issues. The commercialization of nanotechnology takes longer; the time between research and commercialization is estimated to be 3 to 10 years[25]. Therefore, it is difficult to find venture capital or other investment sources. Nonetheless other concerns such as problems related to manufacturing and lack of information about the demand for nanotechnology products affect indirectly the decisions for investing in nanotechnology. As emphasized by Bozeman et al. (2009) "there is a market failure in the capital market because of asymmetry of information about the risk and return associated with the adoption of nanotechnology" and to solve these problems new policies are needed. In conclusion, the success of nanotechnology mostly depends on the elimination of these barriers to nanomanufacturing and commercialization. Especially in the USA and Europe, new funds are allocated for projects aiming mass production and manufacturing of nano-products; and also to eliminate the doubts related to the unknown risks of nanotechnology.

2.5 Conclusions

This chapter reviewed various interrelated issues about nanotechnology which is simply defined as understanding and control of matter at the nanoscale from 1 nm to 100 nm. Although the history of nanotechnology has dated back to the speech of the prominent physicist Feynman in 1959 at CALTECH, nanotechnology innovations have become possible since the invention of scanning probe microscopies at IBM Zurich labs in the mid-1980s. Therefore, nanotechnology is dependent on instrumentation. Darby and Zucker (2004) identify the invention of the instruments as "the inventions of the method of inventing". This is proved by the tremendous increase in nano-publications and nano-patents since the mid-1980s.

[25] "Barriers to nanotechnology commercialization" Final Report to the US Department of Commerce Technology Administration (September 2007). Available online http://www.ntis.gov/pdf/Report-BarriersNanotechnologyCommercialization.pdf accessed on Oct. 23, 2010.

On the other hand, science policy applied since the beginning of 2000s has played an important role in the creation of the current nano-hype. USA and later EU countries and some late-comers such as China, India, Korea, Brazil or Russia have launched special programs and strategies, huge public funding supports for nanoscale research. Hence, there is a race among countries, including both developed and developing ones, to increase the number of nano-publications, nano-patents and to finally achieve commercialization of nanoscale research across various industries.

In spite of the ongoing debates on the possible outcomes of nanotechnology development; science and innovation policies are designed to support nanoscience and nanotechnology. Moreover with the emergence of the notion of "converging technologies" nanotechnology has been proposed as a platform enabling the convergence of various technologies (i.e. biotechnology, ICT, cognitive science) at the nanoscale. Thus, for developing countries, as well as Turkey, the achievement of nano-convergence has become one of the most important issues in science and innovation policy agenda.

However, while most developing countries, i.e. China, Brazil, India, Russia, Iran, spend a considerable efforts (i.e. special nanotechnology programs, patents and publications) and public funds to increase nanotechnology knowledge accumulation, for which Turkey still does not have a specially designed science policy program, strategy or roadmap to achieve a nano-convergence. Notwithstanding, in Turkish academia there is a growing interest for nanotechnology; and the number of nano-publications and scholars who are interested in nanotechnology have largely increased in the last few years. The following chapter explores nano-scale research at Turkish universities through the investigation of nano-publications and provides a picture of nanotechnology efforts in Turkish academia.

CHAPTER 3

REGIMES OF KNOWLEDGE PRODUCTION AND CHANGING UNIVERSITY-INDUSTRY RELATIONS: AN INTERPRETATIVE SURVEY

The twentieth century ended up with the discussions on the changing relations between science and society; the way in which scientific knowledge is produced; the changing social contract between science and the university (Martin 2003); the mission and / or importance of the universities in the social and economic system; and finally the end of the pure science and, hence, freedom of science and scientists. On the one side of the discussion it is argued that scientific activity has undergone a deep change since the 1980s. However, on the other side, arguments are centered on the idea that the change is not that radical; moreover, what is proposed as radical changes are in fact long standing characteristics of scientific activity since the 16^{th} - 17^{th} centuries.

In section 3.1, we discuss the prominent studies and approaches aiming to understand and systematize the changes in the production of knowledge; and how these changes are connected to the societal changes; also the critics to these approaches will be presented. In section 3.1.1, we examine six different approaches to the change in the scientific knowledge production. It is followed by a section which includes arguments emphasizing that what is proposed as the change in knowledge production is indeed the long standing characteristics of scientific activity for five centuries. Section 3.1.3 discusses the role of universities in the society. Section 3.1.4 explores how nanotechnology research has been affected by the science policies designed under the influence of all these discussions / controversies.

In section 3.2, we focus on the literature investigating knowledge and technology transfer between academia and industry. Section 3.2.1 provides an insight to the literature which takes scientific knowledge as a public good and explores how knowledge spillovers occur from universities to firms. Section 3.2.2 focuses on a second strand of literature which takes the Bayh-Dole Act as the turning point in the university-industry relations, and investigates the extent of technology transfer fromnuniversities to firms through university patenting, licensing or spin-off activities. Section 3.2.3 discusses the most recent approaches to different forms of knowledge and technology transfer (KTT) between universities and firms; finally Section 3.3 concludes the chapter.

3.1 Regime of knowledge production

3.1.1 A new mode of knowledge production

In the last three decades since 1980s, significant changes in knowledge production have been observed by many different authors; theorized and given flashy names (Weingart, 1997), i.e. post-normal science (Funtowicz and Ravetz, 1993), finalization in science (Böhme et al., 1983), academic capitalism (Slaughter and Leslie, 1997), Mode 2 science (Gibbons et al., 1994), post-academic science (Ziman, 2000) and Triple Helix (Etzkowitz and Leydesdorff, 1997; 2000; Etzkowitz et al., 2000). Now, we will briefly examine these six different approches.

3.1.1.1 Finalization in science

Theorists of finalization in science (Böhme et al., 1983) claim that all disciplines follow a general development path from explorative phase to, paradigmatic phase and then to post-paradigmatic phase. In the first phase there is no consensus on a single internal theory or method within the discipline. Therefore, there are several paradigms co-existing together. However, in the second phase, one of these paradigms becomes dominant. In this last stage a discipline reaches a theoretical maturity; it becomes open to orientation in accordance with external objectives; hence, finalization may occur. ‘Finalists’ claim that, in this stage, after the discipline has reached its peak of theoretical maturity, the direction of further progress in discipline starts to be determined by other extra-scientific socio-political objectives and concerns about society (Ceyhan, 2010) .

According to finalists, more and more disciplines reach this phase and, therefore, the relation between science and society is changing; and society now becomes much more active partner of the science (Hessel and van Lente, 2008). Hence, the change in scientific knowledge production, in this approach is consequence of an internal process or internal dynamics rather than an external impetus.

3.1.1.2 Post-normal science

Post-normal science (Funtowicz and Ravetz, 1993) approach does not define or systematize a change in the knowledge production but expresses a need for new modes of knowledge production. Authors argue that normal science in the Kuhnian sense[1] (Kuhn, 1962) is not an adequate mode of knowledge production; and the

[1] According to Kuhn, science is driven by ‘paradigms’ which provides the questions (or puzzles) for scientists and tools for their solutions. However, when the questions or puzzles which cannot be solved by the given paradigm (they are also called ‘anomalies’) a crisis in science arises. At the end, crisis is followed by a scientific revolution if the existing paradigm is superseded by a rival paradigm which solve the arisen anomalies. Thus, in the development of a science, there are ‘normal’ and ‘revolutionary’ (or ‘extraordinary’) phases. In the Kuhnian sense, normal science describes the problem solving activities during the normal phase of scientific development; therefore Kuhn describes normal science as puzzle-solving. In other words, in the normal science period, anomalies are not many, most of the problems or puzzles occurring are solved by the existing paradigm; and what scientists generally do is to solve problems or puzzles with the given paradigm (Kuhn, 1962).

problems can be better handled without questioning the broader framework or paradigm. They invented the term “post-normal science” to offer a new science practice which can cope with uncertainty; and support policy makers in decision-making process (Hessel and van Lente, 2008).

Ravetz (2004) makes a distinction between mainstream and post-normal science; and identifies the main features of mainstream science as follows: (i) it has a reductionist tradition in which complex systems can be studied in its elements and components; (ii) it carries on with inherited attitudes and assumptions of inevitable and irresistible progress; and (iii) it is increasingly linked to industry. On the other hand, post-normal science is defined as precautionary to ensure safety and sustainability. In this new science the most important component is the public participation; all stakeholders should be involved in the problem-solving processes.

Post-normal science, in fact, offers a strategy to solve the problems of our current industrial society, i.e. environmental problems, health and safety problems, etc. Authors (Funtowicz and Ravetz, 1993) argue that these problems can be solved with the ‘new science’ which is more open to public participation. In this sense, post-normal science offers a way of building connections between making science, public participation and policy making. Therefore, this approach is widely approved and receipt by the scholars working on environmental problems, toxicology or other issues related to environmental safety and sustainability.

3.1.1.3 Mode 2 production of knowledge

The initial arguments of these two approaches date back to the year 1994 in which one of the most influential book on this subject was published, namely “The New Production of Knowledge: The Dynamics of Science and Research in Contemporary Societies” (thereafter NPK) authored by Gibbons, Limoges, Nowotny, Schwatzman, Scott and Trow (Gibbons et al., 1994). Similar group of authors (Nowotny, Scott and Gibbons) published later another book titled “Re-thinking Science: Knowledge and the Public in the Age of Uncertainty" (Nowotny et al., 2001) on the same issue. These two studies are also known with the famous concepts they propose, i.e. Mode 1 and Mode 2 production of knowledge. Although the approach provided by the books is widely criticized by some scholars, especially NPK (Gibbons et al., 1994) remains the most influential study among others focusing on the change in the scientific knowledge production with higher number of citations (Shinn, 2002; Hessel and van Lente, 2008). More than one thousand citations received by NPK (Gibbons et al., 1994) provide evidence regarding to the wide reception of this study (Hessel and van Lente, 2008).

Gibbons et al. (1994) make a strict distinction between Mode 1 and Mode 2 knowledge production (Table 3.1). According to authors there is a transition between Mode 1 and Mode 2 science; in other words, a shift from disciplinary, university-based, investigator-driven type of science, to multidisciplinary, network based, and problem oriented science of Mode 2 (Bonaccorsi, 2008). In a broader sense, Mode 1 is identical with what is meant by science; in other words, it refers to a form of knowledge production which is presented as equivalent to the Newtonian model of classical science. Mode 1 knowledge production is fundamentally based on single disciplines; the boundaries among disciplines are very strict. Since the scientific inquiries are determined by the internal dynamics of the discipline itself collaborations among scientists from different disciplines are rare. Moreover, in Mode 1 knowledge production problems are set and solved in a context governed by the interests of scientific and academic community. Therefore, scientific community is not be influenced by or concerned about the external non-academic world. This enforces the ivory tower metaphor regarding to the community of science and academia. Mode 1 is characterised by homogeneity; the organizations and institutes of Mode 1 are hierarchical and tend to preserve its form. On the other hand, some attributes of knowledge production in Mode 2 is totally different even opponent to those in Mode 1. Five important attributes of Mode 2 production of knowledge are as follows (Gibbons et al., 1994):

(i) *Knowledge produced in the context of application:* Knowledge production in Mode 2 is not excluded from the supply and demand mechanism of the market and the economy. However, authors argue that although supply and demand processes and markets are important, the context of application is not limited with only commercial considerations but includes all society. Hence, in Mode 2, knowledge production is diffused throughout society and is not limited with the academia likewise in Mode 1 (Gibbons et al., 1994). In other words, in Mode 2 knowledge is produced by, for example start-up companies, consultancy firms, think-tanks, corporate research institutes as well as universities. This does not mean that Mode 1 knowledge does not have any practical applications, but in this mode the production of knowledge and its application are separated from each other in space and time. In Mode 1 there is a gap between the production of knowledge and its distribution or transfer to other agents, organizations, etc. Hence, this gap requires the transfer of knowledge or technology and needs technology transfer mechanisms. Nonetheless, Mode 2 knowledge is produced in a context of application, and does not need transfer mechanisms (Hessel and van Lente, 2008).

(ii) *Transdisciplinarity:* In Mode 2, a range of different theoretical perspectives and methodologies are mobilized to solve practical problems. This characteristic of Mode 2 is appreciated by Gibbons et al (1994) as transdisciplinarity which goes beyond interdisciplinarity in the sense that the interaction of scientific disciplines is much more dynamic (Hessels and van Lente, 2008). In interdisciplinary research disciplinary boundaries still exist but the generated or developed knowledge in different disciplines is applied to solve a specific problem or inquiry. However, with transdisciplinarity Gibbons et al. (2004) refer to a dynamic process in which knowledge is produced on the context of application with collaboration; and the production of such knowledge cannot be achieved within the boundaries of disciplines. Thus, the essential consensus between disciplines is ensured by the context of application and evolves with it (Gibbons et al., 1994).

(iii) *Heterogeneity and organizational diversity:* In Mode 2, knowledge is produced in a variety of organizations (Hessels and van Lente, 2008); therefore, it is heterogeneous in terms of the skills and experience people bring to it (Gibbons et al., 1994). In other words, knowledge is not produced in the traditional sites of knowledge, i.e. universities, research institutes or public and corporate labs but also in consultancies, small spin-off companies, think tanks, or in networks. Moreover Gibbons et al. (1994) argue that new forms of organisations have emerged to accommodate application-based nature of problems that Mode 2 addresses.

(iv) *Social accountability and reflexivity:* Mode 2 scientists and technologists are more sensitive and reflexive to the broader implications of their research. Because of the the context of application that Mode 2 operates in, all participants of Mode 2 should be aware of the potential implications of their work for humans and society (Godin, 1998); and they should consider how their research will touch the values and preferences of different groups of people. All of these considerations shared by Mode 2 scientists are seen as being absent in Mode 1 scientific and technological system (Gibbons et al., 1994).

(v) *Quality control:* In Mode 1, quality control is essentially based on peer review judgements about the contributions made by individual scientists. However in Mode 2, additional criteria are added through the context of application which incorporates not only a range of intellectual interests but also other social, economic, political or cultural ones. This means that quality is determined by a wider set of criteria which reflects the broadening social composition of the review system (Gibbons et al., 1994).

Table 3.1 The attributes differentiating Mode 1 and Mode 2 science

Mode 1	***Mode 2***
Academic context	Context of application
Disciplinary	Transdisciplinary
Homogeneity of sites and practitioners (hierarchical and institutionalized organization)	Heterogeneity of sites and practitioners (various types of organizations, non-hierarchical and transient)
Autonomy	Reflexivity / social accountability
Quality control based on peer review	A new quality control based on a wider set of criteria

Source: Gibbons et al (1994); Hessel and van Lente (2008); Godin (1998)

3.1.1.4 Post-academic science

There are similarities between the notions of NPK (Gibbons et al. 1994) and Ziman's (2000) post-academic science. Ziman sees Mode 2 as a symptom of the post-academic science, which is the whole science system in its new state (Hessel and van Lente, 2008). On the other hand, Gibbons et al. (1994) provide Mode 2 as something supplementing Mode 1 not supplanting; however Ziman's post-academic science refers to a radical, irreversible, worldwide transformation in the way that science is organized, managed and performed; thus, post academic science indicates continuity as well as difference (Ziman, 2000).

The main factor in the transition to post-academic science, according to Ziman, is the greater stress on 'utility'. In this new era of science system, the essential requirement from scientific research is being targeted at recognizably practical problems. As emphasized also by Gibbons et al. (1994), Ziman (2000) argues that post-academic scientists are expected to be concious of the potential applications of their research. In the current science system, i.e. in the USA or Europe, researchers prepare proposals for specific projects which are submitted to funding bodies; project proposals are invited on specific societal problems and grants are awarded not only on the basis of scientific merits but also of their potential for solving these problems. Such a funding system puts considerable pressure on scientists to work on problems favoured by the government or other funding agencies and organizations rather than problems of their own choosing. Therefore, what is now happening in the science system is consistent with defining academic science as a component of a national innovation system and supporting science in that spirit (Ziman, 2000). Furthermore, many big companies have realized that corporate laboratories are expensive to operate; as a result academic institutions are expected to work with the industry and produce more commercially valuable results. This, according to Ziman (2000), is another major factor in transition to post academic science.

Finally, Ziman (2000) emphasizes that post academic science is organized on market principles. In this new science system, research is performed by semi-autonomous research entities that earn their living by undertaking specific projects supported by a variety of funding bodies, including private sector firms and government departments. After all these changes, in post academic science academic and industrial research traditions have converged.

3.1.1.5 Academic capitalism

Academic capitalism is known with the book “Academic Capitalism: Politics, Policies, and the Entrepreneurial University” by Slaughter and Leslie (1997) which reports the observations of increasing market and market-like activities at universities through some empirical case studies held in the US, UK, Australia and Canada (Anderson, 2001; Hessel and van Lente, 2008). Authors define academic capitalism as “institutional and professional market or market-like efforts to secure external funds” (Slaughter and Leslie, 1997). According to this approach, first economic globalisation increases the pressure on industry to innovate and forces corporations to look for new partners from academia; and second, the decrease in the public fundings dedicated to universities and scientific research increases universities propensity to look for new sources of funds, hence, these two pressures make universities more willing to engage in capitalist activities (Anderson 2001; Ylijoki, 2003; Hessel and van Lente, 2008).

The capitalist activities or behaviors of universities are grouped into two by Slaughter and Leslie (1997); these are namely market-like behaviors and market behaviors. Market-like behaviors refer to university and faculty competition for money from external sources, i.e. grants and contracts, endowment funds, university-industry partnerships, or student tuition and fees. On the other hand, market behaviors refer to for-profit activity on the part of universities, i.e. patenting and subsequent royalty and licensing agreements, spinoff companies, or arm's-length corporations. From this perspective, it is easy to see that such market-like activities of universities have important consequences for the entire education system; authors mention that although these activities can increase the revenues of the universities they also bring some societal costs, i.e. failure to meet societal expectations or neglecting students. Finally, academic capitalism and capitalist activities of universities are very similar to the "capitalization of knowledge" argument proposed by Triple Helix approach.

3.1.1.6 Triple Helix

Triple Helix (Etzkowitz and Leydesdorff, 1997; 2000; Etzkowitz, 2008) is mainly based on the assumption that three spheres in society, namely university, industry and government have become much more interdependent and connected to each other. Therefore, the knowledge infrastructure generated in Triple Helix is overlapping institutional spheres; and tri-lateral networks and hybrid organizations are emerged at the interfaces (Etzkowitz and Leydesdorff, 2000). Triple Helix, as different from NPK (Giddons et al., 1994), does not offer a descriptive model of changes in the system of knowledge production instead offer a model which is heuristic in the sense that it encourages researchers to systematically take into account all three spheres in their efforts to study dynamics of knowledge production and innovation (Hessel and van Lente, 2008).

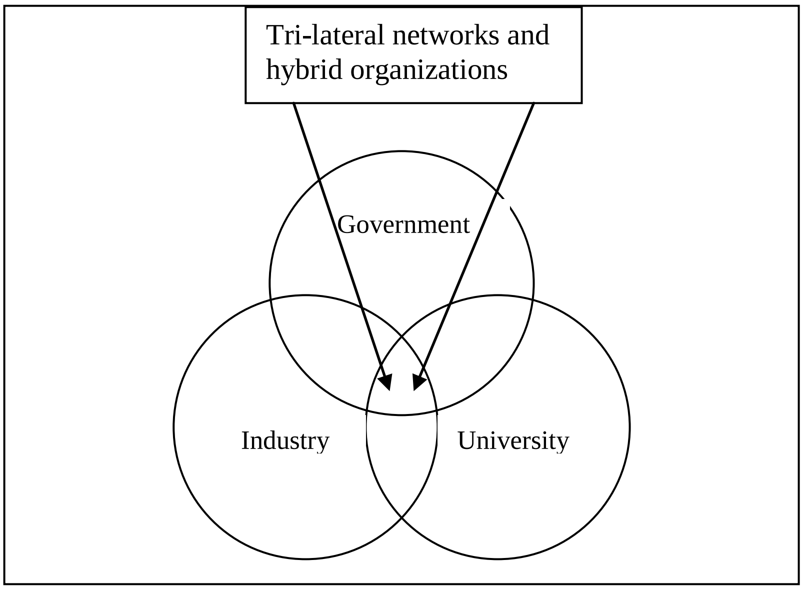
Etzkowitz (2008) clearly states that Triple Helix is a model for capitalizing knowledge in order to pursue innovation; and capitalization of knowledge happens when knowledge generates an economic value added either in direct or indirect ways (Viale, 2010). Theorists of Triple Helix emphasize that the idea of pure science or ivory tower like organization of science or Mode 1 production of knowledge is a construct; however, Mode 2 is the original format of science before its academic institutionalization in the 19th century. The origins of capitalization of knowledge can be found in the development of modern science. In Germany, the academia was a great impetus for the development of pharmaceutical industry; and German academicians in the chemistry field were conditioned to seek practical applications of their research skills. In a similar vein, in the USA, especially land grant universities[2], i.e. MIT, pursued more practical research strategies; and these application-based academic mode existed in paralel with the other one which is focused on pure research for many years (Etzkowitz and Leydesdorff, 1997; 2000).

Hence, Triple Helix does not emphasize the changes in the regime of knowledge production; or does not discuss how the characteristics of knowledge or the way in which knowledge is produced have recently been transformed. Instead it focuses on the co-evolution of three spheres of academia, state and industry; the transformation of relations among these three spheres as well as internal transformation of these three groups of institutes. In the evolution of relations among these three spheres, authors identifies three different models of interactions, namely statist, laissez- faire and triple helix model of university-industry-government relations (Etzkowitz and Leydesdorff, 2000; Etzkowitz, 2008). The

[2] Land grant universities were generated in the USA in the second half of the nineteenth century. Their focus on training farmers and workers, along with research oriented to regional economic development differentiated these universities from European universities of the late nineteenth and twentieth centuries (Mowery et al. 2004). The Morrill Act of 1862 encouraged their development.

statist model is valid in some countries where government is the dominant institutional sphere. In this model industry and academia are subordinated to the state; and they are institutionally weak. This model relies on specialized organizations in academia and industry which are linked hierarchically to the central government in their activities; and in this model universities are largely teaching institutions and distant from the industry. On the other hand, in laissez-faire model, university, industry and government operate in their own areas without close connections. These three institutional bodies have different roles; i.e. university is the provider of basic research and trained employees; the role of government is limited with making regulations to prevent market failure; the industry is a knowledge seeker to be much competitive in national and international markets; and it looks for the new knowledge in the universities. In all these spheres, institutions within their boundaries; and have weak connections with the institutions of the other spheres (Etzkowitz, 2008).

Triple Helix can be characterized by the creation of tri-lateral networks and hybrid organizations from the interactions among university-industry-government (Figure 3.1). Triple Helix model ensures the cooperative interactions among government, industry and academia. Instead of bi-lateral interactions of academia-industry, industry-government, or government-academia Triple Helix brings three strands of academia, industry and government in the same networks and provide multiple paths for collaboration among them (Metcalfe, 2010). On the other hand, in the Triple Helix model, academia, industry and government play the role of each other, i.e. industry may form university-like teaching and research entities; or a university can play industry's role in assisting spin-off companies. This new form of organizations which play new roles in addition to their existing roles is recognized as hybrid organizations.



Source: Etzkowitz and Leydesdorff (2000)

Figure 3.1 Triple Helix Model of university-industry-government relations

3.1.2 Old wine in new bottle?

The aforementioned six approaches aim to understand the changes in the production of knowledge, in the universities as the main entities of knowledge production or offer a model to cope with these observed changes. Among those approaches, NPK (Giddons et al, 1994) and post-academic science by Ziman (2000) provide more radical statements and arguments regarding to the changes in the knowledge production regime. Since NPK is the most popular approach the critics mainly targeted this study and the concept of Mode 2.

The main counter-argument to the NPK approach is that Mode 2 is not a radical change but an existing form of knowledge production that has existed for a long time, at least for the last five centuries (Godin, 1998; Martin, 2003; Pestre, 2003; Shinn, 2002; Weingart, 1997; Martin and Etzkowitz, 2000). Godin (1998) argues that Gibbons et al. (1994), in NPK, focus on a very short period starting with the end of the Second World War; therefore, they are missing the fact that what is attributed to Mode 2 as new is, indeed, not totally new; but also appear in so called Mode 1 science in different forms. Pestre (2003) provides different examples from the history of science covering the last five centuries to prove that today's mode of knowledge production which is identified as Mode 2 is not specific to our times. According to the author (Pestre, 2003), Mode 1 cannot be accepted as an accurate mode of knowledge production in the West since the sixteenth century in the sense that knowledge has always mattered to states and economic elites and, therefore, contributed to social and economic life. Pestre (2003) emphasizes Mode 2 has always been there but, of course, there is no one model of Mode 2 production of knowledge but each moment of history exhibited a particular combination of the elements that characterize Mode 2.

On the other hand, Shinn (2002) criticizes not only NPK approach but also Triple Helix since both approaches present transversality in the sense that crossing cognitive, technical, economic and societal boundaries as something specific to our time and culture. Like other scholars, author (Shinn, 2002) mentions that neither NPK nor the Triple Helix has examined the historical record for the existence of communities in transversal actions. However, if they did so the proponents of these two approaches were aware of the studies in history and sociology of science that suggest that for almost two centuries small but influential groups have operated at interface between established organizations and institutions; and ensured transversality and transdisciplinarity.

In summary, it can be mentioned that the arguments regarding the evolution of knowledge production regimes in our time are gathered around two opposite points. One group of authors emphasize the argument that in the recent period the regime of knowledge production has radically changed; and according to them the main symptoms of this change lies on that (i) science has become more application based; more market oriented and problem-based; (ii) knowledge production has become more transdisciplinary or in other words the boundaries between different spheres of knowledge production has disappeared; and (iii) knowledge has become socially distributed; or knowledge is produced in different spheres or different institutional settings - i.e. Gibbons et al. (1994) argue that universities are losing their importance as one and only institution of knowledge production, and Etzkowitz (2008) emphasizes that the role of academia can be taken by the other spheres of government and industry. However, critical assessments to these approaches argue that all these features of knowledge production are not new and specific to our time and culture; all these features presented as the unique characteristics of today's science are indeed in continuity within the history at least for the last few centuries. Of course the scholars criticizing these approaches admit that science and knowledge production have evolved in the history and co-evolved with the society but what we are confronted with now is not a radically distinct form of knowledge production.

From all these discussions, we can derive that science with all its organizations co-evolves with the society. Therefore, scientific knowledge production system and the role of universities in the society should not be evaluated independent from the societal and political context. According to me, at least in the Western world, both Mode 1 and Mode 2 characteristics of science system are present together. However, some changes in science system are over-emphasized by the proponents of Mode 2 or similar approaches as a part of science and technology policy discourse which occurred after the 1980s. The proponents of NPK or similar approaches present all these changes as "better" than the old system without any criticism. However, such a discourse which makes a clear cut between the 'old system' and the new one seems to me risky especially for developing countries. In the most of developing countries, science system is not well developed; therefore, accepting and following Mode 2-like characteristics without any criticism would create some severe consequences in such countries. For instance, knowledge production which is not excluded from the supply and demand mechanisms of the market and the economy would cause decreasing funds allocated for basic science research or social science research which are not demanded in the market and, in turn, would damage the whole science system

Thus, universities, academics and their role in the process of knowledge production need to be taken into consideration carefully. The following section reviews how the role of academia in the society is formulated in the recent period by the different approaches regarding the regimes of knowledge production.

3.1.3 Universities in knowledge production: A second academic divide

The debate on the change in knowledge production has opened up new discussions about the role of universities and other HEIs as the most important knowledge producing organizations. As mentioned earlier, in NPK (Gibbons et al., 1994) and in "Re-thinking science" (Nowotny et al., 2001), it is argued that universities are no longer the main locus of knowledge production; instead scientific and technological knowledge production are now pursued not only in universities but also in industry and government laboratories, in think tanks, research institutions and consultancies, etc. (Gibbons et al., 1994).

During the twentieth century the university has become the key institution for knowledge production; however, in Mode 2, the university needs to be transformed and turned into a synergistic institution: (i) it should become an open rather than closed, a comprehensive rather than a niche institute (; (ii) it is de-institutionalized in the sense that the boundaries between inside and outside make no sense in Mode 2 of knowledge production (Nowotny et al., 2001). Universities are no longer in a strong position, either scientifically, economically or politically to determine what shall count as excellence in teaching and research (Geuna, 1998). Nonetheless, this is not enough to herald the end of the university or end of its position as a locus of knowledge production in the society. Throughout its history, the university has proved able to evolve in a changing environment and it is very adaptive to new and changing situations (Martin and Etzkowitz, 2000; Geuna 1998). For instance, Geuna (1998) sees the increased number of collaborations between university and industry as the most important indication of the ongoing change of the universities; an empirical study by Godin and Gingras (2000), on the other hand, shows that the importance of universities in the knowledge production does not decrease but the collaborations between universities and other types of institutes increase. Hence, against the arguments of NPK (Gibbons et al., 1994; Nowotny et al., 2001) emphasizing the declining role of universities in Mode 2 of knowledge production some authors (Geuna 1998; Martin and Etzkowitz, 2000; Etzkowitz et al., 2000; Martin, 2003) emphasize that universities are very adaptive to changing environment and have changed throughout the history. Moreover the proposed unique features of universities in Mode 2 of knowledge production can be easily found among the universities of the 19th century, or among the land grant universities (in the USA) of the twentieth century. Therefore, a brief review of the history of universities would be useful to identify what has currently been changing about universities.

The medieval university had two functions: (i) teaching priests and public servants; and (ii) scholarship in a variety of disciplines (classical, philosophical, medical, etc.). However, with the changing social environment these functions of universities evolved. The scholarship was broadened to include activities and actors aimed at the creation of new knowledge; and the universities started to combine two tasks of teaching and research (Martin and Etzkowitz, 2000; Martin, 2003). Etzkowitz (2001; 2003) calls this change that occurred in the 19th century as the "first academic revolution" that made research or producing new knowledge as university function in addition to the traditional task of teaching. As a consequence of this transformation the Humboldt university model came into being in the 19th century in Germany where the research and teaching functions were combined in the same institutional structure. This model subsequently spread from Germany to many other countries in the nineteenth and twentieth centuries; but, of course, the changes in the functions of universities varied in different national contexts; and different types or species of university emerged. For example, in France, universities, particularly *grandes écoles* continued to concentrate on teaching; whereas much of the academic research was carried out in laboratories of organizations such as the Centre National de la Recherche Scientifique (CNRS) and

The Institut National de la Santé et de la Recherche Médicale (INSERM). The European model of university combining research and teaching (or Humboldt university model) came to be called imperial university in Japan and Ivy League universities in the USA with some adaptations and varieties. Despite varieties this group of universities is called as “classical universities”. Later the second species appeared again in Europe which were called technical university or polytechnics which were organized around utilitarian or instrumental ethos; and played the role of creating and disseminating useful knowledge and to train students with skills useful to society; e.g. École Polytechnique in France was set up to provide training for engineers to meet the military needs of the country (Martin and Etzkowitz, 2000; Martin , 2003).

In the second half of the nineteenth century in the USA, a new species of land-grant universities were generated. Their focus on training farmers and workers, along with research oriented to regional economic development differentiated these universities from European universities of the late nineteenth and twentieth centuries (Mowery et al. 2004). The Morrill Act of 1862 provided federal funds to land-grant universities and encouraged the establishment of state-controlled universities whose long term success depended on their responsiveness to the demands of the local community. From a more general perspective, it is argued that academia in the USA is more concerned about the application; and this utilitarian orientation to science influenced the research and other activities of American universities (Mowery et al., 2004).

After the Second World War the higher education system and its relation to society exhibited some changes which were generally linked to Vannevar Bush’s report “Science: The Endless Frontier” (1945). In this report, Bush proposes a linear science-push model of innovation where basic research leads on to applied research, then technological development and finally innovation (Martin, 2003). Indeed, the successful use of scientific discoveries during the war, especially in Manhattan Project, established such a belief in the applicability of scientific findings (Geuna, 1998). What Bush report offered was that whenever the government puts money into the basic research it would eventually bring benefits in terms of innovation and wealth creation (Martin, 2003). From the end of the Second World War to the end of 1970s universities grew rapidly; the driving forces of this growth were (i) an internal logic of scientific knowledge production such as the generation of subdisciplines, reconfiguration of the research fields, an increased reliance on instrumentation which meant that the process of scientific inquiry required more practitioners and a higher financial support; (ii) the successful use of scientific discoveries made during the Second World War (as aforementioned); (iii) especially during the 1960s the shift in demand by industry and government for a higher level and range of skills; thus universities became open to all persons qualified by ability to attend not a minority of students; and (iv) due to the strong economic growth after the war, and to the demographic boom during the 1950s and early 1960s the number of students at secondary schools increased at an extraordinary pace; and the demand for higher education expanded proportionally (Geuna, 1998). All these conditions helped the rise of the ivory tower image of the university as the locus of the knowledge production and dissemination in the society.

However, with the 1980s a number of changes have occurred in the university system. First and foremost the constraints on public expenditure in higher education and basic research have created new challenges for universities and other HEIs (Martin, 2003; Martin and Etzkowitz, 2000; Etzkowitz, 2008; Guena and Muscio, 2009; Sutz, 1997). For new sources of funding universities started to collaborate more with private sector; and chose their research topics in accordance to the needs of the private sector.

On the other hand, scientific and technological competencies in the form of knowledge and skills have gained importance (Martin, 2003). The emergence of new technologies such as ICT, biotechnology or nanotechnology increased dependence of firms on scientific knowledge and basic research. These new technologies have been identified as the new sources of economic development and growth; and moreover these new technologies have arisen as the syntheses of theoretical and practical interests; or basic and applied research (Martin and Etzkowitz, 2000; Martin, 2003; Etzkowitz and Leydesdorff, 2000; Etzkowitz, 2008).

However, in the same period, global competition has increased with the entrance of especially new Asian economies into the world markets. Whereas science has become a strategic competitive resource for firms, operating large sized corporate R&D departments has increased the financial burdens of the firms. Throughout the 1980s and early 1990s the US industry downsized operations and had restructured its scientific labs; e.g. among Nobel-prize winning labs, IBM and Bell, were closed. The Wiesner Symposium in 1996 (in the USA) suggested a reconfiguration of university-industry-government relations in which universities took over some of the functions of industrial labs (Slaughter and Rhodes, 2005). Furthermore, the emerging concept of open innovation (Chesbrough, 2003) underlines the importance of a new trend in which companies tend to utilize the knowledge produced outside the company; and value the importance of universities in the dissemination of knowledge in the society.

Since the economic crises of the late 1970s, not only the capitalist mode of production but the mode of "capitalization of knowledge" has started to evolve; and the role of universities and their contribution to the economy and economic development has been opened to discussion by scholars and policy makers. Decreasing public funds for research and teaching forced universities to look for new resources and, therefore, to seek more application oriented research questions and new ways of direct commercialization of research results. Bayh Dole Act which became effective in 1981 in the USA was the first attempt for regulating patent policy for universities that gave them the rights to any patent resulting from grants or contracts funded by any federal agency. The effect of Bayh Dole Act was great in the sense that the number of patents and patent applications by the US universities and university professors tremendously increased in a very short course (Mowery et al., 2004).

The increasing number of university patents, establishments of technology transfer offices (TTO) at universities, and the increasing number of academic spin-offs since the 1980s have proved universities' changing attitudes toward the direct commercialization of research results. On the other hand, changing mode of production from mass production to flexible mode of production, increasing competition and pressure to innovate, the emerging science-based technologies such as ICT, biotechnology and nanotechnology are all the driving forces for firms to look for new external knowledge resources. All these conditions create a new milieu of scientific knowledge production. While some scholars (i.e. Gibbons et al., 1994) or policy makers interpret these changes as the decline of the importance of universities by losing their position as the monopoly of scientific knowledge production in the society, some others (Etzkowitz and Leydesdorff, 2000; Etzkowitz et al., 2000; Etzkowitz, 2008; Godin and Gingras, 1998; Martin, 2003) argue that, albeit some evolutions, universities still keep their position as the locus of scientific knowledge production in the society. Furthermore, Etzkowitz and Leydesdorff (2000) emphasize that universities can play an enhanced role in innovation in a knowledge based economy; but, of course, this university, according to authors, should governed by a new entrepreneurial paradigm. According to Etzkowitz (2003), the entrepreneurial university is a logical result of the previous development in which the academic enterprise expanded from a focus on teaching to research. However with the increasing contribution of knowledge to economic development has opened up a third mission of direct contribution to economic development (Etzkowitz et al., 2000; Etzkowitz and Leydesdorff, 2000; Etzkowitz, 2008). The four processes toward an entrepreneurial university are described as follows by Etzkowitz et al. (2000):

(i) Internal transformation: It includes the revision of existing tasks and reformulation of university missions; i.e. teaching is currently expanded by students testing their academic knowledge in real world situations, or universities enlarge their role in innovation, for instance, from the dissemination of knowledge to capitalization of knowledge.

(ii) Trans-institutional impact: A new equilibrium of overlapping institutional spheres of government, industry and university; e.g. collaborations and rules for interaction are more easily understood and negotiated.

(iii) Interface processes: Interface specialists or organizations at universities to meet, organize discussions, negotiate contracts, and to facilitate interactions with their counterparts and other potential partners in government and industry.

(iv) Recursive effect: Beyond establishing links with existing organizations, developing capabilities to assist the creation of new organizations; i.e. formation of firms based upon academic research, and leadership in forming regional organizations, bridging the various institutional spheres together for the common purpose of fostering innovation.

Entrepreneurial university is a hybrid organization which combines research, teaching and a third mission of economic development. This type of university is the one found in the Triple Helix Model of university-industry-government relations; it is capable to create new interface organizations to interact with the industry and the government, to support the formation of academic spin-offs, and influential to create new agencies for economic development and support i.e. regional innovation activities and growth.

3.1.4 Nanotechnology and the changing science policy

Nanotechnology has gained impetus with the invention of STM in the mid-1980s at IBM laboratories in Zurich; and it has been developed in a science policy environment mainly shaped by the discussions on the changing mode of knowledge production; the end of pure science; and the new relations between science, technology, economy and policy. From the perspective of social studies of science, the rise of the nanotechnology in such an environment and the path it follows are not coincidence.

Johnson (2004) argues that because of the socio-economic environment of the 1990s, nanotechnology has developed in a particular way in which it perfectly fits to what both companies and the government expect from science (e.g. focus towards applications, ties to industrial research, blurring boundaries of science and technology, transdisciplinarity). Johnson (2004) argues that all these features, combined with the great expectations about the potential of nanotechnology for innovations, put the nanotechnology in an advantageous position for public funding. Nanotechnology was reviewed in detail in its various / diverse aspects in Chapter 2. To remember, nanotechnology is defined simply as the understanding and control of matter at the very small scale (from 1 to 100 nanometer) where unique phenomena enable novel applications; it encompasses nanoscale science, engineering and technology to imagine, measure, model and manipulate matter at this length scale (NNI)[3]. Thus, by definition, nanotechnology emerged as a new type of technology which encompasses different disciplines of science and application; and moreover it has been organized around an innovation-oriented discourse. Science and technology policies focusing on nanotechnology have supported the convergence of various academic disciplines around research problems which have a clear impact on industrial technology (Sá et al., 2008) by using special funding schemes and programs, and promoted close university-industry ties and commercialization of research results (McCray, 2005). The Bayh-Dole Act of 1980 has already created the legal environment for the commercialization of academic research results, and nanoscientists and nanotechnologists have benefited from this environment. Some US universities are among the top institutes having the highest number of nanotechnology patents besides well known multinational companies (Li et al., 2007a).

Nanotechnology fits well into the image of new science or new way of doing science. As emphasized in Chapter 2, in nanotechnology the boundary between science and technology, or science and application has disappeared. Second, nanotechnology is transdisciplinary in the sense that various academic disciplines converge around specific research problems; the project groups involves several scholars from various disciplines and, hence, benefits from the cognitive sources of various disciplines (Schumer 2004; Rafols and Meyer, 2007; Porter and Youtie, 2009; Porter and Rafols, 2009; Rafols and Meyer, 2010). Third, it is reliant on

[3] http://www.nano.gov/html/facts/whatIsNano.html last accessed on October 6, 2010.

instrumentation (i.e. scanning probe microscopes, high speed computers); therefore, it needs considerable amount of funding for research laboratories / centers; new types of skills, and new network formations and collaborations. Fourth, there is heterogeneity in actors and institutes involved in nanotechnology research. Universities are not the only locus of scientific knowledge production. Firms (e.g. the most important instrument of nanotechnology, STM was developed by IBM researchers), government laboratories, academic spin offs, foresight institutes or consultancy firms are very active in producing new knowledge. Finally, nanotechnologists or proponents of nanotechnology are more sensitive and reflexive to the broader implications of their research including social and economic ones; they consider how their research would touch the values and preferences of different groups. Therefore, ethical, legal, social and environmental consequences of nanotechnology are taken into account seriously and investigated by the researchers. Especially in the USA and Europe special programs, research projects and research centers are funded by governments to investigate and foresee the problems related to legal, ethical, environmental or health issues that might prevent the commercialization of research results.

Recent studies provide evidence that boundaries between science and technology and, hence, commercialization and innovation have been disappearing in nanotechnology. New hybrid forms of interactions between science, industry and government have occurred. Bonaccorsi and Thoma (2007) investigate the relation between science and technology and find out that a significant majority of nanotechnology patents (66 percent) have at least one inventor that is also an active scientist (i.e. having a published article). Meyer (2006a) uses US patent data and SCI (Science Citation Index) database for publication and finds out that such inventor-authors account for a relatively large share amongst the nano-inventors, albeit differs by country of origin, it ranges between 27 and 40 percent. This study also indicates that inventor-authors apparently outperform their non-inventing peers in terms of both publication and citation frequencies. Inventor-authors are new to the literature but they provide strong evidence of a highly interconnected knowledge system in which the transformation of scientific achievements into patentable results and of both into commercial ventures is very rapid and takes place through multiple roles played by scientists (Bonaccorsi and Thoma, 2007).

On the other hand, technology platforms rise as a new type of organizational arrangement of interactions between various agents in nanotechnology. A technology platform refers to “a set of instruments which enables scientific and technological production; it allows exploration and exploitation of a variety of options, for strategic research, technology development, and sometimes also product development” (Robinson et al., 2007). But, of course, a technology platform is not just a collection of infrastructure but also a new form of organization in which heterogeneous entities (i.e. scientists, engineers and technicians from different backgrounds) have an access to technological equipments, skills and infrastructure; and have face-to-face interaction with each other (Merz and Biniok, 2010) for further actions (Robinson et al. 2007). Technological platforms have been promoted especially in nanotechnology with the promise that they foster new forms of university-industry partnerships (Robinson et al., 2007; Merz and Biniok, 2010). The most important advantage of technology platforms is the high cost of instrumentation in the NST field; the cost of research decreases when instrumentation is centralized. Another advantage of technology platforms is to centralize expertise, maintenance, support and training (Merz and Biniok, 2010). Since developments in most fields of nanotechnology are tied to technological facilities that are mainly instrumentation and the skills needed to operate the instruments, technology platforms serve as a new form of organizational arrangements amongst nanotechnology actors (Robinson et al., 2007). Moreover Meyer (2010) emphasizes that these platforms are Triple Helix innovation platforms where cooperative relations and tri-lateral networks are built among scientists and professionals from academia, industry and government. This new trend of technology platforms is now observed across science and technology policy instruments throughout the Western world; and new funding instruments are developed and are linked to such platforms which can be focal points for inter-institutional and interdisciplinary collaborations (Meyer, 2010).

To summarize, nanotechnology emerged in an environment where Bayh-Dole Act of 1980s has been already established, universities and industry have become more closer, the ivory tower position of science and university has opened to discussion, and the boundaries between science and technology have become blurred, the applications of scientific research results have been considered in funding of research projects and the best science has become a form science with practical applications and economic implications. It is very difficult to decide whether nanotechnology has arisen in this milieu since its nature fits well to these conditions; or because of these conditions nanotechnology has developed in a particular way. However, the answer to this question does not change the fact that nanotechnology and new mode of knowledge production; i.e. the enhanced interconnections between academia, industry and government present a good match; and, therefore, support each other.

3.2 Changing university-industry relations

3.2.1 Knowledge as a public good: spillovers from universities

In section 3.1, we have reviewed different approaches examining the current changes in the knowledge production system and critics to these approaches. In this new knowledge production system, academia is re-designed as the most important knowledge producing entity but it is not alone; and it needs to be in relation with (or networked to) other knowledge producing entities; i.e. firms, private and public labs, research institutes, governmental bodies, international agencies, etc. Universities are also encouraged to work more close with the industry, to increase their incomes and obtain more industry funds for their research activities. In this context, universities and university-scientists have become much more concerned about the industrial applications of their research outcomes and, hence, important agents of the innovation system.

The role of universities in the national / regional innovation systems; the impact of knowledge produced at universities on industrial innovations; and how knowledge produced at universities is obtained by or transferred to industry have been among the main concerns of the innovation literature since the mid-1980s. One of the first studies aiming to understand the impact of university research on industrial innovation activities is Nelson (1986). In this study, using a questionnaire survey, firms are asked to score the relevance of university research to technical change in their lines of business. The results show that university research on computer science, material science and biological sciences are more relevant to the technological change in various industries compared to other fields of basic and applied sciences. Likewise Mansfield asked firm managers about the percentage of new products and processes launched in the period 1975-1985 (Mansfield, 1991) and in the period 1986-1994 (Mansfield, 1998) that could not have been developed in the absence of recent academic research. In both studies, the findings suggest that nearly 10 percent of the products could not have been developed in the absence of recent academic research. The commercial values of these products confirm that the rate of return for academic research is around 28 percent.

Jaffe (1989) follows a different methodology to measure the impact of academic research on industrial innovations at the regional level. He considers the number of patents produced in a region as an indicator of the new economically useful knowledge; and models the impact of knowledge spillovers from universities on the patents granted. Knowledge produced by universities in a region is measured mainly by university R&D spending. Finally, the results provide evidence for the importance of geographically mediated commercial spillovers from university research; this effect is quite significant in drugs and electronics. This study has opened up the way for other empirical studies focusing on the role of universities and knowledge spillovers from universities in regional economic policies. Acs et al. (1991; 2002) carry out a similar research, but they use the count numbers of innovations listed in leading technology, engineering and trade journals in each manufacturing industry instead of patents. They find that university spillovers have a great impact on innovations; and being geographically closer to universities is important to benefit from these spillovers. Audretsch and Lehmann (2005), using a unique database of 280 firms, find out that knowledge spillovers from universities matter for firm growth. Firms which are closer to universities have higher growth rates; and moreover a positive relationship is found between the number of academic papers published by the universities and firms' growth rate.

Narin et al. (1997), on the other hand, measure the impact of academic research on industrial innovation using academic research papers cited by the US industry patents. The results indicate that 73 percent of the research papers cited by US industry patents belong to universities and other public research institutes. Moreover, the study provides evidence for a rapid growth in the dependence of US industry patents on academic research; from the period 1987-89 to 1993-94 while the patent system grew 30 percent the number of citations to the academic research in patents grew 200 percent. McMillan et al. (2000) narrow this study to the field of biotechnology. Data regarding the intellectual property was collected from 119 biotechnology firms and citations to scientific research papers classified as public and private. Their results indicate that nearly 72 percent of the cited academic papers are authored by researchers at universities or other public research institutes. This method is also used by scholars working on nanotechnology to measure the impact of public science in nanotechnology patents (i.e. Meyer, 2000b; Hu et al., 2007). For instance, Hu et al. (2007) find that about 60% of nanotechnology related patents have on average approximately 18 academic citations.

All these studies reviewed have made a great contribution to the investigation of the impact of knowledge spillovers from universities and other publicly funded research institutes on industrial innovation. However, they are mostly based on the Arrow-Nelson-Romer view (Zucker and Darby, 2007) of basic science / scientific knowledge. Both Arrow (1962) and Nelson (1959) take the issue of basic science leading to invention as a problem of allocation of resources; and define the main features of science and scientific knowledge as a commodity. In this view, basic science is a "public good" with the features of non-excludibility, non-rivalry and durability. Knowledge is non-excludible because it is not possible for a person using and consuming it to prevent any other potential user from using it (Callon and Bowker, 1994; Romer, 1992). In other words, scientific knowledge is a good which can be easily reached by everyone. Public good is non-rival in the sense that nobody competes for its use; For the economics, the property of non-rivalry is essential because it means that the production cost of the good is fixed; and once the good is produced there is no production cost of reproducing it (Callon and Bowker, 1994; Romer, 1992). The final attribute of public good is durability which indicates that it cannot be destroyed or altered by usage (Callon and Bowker, 1994); or it does not lose its validity through use and re-use (Martin et al., 1996; Dasgupta and David, 1994).

Nonetheless, whereas these reviewed studies (Arrow, 1962; Nelson 1959) are important for the rationalization of public funding for basic research activities at universities they ignore how these spillovers occur; the role of interactions and channels among universities and firms and, hence, the factors affecting the formation of these channels. Martin et al. (1996) identify two different approaches to the nature of the economic benefits derived from the publicly funded basic research; this classification can also be applied to university-industry interactions. According to the first approach scientific knowledge produced at universities is a public good and can easily be disseminated due to the attributes of public good, namely non-excludibility, non rivalry and durability. However, the second approach treats scientific knowledge as embodied in technologies, individuals, organizations and networks; and it is not easily transferable to the industry. Kogut and Zanger (1992) emphasize that knowledge is related to human action and commitment. Therefore, its transfer depends on the interactions between agents. This approach is critical for this thesis. One of the main stand points of this thesis is that university-scientists and firm-scientists interact with each other through different channels and mechanisms; during these interactions knowledge and technology is transferred between academia and industry. In the following part, empirical literature investigating the different channels of interaction between universities and firms is reviewed.

3.2.2 Knowledge as embodied in technologies: Direct channels of technology transfer

In most studies carried out after the Bayh-Dole Act of 1980 (the Act), the direct channels of technology transfer (TT) which generate a moderate economic value to the universities such as patenting, licensing and spin offs have been the focus of the research. One reason for this focus is that after the Act, there has been an exponential growth in the number of patents, licensing and spin-off activities of the universities. Another reason is the availability of the quantitative data regarding to the number of disclosures, patents, licenses, royalty income from licensing and the number of spin-offs which, in the USA, is collected by the Association of University Technology Managers (AUTM).

In the TT literature, the Act is treated as the milestone in the commercialization of university research. It provides blanket permission for the researchers of federally funded research to file for patents on the results of such research and to grant licenses for these patents to other parties (Colyvas et al., 2002). Before 1980, Technology Transfer Offices (TTOs) were only established in a small number of universities in the USA; however after the Act these offices have gradually become a common organization in universities. Today almost all universities in the USA have TTOs serving as an intermediary between the suppliers of innovations, i.e. university scientists and other parties who can potentially commercialize these innovations. TT mechanism using TTOs starts with the disclosure of the inventions/innovations made by university scientists; these disclosures are evaluated by TTO personnel / managers and decided to file for patents; after patenting, TTO efforts focus on the marketing of patented technologies, finding the appropriate customers and finally granting licenses for these patents. The explosion in the numbers of university patents, granted licenses by TTOs and the number of academic spin-offs in the last three decades are attributed to the Act by most researchers.

The rationale behind the Act is to motivate firms to invest in developing and improving embryonic inventions (Jensen and Thursby, 2001) developed at universities with federal funding (Rai, 1999, Colyvas et al., 2002; Thursby and Thursby, 2007). Since embryonic inventions require a lot of follow-on research by the firms (Colyvas et al. 2002), intellectual property protection is thought to encourage firms to invest in this type of inventions, i.e. firms do not want to invest in such a costly development process without clear rights or, in many instances, exclusive licenses (Shane, 2004a; Mowery et al., 2004).

Moreover, with the Act, TTOs and universities have an incentive to advertise university inventions to the industry, and this helps closing the informational divide between universities and the industry (Colyvas et al., 2002). The numbers regarding TT activities indicate that the Act has achieved, in some sense, to overcome information asymmetry between universities and firms. Before 1980, the number of university patents in the USA was fewer than 300, but it increased to 3278 in 2005; annual licensing revenue generated by the universities in the USA rose from 160 million USD in 1991 to 1.4 billion USD in 2005. On the other hand, the number of university spin-offs established between 1980 and 2005 in the USA reached 5171 in 2005 in the USA (Siegel et al., 2007). However, this pattern is not unique to the USA; most advanced countries, i.e. Canada, Australia, Western European countries followed up the USA, launched Bayh-Dole fashion arrangements and established TTOs to improve TT from universities to firms. In these countries, some marked increases in university patenting, licensing and university based start-ups have occurred (Wright et al., 2008).

The Act has received extensive attention; its effects on universities have been widely discussed and empirically analyzed (Henderson et al. 1998; Mowery et al., 2001; Mowery and Ziedonis, 2002; Sampat et al., 2003; Mowery et al., 2004; Shane, 2004a; Mowery and Sampat, 2001). Most of these studies (Mowery et al., 2001; Mowery et al., 2004; Sampat et al., 2003; Mowery and Ziedonis, 2002; Mowery and Sampat, 2001) argue that its impact on the increase in TT activities from university to industry is very little. These studies compare patenting and licensing activities of the universities in the USA before and after the Act and conclude that the Act did not dramatically affect the universities that were already active in patenting and licensing i.e. Stanford University, University of California; however the others formerly inactive were led to revise their policies and enter into large scale patenting and licensing (Mowery et al., 2001; Mowery et al., 2004). However, some authors emphasize the role of biomedical science in the upsurge of the university patents in the post-1980 period and argue that the dramatic increase in university patents in the USA in the recent period is not solely because of the Act. The institutional changes regarding the role of universities in society, or decrease in public funds provided for universities can also be considered among the factors affecting the change in patenting and licensing activities of universities. Hence, several factors in addition to the Act have stimulated the exponential increase in university patenting and licensing after 1980 and it is difficult to separate the effect of the Act from the others (Mowery et al., 2001). While Henderson et al. (1998) argue that the quality of university patents have decreased after the Act Mowery and Ziedonis (2002), Mowery et al. (2004) and Sampat et al. (2003) find no evidence regarding to a decline in quality of university patents issued in the post-1980 period. However, Shane (2004a) opposes the arguments of 'no clear impact of the Act' and emphasizes the importance of industrial differences to understand its impact. The results show that in certain industrial sectors where licensing is an efficient mechanism for acquiring new technical knowledge the Act provided incentives for universities to increase patenting in the fields related to these sectors.

Nonetheless, some studies (Heller and Eisenberg, 1998; Murray and Stern, 2007; Nelson, 2004; Argyres and Liebeskind, 1998; David, 2004; Walsh et al., 2002) focus on the negative effects of the Act on the scientific research. These studies emphasize the importance of the scientific commons for ensuring public benefit; and the possible negative effects of privatization of scientific discoveries generated from publicly funded basic research through patenting and exclusive licensing. In these studies, it is argued that hampering "open science", i.e. free distribution and diffusion of scientific knowledge, deteriorates cumulativeness in scientific knowledge and sometimes prevents the creation of new knowledge and innovations. Heller and Eisenberg (1998) focus on the situations where development of an advanced technology needs to combine different technologies patented by different parties; and combination of these different technologies for an innovation would depend on the agreement among the parties. Therefore, any disagreement between parties might hamper the innovation process. On the other hand, Walsh et al. (2002) emphasize the possible problems occurring due to patents on research tools; since research tools are keys to scientific research their patentability prevents the usage of these tools and hampers scientific research.

The Act in the USA and the equivalents issued in other countries have completely changed the attitudes towards basic science and scientific discoveries generated in university labs. Public good nature of scientific discoveries has been partially deteriorated; and it brought new challenges for universities and researchers. However, some empirical studies demonstrate that the transformation of academia is not that easy due to its internal dynamics. Thursby and Thursby (2002) argue that university researchers do not prefer to disclose their research results for patenting and licensing because (i) they may be unwilling to spend time on the applied R&D in the process of licensing the invention; (ii) they may be unwilling to risk publication delays and (iii) they may believe that commercial activity is not appropriate for academic researchers. However, the number faculty disclosures provide very tiny evidence for patenting and licensing activities; Mowery and Ziedonis (2002) present that in the USA, only 20 percent of the disclosures are turned into patents and only 10 percent of those patents are licensed to firms. Not only the efforts of the TTO management but also the willingness of the faculty to engage in commercial activity is determinant in the success of TT activities of the university (Thursby and Thurby, 2002; Jensen and Thursby, 2001). Since most of the licensing activities include embryonic inventions which need follow-on research to be commercialized and, hence, the mobilization of tacit knowledge embodied in inventors, Jensen and Thursby (2001) find out that 70 percent of all university inventions cannot be licensed without cooperation of the inventors. In other words, transferring knowledge embodied in technology through patenting and licensing requires other forms of KTT activities, i.e. consulting.

In this section, empirical studies focusing on the direct commercial channels of TT between universities and firms were reviewed. The context of university-industry interactions has considerably changed with the Act of 1980. Universities have become much concerned about their efforts in patenting, licensing and spin-off formation and, hence, increasing their TT income. However, in spite of the attention received by the direct channels of TT there has been a growing strand of empirical literature dealing with various alternative channels of KTT between universities and firms.

3.2.3 Knowledge as embodied in individuals and organizations: Interpersonal and interorganizational channels of KTT

The over-emphasized channels of TT (patents, licenses and spin-offs) may obscure the presence of other types of interactions which are much less visible but can be equally as important both in terms of their frequency and economic impact (D'Este and Patel, 2007). This gap in the literature has been widely considered in empirical studies for the last decade. Agrawal and Henderson (2002) point out that patents and licenses are only a small proportion of the knowledge and technology transfer (7 percent) from Massachusetts Institute of Technology (MIT) to firms; consulting, publications or collaborative research are seen as more important KTT activities than patenting by the MIT researchers. These results are consistent with the findings of Cohen et al (1998; 2002). They emphasize that only about 11 percent of the information obtained from universities is transferred from patents; and the most important channels of information flowing between public research institutes and firms are the channels of open science i.e. publications, public meetings and conferences. Similar patterns can be observed in other countries. For example, Landry et al. (2007) indicate that university researchers in Canada much more actively transfer knowledge when no commercialization based on IPR is involved; D'Este and Patel (2007) for the UK, Meyer-Krahmer and Schmoch (1998) for Germany, Schartinger et al. (2001; 2002) for Austria; Arvanitis et al. (2008) for Switzerland or Bekkers and Freitas (2008) for the Netherlands suggest that IPR based KTT explains only a small proportion of university-industry interaction and a high proportion of technology and knowledge generated in the universities and other public research organizations is transferred through more informal and interpersonal contacts between universities and firms.

Although informal and interpersonal channels between university and business sectors are very difficult to define and gauge, some empirical studies have attempted to work on these various channels, their importance and the factors determining the usage of these channels (Kreiner and Schultz, 1993; Meyer-Krahmer and Schmoch, 1998; Schartinger et al., 2001, 2002; D'Este and Patel, 2007; Landry et al., 2007; Link et al., 2007; Bekker and Freitas, 2008; Arvanitis et al., 2008; Ponomariov and Boardman, 2008; Grimpe and Fier, 2010). Among those studies while Kreiner and Schultz (1993) investigate the informal collaborations and network formations in Danish biotechnology industry, Meyer-Krahmer and Schmoch (1998) focus on four different application-oriented science fields in Germany and find that collaborative research and informal contacts are the most important interaction types between universities and industry. Schartinger et al. (2001) indicate that while for Austrian university researchers the joint supervision of master and PhD students are the most important channel of interaction with industry, on the part of firms, employment of graduates is the most pervasive channel of KTT. Likewise, Arvanitis et al. (2008) demonstrate that educational activities (i.e. master and PhD thesis projects in collaboration with firms, joint teaching courses and programs of university scientists, special training courses or seminars provided by university researchers to firms) are given the first priority by the university departments in KTT activities and followed closely by informal activities. Link et al. (2007) and Grimpe and Fier (2010), on the other hand, mainly focus on informal channels; i.e. joint publications, consulting and cooperative work for the commercialization of a technology. Ponomariov and Boardman (2008) provide evidence for that informal interaction is important as catalysts of the formation of collaborative research channels between universities and firms. Authors find that university scientists who engage in informal interactions with private companies spend a higher percentage of their research related work time to collaborative research with industry. Table 3.2 provides a selected sample of articles focusing on different channels of KTT.

Nonetheless the number of studies focusing on the factors affecting the variety of channels across scientific disciplines or industrial sectors is quite limited. Among those Meyer-Krahmer and Schmoch (1998) investigate how the importance of channels vary across four fields, i.e. chemistry, information technology, biotechnology and production technology. Authors observe certain differences regarding the importance of KTT channels among these fields. While collaborative research and informal contacts are important channels of KTT in information technology and biotechnology fields, in production technology field contract research is mentioned in the first place, and in chemistry, academicians mentioned that their education related KTT activities are as important as collaborative research and informal contracts. Using two questionnaire surveys carried out at university departments and firms, Schartinger et al. (2002) emphasize that different industry sectors and academic fields engage in different types of interactions; but there is no sectoral pattern in university-industry interactions. Authors also point out that technical sciences and R&D intensive manufacturing industries tend to use research cooperation more intensively than other sectors; and some industrial sectors needs a high degree of interdisciplinary knowledge and, therefore, interact with partners from a broad range of fields of science (Schartinger et al., 2002).

Table 3.2 A sample of empirical studies focusing on different channels of KTT

Publication	*Unit of analysis*	*Data Collection*	*Country*	*Channels*
Henderson et al. (1998)	University patents	Patent database	USA	Patenting
Mowery et al. (2001)	University patents; licenses	Data from 3 universities	USA	Patenting; licensing
Thursby and Thursby (2002)	Universities	Survey	USA	Licensing
Schartinger et al. (2001)	University departments/ Innovative firms	Survey	Austria	Joint research projects; contract research; joint supervision of Ph.D.s and Masters Theses by university and firm members; mobility of university researchers into private firms.
Arvanitis et al. (2008)	Public institutes/ University departments	Survey	Switzerland	Educational activities; informal informational contacts; activities related to the use of technical facilities; research activities; consultancy (*)
D'Este and Patel (2007)	University researchers	Survey	U.K.	Meetings and conferences; consultancy and contract research; creation of physical facilities; training; joint research
Link et al. (2007)	University researchers	Survey	U.S.A.	Joint publications; consulting; cooperative work for the commercialization of a technology
Meyer-Krahmer and Schmoch (1998)	University researchers	Patent, publication data and interviews	Germany	Collaborative research; informal contacts; education of personnel; doctoral theses; contract research; conferences; consultancy; seminars for industry; scientist exchange; publications; committees

(*) These final lists of channels are obtained after a factor analysis or hierarchical cluster analysis of a higher number of KTT activities.

Table 3.2 (cont'd) A sample of empirical studies focusing on different channels of KTT

Publication	*Unit of analysis*	*Data Collection*	*Country*	*Channels*
Agarwal and Henderson (2002)	University researchers	Patent, publication data and interviews with the researchers	U.S.A.	Patents & licenses; publications; consulting; conferences; conversation; co-supervising; collaborative research; recruit grades
Bekkers and Freitas (2008)	University researchers / firm researchers	Survey	Netherlands	Scientific output; informal contacts and students; labour mobility; collaborative and contract research; contacts via alumni or professional organizations; specific organised activities; patents and licensing (*)
Cohen et al. (1998;2002)	Industry R&D managers	Survey	U.S.A	Publications/reports; informal interaction; public meetings or conferences; contract research; consulting; joint or cooperative ventures; patents; personnel exchange; licenses; recently hired graduates

(*) These final lists of channels are obtained after a factor analysis or hierarchical cluster analysis of a higher number of KTT activities.

Bekkers and Freitas (2008) provide the most extensive study focusing on the factors that are important to explain the varying importance of different channels: sectoral effects; the basic characteristics of knowledge; academic disciplines; characteristics of the organizations and the characteristics of individuals involved in the interaction. Using two surveys carried out with the individual researchers in academia and industry in the Netherlands, authors suggest that sectoral effects do not significantly explain the differences in the importance of channels used for KTT activities; instead these differences can largely be explained by (i) basic characteristics of knowledge (i.e. tacitness); (ii) the disciplinary origin of the knowledge involved; and (iii) individual or organizational characteristics of those involved in the KTT process (i.e. seniority, publication records, patent records, entrepreneurship, etc.). Finally, D'Este and Patel (2007) emphasize the importance of using a wide variety of channels on the individual level. According to authors "the greater the engagement of a particular researcher in a wider variety of knowledge transfer activities with industry, and thus the greater the participation in a variety of inter organizational arrangements, the more likely it is that the individual will build the skills necessary to integrate science and technology".

Although the empirical studies investigating the formal or direct channels of technology transfer between universities and firms are numerous due to their immediate and measurable economic impact, recent studies widely emphasize that there are various channels of university-industry interactions and the economic impact of these channels is as high as the formal channels. These interpersonal and informal channels are critical for this dissertation because in Turkey formal / direct channels of technology transfer from universities to the industry is nearly absent. Hence, these reviewed empirical studies considering the variety of KTT activities between universities and firms provide an essential guide for this study, especially in investigating the key channels of interaction between nanotechnology scientists and firms.

3.3 Conclusions

This chapter first provides a brief review of theoretical approaches focusing on how the knowledge production system and the universities as the main actors of this system have been transformed for the last three decades. Second, different strands of literature exploring the impacts of scientific knowledge produced at universities on the industrial innovations and the channels through which academic knowledge is transferred to industry are reviewed.

From this chapter, we can derive following conclusions: (i) national science policies under the discourse of 'new' form of knowledge production have been re-designed to support more industrially applicable research; and to encourage universities in their engagement with the industry; and their transformation from isolated, ivory tower-fashion knowledge generating entities to more entrepreneurial organizations; (ii) Bayh-Dole Act in the USA and equivalents in other countries provide initiatives to universities for the commercialization of scientific discoveries and increasing their income; new form of intermediary organizations (i.e. TTOs) has emerged; and the information asymmetry between academia and industry has been considerably reduced ; and finally (iii) in spite of the great emphasis on the role of Bayh-Dole fashion regulations on the formation of KTT linkages between universities and industry, recent empirical studies provide evidence that universities and firms interact each other in various ways; and among them the share of patenting, licensing or spin-offs which are encouraged by the regulations is very small proportion.

Taking as given the arguments regarding the variety in the forms of university-industry interactions, Chapter 4 reviews the literature exploring individual or organizational level factors influencing the formation of KTT linkages between universities and industry.

CHAPTER 4

DETERMINANTS OF UNIVERSITY-INDUSTRY RELATIONS: THEORETICAL AND EMPIRICAL FOUNDATIONS

In Chapter 3, we reviewed the literature focusing on the nature of university-industry relations and, the variety in the number of KTT channels connecting universities and firms. However, in this chapter, we focus on how these links between universities and firms are established and present an extensive review of the empirical studies investigating the factors which influence KTT between universities and firms. Not only the empirical evidence provided by these empirical studies in supporting the importance of certain individual and organizational level factors in KTT but the theoretical foundations they rely on deserve special attention for the main objectives of this thesis.

Scholarly attention to the factors affecting the formation of university-industry relations at the individual, university or firm level has been growing steadily since the 1990s. In spite of the growing attention Powers (2003) emphasizes that “no theory of university technology transfer per se exists at this time”. However, there are some efforts to build on more developed theories or approaches in other fields such as business strategy or organizational theory to understand the phenomenon of university-industry KTT activity.

Most recent studies in university-industry interactions take one of three theoretical perspectives. The first one is at the institutional level and mainly focuses on the changing relationships between university-government-industry relations, norms of scientific knowledge production and its capitalization, evolving universities and the contract between university and society as discussed in Chapter 3, notably Triple Helix (Etzkowitz and Leydesdorff, 2000; Etzkowitz et al., 2000;

Etzkowitz, 2008), Mode 2 production of knowledge (Gibbons et al., 1994) and academic capitalism (Slaughter and Leslie, 1997). Second is the resource-based view (RBV) either at the firm level (Santoro and Chakrabarti, 2002; Santoro and Bierly, 2006) or at university level (O'Shea et al., 2005; Powers, 2003; Powers and McDougall, 2005; Lockett and Wright, 2005) or at individual level (Landry et al., 2006; Landry et al.,2007; van Rijnsoever et al., 2008). The final perspective is "scientific and technical human capital" (STHC) approach (Bozeman et al., 2001) which is used in some of the most recent empirical studies focusing on the factors influencing university-industry KTT activity at the individual level (Boardman and Ponomariov, 2009; Boardman 2009; Edler et al., 2011).

Although institutional approach is widely discussed in the university-industry KTT literature it has some significant limitations. Van Rijnsoever et al. (2008) identify these limitations as (i) macro perspective addressing the trends at a higher aggregate level while ignoring changes at the organizational and individual level; (ii) being descriptive in the sense that it focuses on describing the change rather than explaining it; and (iii) being normative and lack of empirical support. Considering Triple Helix and Mode 2 perspectives Shinn (2002) emphasizes that these perspectives fail to recognize that the university, industry and government function in a national context. Since university-industry interactions show a great variety in developing countries, such context-independent approaches might not be very useful for the understanding of KTT activities in these countries (Eun et al. 2006). Hence, in this study we utilize two theoretical approaches which are supporting and completing each other, namely resource-based view and scientific and technical human capital approach.

Thus, this chapter briefly reviews RBV and how it is applied in studies investigating university-industry relations in Section 4.1; and STHC approach in Section 4.2. The rest of the chapter focuses on reviewing empirical studies based on these two approaches. In Section 4.3, empirical studies focusing on academia and investigating organizational and individual factors affecting the establishment of ties with the industry are reviewed. Section 4.4 reviews the empirical studies focusing on what type of firms interact with the academia. The literature exploring the university-industry interactions in the emerging field of nanotechnology is discussed in Section 4.5. Finally, conclusions of the chapter are presented in Section 4.6.

4.1 Resource-based view of university-industry relations

The logic behind the use of RBV in order to understand university-industry KTT activity is that universities and individual researchers control bundles of idiosyncratic resources and capabilities which can be mobilized in KTT activities (Landry et al., 2007). Powers and McDougall (2005), O'Shea et al. (2005) utilize RBV to explain why some universities produce more spin-offs than others; and Powers (2003) use it to investigate why some universities are more active in licensing than others. However, Landry et al. (2006; 2007) and van Rijnsoever et al. (2008) employ RBV to explain the tendency of individual university researchers to engage in KTT activity. Eun et al. (2006), on the other hand, take the case of university-run entreprises in China and offer RBV as the most appropriate theoretical framework for understanding university-industry relationships in developing countries. Before presenting how RBV is utilized in empirical studies investigating university-industry KTT activity at the organizational and individual level, RBV literature is briefly introduced and examined below.

RBV mainly deals with the firms, their differences and how these differences bring competitive advantage in the market. Although the first publication using the term "resource based view of the firm" is published by Wenderfelt (1984) its theoretical antecedents went back to Penrose (1959) who argues that a firm should be understood, first, as an administrative framework linking and coordinating activities of individuals working for it; and, second, as a bundle of productive resources (Barney and Clark, 2007). Wernerfelt (1984) presents an attempt to look at firms in terms of resources rather than in terms of their products, and argues that resources of a firm (i.e. brand names, in-house knowledge of technology, employment of skilled personnel, trade contacts, machinery, procedures, capital) provide a competitive advantage to the firm.

RBV of the firm is based on two fundamental assumptions which affect the competitive advantage of the firm: (i) firms within an industry or even a group are heterogeneous with respect to their resources they control; and (ii) these resources are not perfectly mobile across firms or imitable by other firms (Barney, 1991). Therefore, for sustainable competitive advantage, firms must build ‘critical or strategic asset stocks’ which are non-tradable as well as non-imitable and non-substitutable (Dierickx and Cool, 1989). The RBV of the firm asks why firms differ; and how resources acquired by the firm explain the differences between firms and the superior performance of some firms in the market (Lazonick, 2002).

RBV of the firm or sometimes called as *resource based theory* is widely used in empirical studies aiming to understand firm performance, corporate strategies, international strategies of firms and the formation of strategic alliances along various management disciplines; i.e. human resource management, marketing, management information systems, operations research and technology and innovation management (Barney and Clark, 2007). Considering that RBV is still in the process of improvement there are various interpretations as to the factors of production controlled by a firm; and thus the terminology used to describe these factors (i.e. resources, capabilities, competencies, etc.). Wernerfelt (1984) and Barney (1991) call these factors as *resources* and they categorize them simply as tangible and intangible resources. Dierickx and Cool (1989) make a difference between stocks and flows and they call firms’ non-tradable, non-imitable and non-substitutable assets as *critical or strategic asset stocks*. Authors argue that resource flows (e.g. R&D expenditure) can be adjusted instantaneously but stocks (e.g. know-how) cannot; on the other hand, a desired change in strategic asset stocks needs a consistent pattern of resource flows.

Prahalad and Hamel (1990) develop the term of *core competences* which are defined as “the company’s collective knowledge about how to coordinate diverse production skills and technologies”. After a review of various companies including NEC, Canon, Philips, authors provide that these core competencies are the major factors behind the global competitiveness. Grant (1991) adds *capabilities* to the terminological fray of RBV. This author uses resources and capabilities together as the primary source of profit for a firm. Six major categories of resources are identified by Grant (1991): financial resources, physical resources, human resources, technological resources, reputation and organizational resources. Capabilities, on the other hand, are much more difficult to identify. Author makes an analogy between capabilities and organizational routines (Nelson and Winter, 1982). According to Grant, capabilities involve a complex pattern of coordination between people and between people and resources; and such coordination needs learning through repeated actions, i.e. routines.

Leonard-Barton (1995) introduces the term *core capabilities* which have been built up over years and cannot be easily imitated and which are essential to the competitive advantage of a firm. These core capabilities are closely linked to the learning and knowledge creating activities in the firm and can be defined as the ability to transform knowledge into new product and process. Author identifies four dimensions of core capabilities: physical systems, skills, managerial systems and values. Hence, Leonard-Barton puts the knowledge-creating activities at the center of the discussion related to the firms' competitive advantage. However such a perspective prioritizing knowledge-creation capabilities of firms has been popularized in the literature as the *knowledge-based view* (KBV) of the firm (Grant, 1996; Spender and Grant, 1996; Conner and Prahalad, 1996; Cohen and Levinthal, 1990; Nonaka et al., 2000; Nonaka and Takeuchi, 1995; Nonaka, 1991; Kogut and Zanger, 1996). According to this approach while knowledge is the most important strategic resource of a firm, creating knowledge is the most important skill of a firm to sustain competitive advantage (Grant, 1996; Nonaka et al., 2000). This perspective views firms as knowledge-creating entities.

Teece et al. (1997), on the other hand, introduce dynamic capabilities which are difficult to replicate by other firms. Although RBV of the firm emphasizes that a firm has some idiosyncratic and difficult to trade assets / resources / competencies, dynamic capabilities approach argues that for sustainable competitive advantage these assets are not enough; but dynamic capabilites which enable firm to create, extend, upgrade, protect and keep these assets are required (Teece, 2009). Thus, dynamic capabilities are organizational and strategic routines by which firms change their resource-bases and create new resource combinations (Teece et al., 1997; Eisenhardt and Martin, 2000). According to Teece (2009), a firm which possesses resources / competences but lacks dynamic capabilities earns Ricardian rents when demand for its output increases to its output but does not earn Schumpeterian rents which are associated with new combination of existing factors of production.

There are some fundamental theoretical differences between earlier contribution to RBV (i.e. Wernerfelt, 1984; Barney, 1991) and later ones, especially dynamic capabilities approach. First of all classical RBV comes from the tradition of American strategic management thinking and the tradition of Chicago School industrial economics (Foos et al., 1995). Moreover, the early proponents (i.e. Wernerfelt, Barney) of this approach follow a neoclassical paradigm of an economy in which markets rather than organizations allocate resources (Lazonick, 2002). One of the theoretical antecedents of the RBV is Ricardo's analysis of land rents. Hence, firm resources which are inelastic in supply are the main sources of economic rents, and firms that control such resources are able to earn economic rents only by exploiting them (Barney and Clark, 2007). As mentioned by Lazonick (2002) the firm defined by the early proponents of RBV is not an innovative firm. On the other hand, proponents of KBV view of the firm or dynamic capabilities are more focused on organizational learning, routines and innovation creating capabilities of firms. However, in spite of such theoretical differences RBV of a firm is presented as a body of knowledge including all these variations (i.e. Barney and Clark, 2007; Mowery et al., 1998; Eisenhardt and Martin, 2000; Hodgson, 1998). Since in-depth analysis of the details of resource-based approach is not in the locus of this research, we are now going to review how RBV is utilized in research on the formation of strategic alliances.

RBV is succesfully utilized by some studies focusing on interfirm cooperation or strategic alliances. These studies provide evidence for the success of RBV in explaining how firm resources and capabilities influence the decision of firms to cooperate with other firms or how these resources and capabilities affect partner choice in alliances (Eisenhardt and Schoonhoven, 1996; Tsang, 1998; Mowery et al., 1998; Combs and Ketchen, 1999; Das and Teng, 2000). Although RBV seems appropriate for understanding strategic alliances because firms essentially use alliances to gain access to other firms' resources and capabilities, the number of empirical studies examining the role of resources / capabilities in the formation of strategic alliances is very limited. Among those Eisenhardt and Schoonhoven (1996) indicate that interfirm cooperation is more likely to occur when each firm needs the other's resources or when firms possess valuable resources to share. Moreover, acquiring resources which are not perfectly tradable in the market or embedded in organizations needs out-of-market strategies such as mergers, acquisitions or strategic alliances (Das and Teng, 2000).

Powers and McDougall (2005), Powers (2003) and O'Shea et al (2005) use RBV to examine the performance of universities in technology transfer activities (licensing and spin-off formation). Drawing from Wernerfelt's work (1984) O'Shea et al. (2005) categorize four types of resources (financial, institutional, human capital and commercial) and investigate what role these resources play in explaining differences among universities in terms of spin-off activites; i.e. why some universities produce more spin-offs than others. Powers and McDougall (2005), on the other hand, apply resource-based approach to research universities in order to understand which resources provide a university some advantages in technology transfer. Although resource based approach is normally applied at the organizational level Landry et al (2006; 2007) and van Rijnsoever et al. (2008) use this approach also at the individual level. Landry et al (2007) categorize various individual and organizational level assets to examine the impact of these assets on individual university researchers' knowledge transfer activities. On the other hand, van Rijnsoever et al. (2008) utilize a knowledge-based perspective to investigate networking among researchers.

Santoro and Bierly (2006) and Santoro and Chakrabarti (2002) utilize a KBV but take the firm as the unit of analysis. Santoro and Chakrabarti (2002) use an extended resource-based theory as including dynamic capabilities of a firm utilized for the acquisition of external tacit and codified knowledge. Lockett and Wright (2005) also utilize a dynamic capabilities approach. Authors first include a number of resource stocks in their model which have a positive impact on the creation of university spin off companies; then they add capabilities and routines developed by the universities to enable them to create spin offs more likely. Routines considered by authors mainly include the incentives and rewards to commercialize the technology developed at the university labs.

Finally, RBV can contribute positively to the examination of individual or organizational level resources and (dynamic) capabilities that are at the origin of a superior performance in KTT, and the variations among universities or university researchers in terms of participating to KTT activity. Although the number of empirical studies in this field is very limited it provides a useful theoretical framework to understand how idiosyncratic resources and capabilities of universities, firms and even individual researchers increase their success to engage in KTT activity. Thus, pertinent inputs can be provided to science and technology policy.

4.2 Scientific and technical human capital approach to university-industry relations

The "scientific and technical human capital" (STHC) approach (Bozeman et al., 2001) has guided a number of recent inquiries into knowledge production and academic productivity (Lin and Bozeman, 2006; Dietz and Bozeman, 2005), research collaboration of university researchers (Bozeman and Corley, 2004; Lee and Bozeman, 2005; Boardman and Corley, 2008), brain drain (Davenport, 2004), academic / scientific career (Gaughan and Robin, 2004) and male-female differences and gender equity in academia (Corley and Gaughan, 2005). Moreover, this approach is extensively used by some very recent studies focusing on the factors influencing the decision of university scientists to engage in KTT activity, i.e. Edler et al., 2011; Boardman, 2009; Ponomariov, 2008; Boardman and Ponomariov, 2009; Murray, 2004.

STHC approach was originally developed as a model for evaluating scientific projects and programs. While existing evaluation models focus primarily on the discrete products and immediate outcomes, STHC approach recognizes “the socially-embedded nature of knowledge creation; transformation and use; and the dynamic, capacity-generating interchange between human and social capital” (Bozeman et al., 2001). R&D investments made by governments are very important for the generation of human capital; therefore, authors argue that the evaluation of scientific projects and programs should center not only on economic value but also on the growth of scientific capacity.

Although this approach is centered on the concept of human capital, the notion of human capital used is not limited with the original *human capital* concept developed by Schultz (1961), Becker (1962) and Mincer (1958, 1962). The notion of human capital refers to knowledge, skills, health or values which are embodied in people and, therefore, cannot be separated from people (Becker, 1993). It is argued that schooling, training on the job, expenditures on health care and nutrition are all capital because they increase earnings, improve health and provide a person a good life. Human capital theory suggests that both individuals and society benefit from investments in people; these investments are in the form of expenditures on medical care and nutrition, education, formal or informal training (Sweetland, 1996). However, in STHC approach the notion of human capital is expanded as to include, researchers’ tacit knowledge, craft knowledge and know-how as well as social capital. In this sense, *human capital* used by the proponents of STHC approach are similar to *intellectual human capital* of biotechnology researchers in Zucker et al. (1998a). According to Zucker et al. (1998a), innovations in biotechnology is linked to creating intellectual human capital characterized by natural excludability which arises from the complexity or tacitness of the knowledge required in the innovation process. Bozeman et al. (2001) follow Coleman’s (1988) argument that social capital is essential for the formation of human capital at the individual level. The relationship between human and social capital is critical for this approach. Since social capital play a critical role in the exchange of human capital (Coleman, 1988), Bozeman and Corley (2004) argue that, in practice, these two forms of capital cannot be easily disentangled.

A second key point related to STHC approach is that it proposes a multi-level model, i.e. individual and project / organization level assessments. At the individual STHC level, the model includes the human capital endowments (i.e. cognitive, knowledge-based, and skill-based) and social capital endowments (i.e. social ties) of the individual researcher. On the other hand, at the project / organization STHC level, the focus is on the aggregate of all project participants' or organization members' human and social capital endowments as well as the physical and economic resources available to a project / organization. Moreover, the number of levels included in the model can be increased through inclusion of, for instance; academic disciplines, fields, subfields or formal / informal networks (Bozeman et al. 2001).

STHC approach is similar to RBV (Boardman, 2009; Bozeman and Corley, 2004) in the sense that human capital refers to "a unique set of resources the individual brings to her own work and to collaborative efforts" (Bozeman and Corley, 2004). Boardman (2009) argues that STHC approach emphasizes both institutional approach and RBV due to multi-level model it proposes. According to the author, this approach is "resource-based" in the sense that it addresses not only individual level resources and capabilities such as knowledge integration but also individuals' professional linkages and network ties, and also institutional resources/capabilities that create variations between organizations.

Edler et al. (2011), Boardman (2009) and Boardman and Ponomariov (2009) utilize STHC approach in order to examine the factors influencing individual university researchers' links to the industry. Edler et al. (2011), for example, argue that international mobility contributes to human and social capital of the individual researcher and, therefore, positively correlates with his/her proclivity to interact with the industry. On the other hand, Lin and Bozeman (2005) find that academicians who are more experienced in working with the industry have higher scientific productivity than the others who have no such experience due to the fact that working with the industry positively contributes to human and social capital of researchers. Boardman (2009) and Boardman and Ponomariov (2009) utilizes STHC approach in order to understand both individual and institutional level determinants of a university researcher's decision to have connections with the industry.

4.3 Who, at universities, interacts with the industry: A review of empirical studies

There is a large literature investigating inter-organizational and/or inter-personal variations affecting the likelihood of either universities as organizations or researchers at universities to engage in any form of KTT activity. Some of these factors are individual (i.e. seniority, age, number of publications, individual networks, gender, etc.) and some are organizational (i.e. knowledge stock of the department or university, number of patents, presence of TTO, institutional experience in KTT, policies and rewarding, royalty payments etc.).

We study hereafter the literature focusing on universities and academicians; and the determinants of their engagement in KTT activity in two main groups which simply differ in terms of the unit of analysis. The first group of empirical studies takes the university as the unit of analysis and deal with the organizational capabilities and resources as the main sources of the variation observed in university-industry relations. On the other hand, empirical studies in the second group take the university scientist as the unit of analysis and focus primarily on the individual characteristics/capabilities affecting her/his tendency to involve with the industry.

4.3.1 Organizational resources/capabilities

Many changes occurring since the 1980s in the organization of the science system have brought new challenges to universities, including transformation in their organizational structures, strategies and human capital formation. There are a number of studies focusing on the role of organizational capabilities / resources in KTT activity and on the variety of these capabilities / resources. For example, Thursby and Thurby (2002) emphasize the importance of faculty willingness and the propensity of central administration for TT from universities to firms; Bercovitz et al. (2001), Powers (2003) and Friedman and Silberman (2003) deal with factors affecting inter-organizational variations among universities to involve in formal technology transfer (i.e. patenting and licensing); DiGregoria and Shane (2003), Lockett and Wright (2005), O’Shea et al. (2005; 2007) and Powers and McDougall (2005) try to understand why some universities generate more spin-off companies than others; Arvenitis et al. (2008), Schartinger et al. (2001) and Perkmann et al. (2011), on the other hand, focus on the organizational factors facilitating universities’ KTT activities across various formal and informal channels.

Among the organizational-level determinants of universities’ KTT activities “human capital resources” which are generally operationalized by the quality of research papers, the number of researchers or the national rank of the university are widely tested in the empirical studies. O’Shea et al. (2005) find that the number of post doctoral staff and faculty working in R&D activities in the university positively influence the number of spin off companies formed. Powers (2003), Di Gregoria and Shane (2003) and Perkmann et al. (2011) uses the nation-wide evaluations for the quality of the faculty; and provide evidence supporting the positive impact of the faculty quality on certain KTT activities such as spin-off formation (Powers 2003; Di Gregoria and Shane, 2003); patenting and licensing (Powers, 2003) and collaborative research, contract research and consulting (Perkmann et al., 2011). Powell and McDougall (2005) prefer to use the number of citations as the indicator of human capital resources of the faculty and find a positive relationship between the spin-off company formation and human capital resources of the faculty. On the other hand, Schartinger et al. (2001) operationalize human capital quality of the faculty by the number of international publications and find a significant and positive impact of this variable on the faculty's joint research activities with the industry.

Financial resources provided by the industry are another important determinant of the presence of university-industry KTT activity at the organizational level. Arvenitis et al. (2008) find a positive and significant relationship between industry funding and the formation of KTT linkages between universities and firms. Powers and McDougall (2005) and O'Shea et al. (2005) provide evidence regarding to the positive impact of industrial funding on the formation of spin-off companies. Nonetheless, Powers (2003) posits that while industrial funding is an important contributor to patenting activity its effect disappears in licensing. Di Gregoria and Shane (2003) find positive but insignificant relationship between the share of industrial funding and the spin-off activities of the universities. The share of the industrial funding is important to capture the applied nature of research at universities (O'Shea et al, 2005). However, Arvenitis et al. (2008) directly test the impact of applied research; and provide that institutes with a stronger orientation toward applied research are more strongly inclined to get involved in KTT activity.

TTO experience, the number of TTO staff allocated for TT activities, TTO experience and experience of the university in certain KTT activities are considered as the indicators of organizational capabilities and resources of the universities in the industry involvement process. TTOs have become substantial intermediaries in technology transfer especially in the USA; and number of studies examining the impact of TTO on technology transfer have been carried out (i.e. Thursby and Thursby, 2002; Jensen et al., 2003; Carlsson and Fridh, 2002). Since technology transfer needs strong interpersonal and inter-organizational relationships and the formation of a culture for boundary spanning, TTO experience is an important predictor of KTT activities (Friedman and Silberman, 2003). Moreover the number of TTO staff indicates the resources dedicated to the technology transfer activities. Therefore, Lockett and Wright (2005), Friedman and Silberman (2003), O'Shea et al. (2005) use TTO-related variables in their models. Friedman and Silberman (2003) provide evidence regarding the importance of TTO experience. While O'Shea et al (2005) finds a positive and significant relationship between the number of TTO staff and the number of spin-off companies, Lockett and Wright (2005) provide little evidence for the impact of TTO size on the spin-off formation. University's institutional experience in spin-off formation is also provided as another important factor affecting spin-off formation by O'Shea et al. (2005).

Last but not least the policies developed by universities to promote university-industry KTT activities attract attention from 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 the various technology transfer policies used by the university administrations enhance technology transfer and spin-off activities.

Table 4.1 provides a sample of studies focusing on the factors impacting on university-industry relations at the university level. Empirical studies provided in Table 4.1 differ in the KTT channels they primarily focus on but they all examine how capabilities / resources of universities influence KTT occurring via these channels. The most common capabilities / resources of universities scrutinized in these studies are human capital resources or research quality (Schartinger et al., 2001; Di Gregoria and Shane, 2003; Powers, 2003; Powers and McDougall, 2005; O'Shea et al., 2005; Perkmann et al., 2011) and organizational / institutional capabilities, policies (Bercovitz et al., 2001; Powers, 2003; Powers and McDougall, 2005; O'Shea et al., 2005, Friedman and Silberman, 2003).

Table 4.1 A sample of empirical studies focusing on universities' organizational capabilities / resources in KTT activities

Publication	*Country*	*Data source*	*KTT activity investigated*	*Number of observations*	*University resources / capabilities*
Schartinger et al. (2001)	Austria	Question.	Joint research; contract research; supervision of graduate thesis; mobility of researchers	421 depart.	Personnel structure; international publications; university experience in contract research; intensity of graduate students
Bercovitz et al. (2001)	USA	Interviews	Patenting; licensing; sponsored research	3 univ.	The organizational structure of the TTO (Matrix structure; hierarchical structure; multidivisional structure)
Friedman and Silberman (2003)	USA	AUTM	Licensing	83 univ.	Policy; university mission; TTO experience
Di Gregoria and Shane (2003)	USA	AUTM	Spin-off	116 univ.	Intellectual eminence; policy; commercially oriented research; venture capital
Powers (2003)	USA	AUTM	Patenting, licensing	108 univ.	Physical resources; human capital resources; organizational resources; financial resources
O'Shea et al. (2005)	USA	AUTM	Spin-off	141 univ.	Institutional resources; human capital resources; financial resources; commercial resources

Table 4.1 (cont'd) A sample of empirical studies focusing on universities' organizational capabilities / resources in KTT activities

Publication	*Country*	*Data source*	*KTT activity investigated*	*Number of observations*	*University resources / capabilities*
Powers and McDougall (2005)	USA	AUTM	Spin-off	120 univ.	Financial capital; human capital; organizational resources
Arvenitis et al. (2008)	Switzerland	Questionnaire	Formal and informal KTT activities	241 depart.	Applied research; funding; time allocated for teaching activities; obstacles; motivations; disciplines
Perkmann et al. (2011)	UK	Higher Education Business and Community Interaction survey	Collaborative research; contract research; consulting.	164 univ.	Faculty quality; academic disciplines

4.3.2 Individual resources/ capabilities/ skills

Even though the terminology "university-industry relations" refers to an organizational level interactions, collaborations, or information and resource exchange, relationships mostly materialize between individuals. Melin (2000) emphasizes that as moving from macro to micro level the individual motivations for collaboration become more apparent; for example the individual reason of increased collaboration among researchers would not be due to the increased telecommunication facilities but other interests, such as increasing the number of publications, having new sources of funding, accessing new networks, etc.

There are number of empirical studies focusing on the importance of interpersonal information exhange. Balconi and Laboranti (2006) track university-industry collaborations on patents and find that border crossing collaborations are mostly driven by personal relationships between researchers. Using patent data Breschi and Catalini (2010) also identify particular individuals, "inventor-author", bridging boundaries between academia and industry. Thus, in the university-industry KTT literature, number of studies investigating the factors influencing individual researchers' decision to contact the industry has been recently increasing.

Landry et al. (2007) investigate the determinants of knowledge transfer among Canadian university researchers in natural sciences and engineering from a resource-based perspective. Authors argue that, like firms, individuals control bundles of idiosyncratic resources and capabilities that enable them to transfer knowledge across boundaries. Financial, organizational, relational and personal assets of researchers along with some attributes of knowledge (i.e. novelty of research findings, academic field, publications, industrial applicability) produced by university scientists are tested in the study. Based on a nationwide survey of 1,554 university researchers, this research provides evidence for the strong influence of private and public funding, individual research experience, number of publications, novelty of the research carried out by the researcher and it being focused on user needs and linkages with non academic users as well as organizational assets (i.e. research unit size) on the propensity of researchers to transfer knowledge. While the impact of certain factors change across research / academic fields, only two determinants, i.e. 'linkages between university researchers and nonacademic researchers' and 'focus of the research on users' needs' are obtained as variables explaining knowledge transfer across all fields.

Another study (Link et al., 2007) presents empirical evidence on the determinants of three types of informal knowledge and technology transfer activity: transfer of commercial technology; joint publications and consulting. Authors find that male, tenured researchers and those who allocate a relatively higher percentage of their time to grants-related research are more likely to engage in all three forms of informal KTT activities.

On the other hand, using questionnaire data collected from a representative national sample of 1,564 academic researchers in the USA, Bozeman and Gaughan (2007) investigate the impact of research grants received by a university scientist on the nature and extent of her/his knowledge transfer activity with the industry. The particular aim of the study is to understand the independent contribution of research grants provided either industry or government on the level of a university scientist's industrial involvement. Results derived from the study support the hypothesis that university scientists with more grants and contracts of public and private source have a greater propensity for industrial involvement than those who have fewer grants and contracts.

Boardman and Ponomariov (2009), based on a national survey of the US university scientists in 2003-2004, identify personal and professional characteristics affecting whether university scientists interact with private companies, if so, which channels. Authors examine the impacts of various individual factors, i.e. industry funding, percentage of time allocated to research supported by the government grants, affiliation with a university based research center, number of collaborators, number of graduate students funded, tenure status and gender; and find out that the effects of these factors are not uniform across nine different forms of interactions identified by authors. However, research result indicate that research grants provided by the industry, affiliation with a university-based research center, number of graduate students funded and tenure status positively correlate with many forms of university-industry interaction included in the survey.

Ponomariov (2008) investigates how university characteristics influence the propensity of a university scientist to interact with firms. University characteristics proposed by the author to approximate the university-level organizational context in which individual level interactions occur are academic quality, level of university patenting, industrially funded R&D expenditure and total R&D expenditure of the university. The results of the study provide evidence for the positive effect of industrially funded R&D; but no support for the impact of patenting and total R&D expenditure. The most interesting result is that academic quality of the university has a negative and significant impact on the relationship. In other words, the higher the academic quality of an institution is the smaller is the propensity of individual university researcher to interact with the industry. The explanation of the author for this unexpected result is that the scientists in more prestigious academic institutions may receive greater incentives to engage in basic, peer-reviewed research and, therefore, may consider interactions with the industry as somewhat distracting to such pursuits.

Boardman (2009) is another study using a survey conducted among US university scientists. Likewise Ponomariov (2008), this study examines the impact of the organizational context on individual level university-industry interactions. In Boardman (2009), the focus is on how different types of university research centers affect the propensity of university researchers to interact with the firms. The study presents, first of all, that affiliation with the university research centers which are not solely sponsored by industry but also sponsored by public programs correlates positively with the likelihood of an academic researcher having an interaction with the industry.

Chang et al. (2009) is another study dealing with the institutional changes affecting a university researcher's efforts for the commercialization of academic research. Based on a survey conducted in Taiwan with 474 university researchers who have patents the study investigates the impact of organizational ambidexterity on the technology transfer activities (patenting, licensing, equity participation in start-up firms) of university researchers. Authors argue that entrepreneurial universities have become ambidextrous organizations which are not only dealing with teaching and research but a third mission of economic development (Etzkowitz et al., 2000). According to authors, there are two different types of ambidexterity; i.e.
structural ambidexterity which creates a top down institutional policy, commercial infrastructure and organizational guidelines in order to support research commercialization; contextual ambidexterity, on the other hand, creates a bottom up flexible context which encourages university researchers for research excellence and commercialization. To understand the impact of these two types of organizational ambidexterity on the technology transfer activities of individual researchers authors develop a model including variables related to governmental policies and organizational strategies (such as presence of IPR agency, incubator facility, entrepreneurial fundings) for structural ambidexterity and variables related

to individual network capabilities (i.e. academic links, contract links, collaborative links, business actors links, and venture capitalist links) and personal entrepreneurial capabilities for contextual ambidexterity. This study suggests that structural and contextual ambidexterity are complementary in patenting and licensing; and in fostering university start-up activities contextual ambidexterity is more important than structural ambidexterity.

Another study (Azagra-Caro, 2007) uses both organizational level and individual level variables to understand what type of faculty members interacts with firms in Spain. While author finds out that individual level factors such as being male, senior or a department chair; and having a higher proportion of time devoted to R&D activities have a positive and significant impact on the likelihood of a university researcher to interact with industry.

In one of the most recent studies, Edler et al. (2011) investigate how the duration and the frequency of a university scientist's visits at research institutes outside their home country affect her/his interaction with the industry. Authors argue that international mobility may increase the scientist's professional networks and her/his intellectual human capital and play a key role in the transmission of knowledge and technology from academia to industry. The results of the study support authors' argument and indicate that most of the internationally mobile university scientists engage in KTT activities both in the host and in their home countries; and longer visits increase the proclivity of scientists to engage in KTT activities both in host and home country.

Bercovitz and Feldman (2003; 2008) examine the impact of localized social learning in organizational units on the individual level TT activities; i.e. the propensity for disclosing inventions and the number of disclosures to TTO. The main argument in these studies is that TT is learned in organizational environments. The results suggest that academic researchers who are trained at academic institutions where participation in TT is a legitimate activity and actively practiced have higher propensity to engage in TT activities. Moreover, these studies provide evidence for the impact of department chair and other local peers on an individual researcher's choice in participating to technology transfer activities. Authors argue that the chairman of the department plays a direct role in reviewing and evaluating a researcher's performance; and a department chair active in technology transfer sends a signal to improve technology transfer activities at the individual level. In addition to department chairs, authors suggest that peer groups also act as a reference point in social learning process; and researchers may learn from those with whom they frequently interact. Stuart and Ding (2006) also provide that working in close proximity to peers who have participated in commercialization of scientific research stimulates a university researcher's propensity to engage in entrepreneurial activity.

Last but not least D'Este and Patel (2007) is another study designed to explain the impact of individual and organization level characteristics on KTT activities. However, what is special about the study is that it deals with the factors influencing the variety of channels through which knowledge transfer occurs between universities and firms. Authors argue that academic researchers who interact with the industry through various channels develop some individual capabilities necessary to integrate the worlds of scientific research and the worlds of manufacturing and product application. Hence, this study examines the relative impact of department and university level characteristics of the organizational context and individual characteristics in explaining the likelihood of engagement in a wider variety of interactions with industry. The results derived from the research point out that some individual characteristics of university-researchers have a larger influence than department and university characteristics over the variety of channels.

Table 4.2 provides a list of selected empirical studies which take the individual university-scientist the unit of analysis of the research. Although they focus on individuals to understand the factors influencing KTT between academia and industry, they follow a multi-level approach to the issue. In other words, they account for not only the impact of individual level factors such as seniority, gender, research grants taken from industry or government or scientific publications but also the impact of organizational level factors related to faculty or university where individual researcher occupies a position.

Table 4.2 A sample of empirical studies focusing on university scientists' characteristics and capabilities in KTT activities

Publication	*Country*	*Data source*	*KTT activity investigated*	*Number of observations*	*Factors under investigation*
Landry et al. (2007)	Canada	Survey	7 knowledge transfer activities	1,554	Financial assets; organizational assets; relational assets; personal assets; knowledge attributes
D'Este and Patel (2007)	UK	Survey	5 channels	1,528	Individual; department and university characteristics
Link et al. (2007)	USA	Survey	3 channels	1,502	Research grants; gender; tenure
Azagra-Caro (2007)	Spain	Survey	Any type of contracts with firms	380	Type of university; academic discipline; time for R&D activities; seniority; gender; administrative position; mobility
Bozeman and Gaughan (2007)	USA	Survey	9 activities	1,564	Industry grants; government grants; gender; career; affiliation with a research center; academic disciplines
Bercovitz and Feldman (2008)	USA	TTO data	Patenting, licensing	1,780	Training effect; leadership effects; local peer effects
Ponomariov (2008)	USA	Survey	8 activities	1,638	Academic quality; patenting; total R&D expenditure; industry funded R&D

Table 4.2 (cont'd) A sample of empirical studies focusing on university scientists' characteristics and capabilities in KTT activities

Publication	*Country*	*Data source*	*KTT activity investigated*	*Number of observations*	*Factors under investigation*
Boardman (2009)	USA	Survey	8 activities	1,647	Types of university based research center
Boardman and Ponomariov (2009)	USA	Survey	9 activities	1,643	Industry funds; government grants; affiliation with a research center; no. of collaborators; no. of graduate students funded; tenure status; gender
Chang et al. (2009)	Taiwan	Survey	2 channels	474	Institutional legitimacy; organizational resources; network capabilities; personal entrepreneurial capabilities
Edler et al. (2011)	Germany	Questionn aire	Any type of KT activity	958	The frequency and length of visits to research institutes outside of the country

4.4 What type of firms interacts with the universities: A review of empirical studies

What type of firms interact with universities and other public research institutes and why; and the impact of collaborating with universities on firms' innovative capacities are the issues attracting scholarly attention in the technology transfer literature. Studies taking firms as the unit of analysis generally utilize large scale surveys which are not mostly designed in order to understand the characteristics of the firms collaborating with the universities or other public research institutes (for example innovation surveys). Therefore, the results derived from these studies mostly emphasize the importance of some structural factors (firm size, age of the firm, R&D expenditure, industry sector, etc.) for collaboration with universities.

Using innovation survey data collected from manufacturing firms in the UK, Laursen and Salter (2004) investigate how a firm's search strategy in the innovation process affects its proclivity to use universities as a knowledge source of innovation. Authors find out that firms that adopted an open search strategy, in other words, used various external sources of knowledge in the innovation process tend to use more knowledge and information produced at universities. The study also confirms the importance of some structural factors (i.e. R&D intensity, firm size and the sector of the firm) in explaining why some firms collaborate with universities. Veugelers and Cassiman (2005), based on the nation-wide innovation survey in Belgium, provide evidence for the importance of innovation strategy on the decision of the firm to cooperate with the universities. Results confirm the presence of a complementary relationship between cooperating with universities and a knowledge sourcing strategy, which is based on using universities and other public research institutes as an information source in the innovation process. Van Beers et al. (2008), using innovation surveys in Netherlands and Finland, examine the impact of academic spillovers on the propensity of firms to collaborate with universities and other public research institutes; and find a positive and significant relationship at least for Dutch firms.

Another study, Mohnen and Hoareau (2003), based on innovation survey data for France, Germany, Ireland and Spain, to understand what type of firms are collaborating with universities indicate that R&D intensive firms and radical innovators tend to benefit from knowledge spillovers from universities and government labs but they do not cooperate for research with them. On the other hand, large firms and those which receive government support for innovation tend to collaborate with universities and other public research institutes.

Using a survey conducted in seven EU countries with SMEs Fontana et al. (2006) demonstrate that openness of the firm to external knowledge resources have a significant impact on the proclivity of firms to engage in collaborative research agreements with public research organizations. The findings of the study indicate that firms which have access to external knowledge through screening academic publications and participating in projects supported by regional, national or EU organizations tend to sign a collaborative research agreement with a public research organization. The research also suggests that firms' absorptive capacity which is measured by total R&D expenditure and R&D intensity have a positive and significant impact on their tendency to collaborate with public research organizations.

Cohen et al. (2002) based on the Carnegie Mellon Survey with R&D managers of firms indicates that larger firms are more likely to use public research as well as start ups. Although small firms in general exploit public research less, start ups especially those in pharamaceuticals industry appear to use it more. Schartinger et al. (2001), on the other hand, use a smaller data of 99 firms in Austria and find out that while firm size positively and significantly correlates with the proclivity of the firm to interact with universities age of the firm has a negative and significant impact on the same tendency.

Bercovitz and Feldman (2007) deal with the question of how innovation strategy of a firm influences its decision to engage in R&D alliances with universities. Authors consider two issues central to innovation strategy design: the balance between exploitation and exploration of existing competencies (March, 1991) and sourcing of knowledge either internal or external to the firm. While exploitation based alliances are also common between universities and firms, many university firm collaborations, according to authors, are exploratory in character. Exploration enables firm to search and discover the knowledge that is new to the firm. Firms carry out internal exploratory activities to develop new capabilities but also improve their relations or access into networks to reach external sources of knowledge. Therefore, linking with external organizations is the key element of firms' successful exploration strategies. Bercovitz and Feldman (2007), in this research, seek for the complementarity between internal exploration activities of the firm and the use of university exploratory research. Finally, results provide evidence for the strong relationship between firm innovation strategy and firm-university research interactions. When a firm follows an internal innovation strategy toward exploration and when a greater share of the research conducted at universities is exploratory then the firm spends a greater share of their R&D expenditure on university-based research projects.

Santoro and Chakrabarti (2002) and Santoro and Bierly (2006), on the other hand, emphasize the role of key person, i.e. champions (Chakrabarti, 1974) both in firms and at universities in the process of knowledge transfer between universities and firms. In bridging the information gap between universities and firms, authors argue that such key persons or champions are important because the presence of such persons ensure that there is frequent, on-going and personal involvement between universities and firms. Both of these studies provide empirical evidence regarding the important role of such key persons in the knowledge transfer between universities and firms. Santoro and Bierly (2006) also examine the role of firm’s trust in universities, university policies to support technology / knowledge transfer and technological capability of the firm on the intensity of the firm’s relations with universities. Results of the empirical study indicate that trust, university policies and technology capability of the firm are facilitators of the university-firm interactions.

There is also a number of studies focusing on why firms interact or engage in collaboration with universities and the impacts of these interactions / cooperation on firms’ performance. Feller et al. (2002) based on a questionnaire survey with 355 firms participating to engineering research centers at US universities find that firms participate to these centers in order to gain access to upstream knowledge. The most important reasons for interactions with these centers are accessing to new ideas, expertise of the center, joint project opportunities and equipments and / or research facilities at the university research center. Lee (2000), based on a survey carried out with firm technology managers, presents that according to these managers product development is a primary interest of having university faculty involvement in firms’ research projects and the exploratory "blue sky" research is mentioned as the second leading objective. Empirical results provided by Lee (2000) also indicate that the most significant benefit realized by firms from collaborating with universities is an increased access to new university research and discoveries.

Murray (2004), based on interviews with 25 entrepreneurial biotechnology firms, brings a new perspective for understanding the impact of interactions with academists. Author argues that university scientists contribute by their social capital to entrepreneurial firms. In other words, the scientist 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. The social capital of the scientist has two components; local laboratory network and cosmopolitan network. While a local laboratory network is shaped by the specific career experience of the scientists a cosmopolitan network contains widely dispersed peers within her/his academic field. Thus, the local laboratory network of an academician can enable the firm s/he works with to access into a source of ongoing specific expertise; however the cosmopolitan network allows firm to be embedded into a broader scientific network.

Some studies measure the impact of university collaboration on firm performance with new product development. Cockburn and Henderson (1998), using data on co-authorship of scientific papers between pharmaceutical company scientists and publicly funded researchers, find that connectedness to open science community has a positive impact on firms' performance in drug discovery. Again Zucker et al. (1998b) scrutinize the impact of co-authorships between university and firm researchers in biotechnology and find that for an average firm five articles co-authored by "star scientists" and the firm's scientists imply about five more products in development and 3.5 more products in the market. Likewise Baba et al. (2009) identify the effect of university-industry collaboration on firm performance through the analysis of new product development, i.e. number of patents, in the advanced materials field. In order to measure these effects authors identify three non-overlapping typologies of scientists: (i) 'Star Scientists' with above the average publication record and below the average patenting activity; (ii) 'Edison Scientists' with over the average patenting activity and below the average publication record; and (iii) ‘Pasteur Scientist’ with over the average publication and patenting activity. Based on a sample of 455 firms active in photocatalysis in Japan, Baba et al. (2009) confirm that engaging in research collaborations with ‘Pasteur Scientists’ increases firms’ R&D productivity which is measured by the number of registered patents.

A selected list of empirical studies which focus on firms’ characteristics and capabilities influencing their KTT activities is provided in Table 4.3. Most of these studies in the list use data derived from innovation surveys (Laursen and Salter, 2004; Veugeleurs and Cassiman, 2005; Mohnen and Hoareau, 2003, Eom and Lee, 2010) or some others which are not originally designed to investigate university-industry interactions (Cohen et al., 2002; Fontana et al., 2006) in order to examine the role of firm-level factors in KTT. Therefore, they provide limited information, mostly on structural factors such as firm size, age of firm, industry, presence of R&D activity. However, specifically designed surveys which investigate firms’ relations with universities (Santoro and Chakrabarti, 2002; Santoro and Bierly, 2006; Bercovitz and Feldman, 2007) bring further insight on KTT activities. For instance, Santoro and Bierly (2006) and Santoro and Chakrabarti (2002) examine the role of some key firm professionals and Bercovitz and Feldman (2007) investigate the impact of the organization of firms’ R&D activities on the KTT between universities and firms.

Table 4.3 A sample of studies focusing on firms' characteristics and capabilities influencing KTT

Publication	*Country*	*Data source*	*Form of relationship investigated*	*Number of observations*	*Factors under investigation*
Laursen and Salter (2004)	UK	Innovation survey	Use of university knowledge	2,655	Firm strategy; R&D expenditure; age of firm; firm size
Veugelers and Cassiman (2005)	Belgium	Innovation survey	Research collaboration	325	Information sourcing strategy; firm size; barriers to innovation; industrial sector effects
Mohnen and Hoareau (2003)	France, Germany, Ireland, Spain	Innovation survey	Use of university knowledge; research collaboration	9191	Firm size; belonging to science-based sector; government support; R&D intensity; number of patents; being a radical innovator;
Fontana et al. (2006)	Denmark, France, Germany, Greece, Italy, Netherlan ds, UK.	KNOW survey	Research collaboration	558	Openness of the firm; firm size; firm R&D activity; firm innovative activity
Santoro and Bierly (2006)	USA	Survey	Knowledge transfer	173	Social connectedness (key persons); trust
Bercovitz and Feldman (2007)	USA	Survey	Research collaboration	45	Internal R&D (i.e. share of exploratory research); R&D organization (centralized vs decentralized); industry effect

Table 4.3 (cont'd) A sample of studies focusing on firms' characteristics and capabilities influencing KTT

Publication	*Country*	*Data source*	*Form of relationship investigated*	*Number of observations*	*Factors under investigation*
Santoro and Chakrabarti (2002)	USA	Survey	Research support; cooperative research; knowledge transfer; technology transfer	202	Firm size; organizational structure; firm capabilities; presence of champions
Eom and Lee (2010)	S. Korea	Innovation survey	Cooperative research	538	Participating national projects; firm size; R&D intensity; reasons for collaboration (cost c-sharing, risk sharing); affiliation to business group; firm location; sector
Cohen et al. (2002)	USA	Carnegie Mellon R&D managers survey	Using public research results	1,267	Firm size; start up; industry
Schartinger et al. (2001)	Austria	Survey	Joint research; contract research; supervision of graduate thesis; mobility of researchers	99	Firm size; firm age; motivations for interaction; barriers to interaction

4.5 University-industry relations in nanotechnology: A review of empirical studies

Although KTT between universities and firms is a critical issue in the field of nanotechnology due to its tight links to basic science, the number of studies exploring university-industry relations in this technology field is very limited. As reviewed in Chapter 2, empirical studies focusing on the economic impact of nanotechnology mainly deal with the knowledge stocks in the form of publications and patents at the national and organizational level; and interconnections between these two different stocks of knowledge, i.e. academic publications cited in patents (Meyer 2000a; 2000b; Hu et al., 2007).

Meyer (2006a, 2006b) and Bonaccorsi and Thoma (2007), on the other hand, investigate the connection between science and industry over the indivuals who are both publishers of NST related academic papers and inventors of nanotechnology patents. Both of these studies focus on these "author-inventors" performance. Meyer (2006a) finds that researchers who both publish and patent outperform non-inventing researchers in terms of number of publications and citation frequency. Bonaccorsi and Thoma (2007) provide that over 66 percent of patents have at least one inventor that is an active scientist with publications. Authors argue that this is evidence of a highly interconnected knowledge system in which the transformation of scientific achievements into commercial results is very rapid and takes place through the multiple roles played by scientists themselves.

Palmberg (2008) and Nikulainen and Palmberg (2010), based on a questionnaire survey carried out with individual nanotechnology researchers employed by universities and firms in Finland, provide valuable information about the KTT related issues in nanotechnology. Palmberg (2008) investigate how the perceptions of university and company researchers differ in terms of challenges, modes of interactions, and outcomes of technology transfer. University scientists mention the basic research orientation of the field, problems in the identification of commercial applications, and the lack of business skills amongst university researchers as the main challenges in KTT in nanotechnology. On the other hand, IPR ownership issues and the underdevelopment of production technologies are highlighted by company scientists as the main challenges. Findings provide that conferences, seminars and public programs are the most common modes of interactions between universities and firms in Finnish nanotechnology community. Among the university scientists, identification of new research questions and receiving research funds are the mostly mentioned outcomes of technology transfer; but company scientists emphasize the role of technology transfer on the development of existing products and processes.

Using the same survey data Nikulainen and Palmberg (2010) focus on nanotechnology scientists at universities and investigate the differences between perceptions of more active and less active scientists in nanotechnology. Results provide that nanotechnology differs in a few aspects only. For example, the researchers more involved in nanotechnology related research are more likely to have commercial motivations; hence, it suggest that some of NST research is conducted in more applied areas allowing commercialization. Second, the availability of public funding has been an important motivation for more active nanoresearchers to enter into field. It indicates that public investments have had an impact on the field. However, authors finally argue that the differences between more and less active nanoresearchers in terms of perceptions regarding the technology transfer are not very huge; therefore, at least for now, there is no need for a special policy framework for the field of nanotechnology to support technology transfer activities.

Wang and Shapira (in press) on the other hand explore how three resources possessed by academia, namely intellectual capital, social capital and positional capital (which is associated with the position and reputation of the scientists' academic institutions) affect nanotechnology start-up firms to collaborate with universities and to reap benefits through the resource spillovers associated with these relations. Although authors find that collaboration with university scientists contributes to firm performance, empirical results provide evidence only for the positive and significant impact of intellectual capital resources of the scientists on the firm performance. The research indicates that collaborating scientists' social and positional capitals are not as valuable in enhancing the anticipated performance of firms.

The number of empirical studies for NST is limited; but they have all one common point: they take the individual researcher as the unit of analysis. They focus on individuals as bridging different organizational spheres (Meyer, 2006a; 2006b; Bonaccorsi and Thoma, 2007), or on individual perceptions of challenges, motivations in technology transfer (Palmberg, 2008; Nikulainen and Palmberg, 2010); or on resource endowments of university scientists as the main drivers of university-industry collaboration (Wang and Shapira, in press). Finally, Palmberg (2008), Nikulainen and Palmberg (2010) and Wang and Shapira (in press) also provide important insights for our research for the design of the data collection process and of the conceptual framework (see Section 6.1 and Section 7.3).

4.6 Conclusions

In this chapter, two theoretical approaches, RBV and STHC, were pointed out to explain the determinants of university-industry interaction at individual, university or firm level. Both of these approaches center on the assumption that both individuals and organizations have some idiosyncratic resources, capabilities or skills which are not easily imitable, tradible or substitutable; and they can only be mobilized during interactions. Since both individuals and organizations interact with each other to mobilize and obtain these resources, capabilities and skills; they are expected to play an important role in the formation of linkages among organizations or individuals.

The review of the empirical studies investigating the factors, both individual and organizational, which influence the establishment of university-industry relations provide a deeper inside for understanding how these RBV or STHC-fashion approaches are successful in modelling the formation of KTT links between universities and firms. Empirical evidences demonstrate that individual human and social capital as well as organizational resources and capabilities influence the decision of university-scientists and firms to engage in KTT activity.

The theoretical approaches and empirical evidence which examined in this chapter will be used in the model selection and hypotheses / propositions building for the empirical investigation of university-scientists and firms in Chapter 7 and Chapter 8, respectively.

CHAPTER 5

NANOSCIENCE AND NANOTECHNOLOGY RESEARCH IN TURKEY: A UNIVERSITY-DRIVEN ACHIEVEMENT

Using scientific publication data which were retrieved from ISI WoS SCI-EXPANDED, this chapter investigates NST research carried out at Turkish universities. The main purpose of this chapter is to identify the main characteristics and the actors of NST research in Turkey. To this end, in Section 5.1, we review some efforts launched in a range of developing countries in order to support nanotechnology research. Section 5.2 presents an overview of policies and strategies for nanotechnology development in Turkey. In Section 5.3, we explain how bibliometric data of publications were retrieved from WoS-SCI, and manipulated. Section 5.4 provides the results of bibliometric analyses. This section provides extensive information about the change in the numbers of NST-related research articles in a ten-year period from 2000 to 2009, the main characteristics of Turkish NST research, the most prolific universities and researchers in the field and, national and international research collaborations of NST researchers. Section 5.5 concludes the chapter and discusses some science and technology policy implications of the research.

5.1 Nanotechnology efforts in developing countries

In the previous chapter on nanotechnology, the expected economic impact of this emerging technology was presented and discussed. All these expectations regarding the innovative and transformative capacity nanotechnology have long been considered by policy makers. Therefore, not only advanced industrial countries but also some developing countries such as China, Brazil, India, Argentina or Mexico have started to invest in basic and applied nanotechnology research since the very early days of the 2000s.

Brazil launched a pioneer program for nanotechnology research and development in 2000 which was in the same year as the US initiative (Invernizzi and Foladori, 2005). With this program four institutional, multidisciplinary networks aiming at promoting NST research were created. The number of researchers in these networks reached 300, the number of institutes 77 and number of companies 13 in the period 2002-2005 (Kay and Shapira, 2009). In India, the Nanomaterials Science and Technology Initiative (NSTI) has been launched in the beginning of the 2000s and with this initiative the Indian government committed to invest 20 million USD into nanomaterials research and commercial development over the period 2004 - 2009 (Matsuura, 2006). South Korea is also an early mover country in the field of NST. The government of South Korea had planned to spend 2 billion USD over the first decade of the new millennium (Niosi and Reid, 2007). Among late coming countries China has the most aggressive NST research policy; and several nanotechnology programs at national and regional level have been launched between 1995 and 2005 (Matsuura, 2006). Chinese government launched "Climbing Project on Nanometer Science' for the period 1990–1999 (Wonglimpiyarat, 2005) and 240 million USD in four years from 2003 to 2007 were granted to the sector by the central government and approximately 240–360 million USD by local governments to support nanotechnology research (Niosi and Reid, 2007; Wonglimpiyarat, 2005). While Singapore, in 2002, established University of Singapore Nanoscience and Nanotechnology Initiative (NUSNNI) in Taiwan the National S&T Priority Program on Nanotechnology (NPNT) with a budget of 680 million USD was established in the 2000s. Finally, in Russia, a nanotechnology funding programme has been approved, making it the largest one in the world, with 3.95 billion USD earmarked until 2015 (Mini-IGT 2010, OECD 2009a).

5.2 An overview of nanotechnology efforts in Turkey

Turkey has attempted to integrate nanotechnology into its technology development strategy with the inclusion of this field in Vision 2023 strategy document (TUBITAK, 2004). In this document, Turkey's future strategy for nanotechnology has been stated by the Scientific and Technological Research Council of Turkey (TUBITAK). According to this document, the subjects which are planned to be focused on are (i) nanophotonics, nanoelectronics, nanomagnetism; (ii) nanomaterials; (iii) fuel cells, energy; (iv) nanocharacterization; (v) nanofabrication; (vi) nanosized quantum information processing; and (vii) nanobiotechnology. Nanotechnology is also included in the last Development Program prepared by SPO for the period 2007-2013 as among the technology fields with priority. Albeit its given importance by these documents, until now no special policy initiative, program, allocated budget or funding scheme have been launched to support nanotechnology research in Turkey. However there are many distributed efforts to support NST research in the country. These efforts can be divided into three groups: (i) foundation of NST-related research centers and institutes to which SPO provides funding, (ii) graduate nanotechnology programs and finally (iii) public funds provided to academia and industry for nanotechnology research and development projects.

In NST field there has been a growing effort for the establishment of nanotechnology research and application centers. A search in the achieves of the Turkish Official Journal (T.C. Resmi Gazete) indicates that six research centers or institutes having nano prefix in their names have been established since 2004. Table 5.1 provides a list of these centers and institutes. Besides these institutes "Advanced Technologies Education, Research and Application Center at Mersin University" which was founded in 2006 has a declared aim to carry out research in nanotechnology field in its rules and regulations document. The Central Laboratory established at Middle East Technical University (METU) provides state of the art instrumentation not only to the researchers at this university but also to partners from other universities and firms working in nanotechnology field. Moreover, many universities in Turkey (i.e. Gazi University and Hacettepe University in Ankara or Institute of Technology in Izmir) have established their own nanotechnology laboratories.

Table 5.1 List of nanotechnology research and application centers

NST Research and Application Centers and Institutes	The announcement (Turkish Official Journal)
Gebze Institute of Technology Nanotechnology Research and Application Center	24 May 2004
Bilkent University Material Science and Nanotechnology Institute (UNAM)	8 May 2007
Marmara University Nanotechnology and Biomaterials Application and Research center	24 June 2008
Çanakkale Onsekiz Mart University Nanoscience and Technology Research and Application Center	19 June 2009
Gazi University Nanomedicine and Advanced Technologies Research and Application Center	16 June 2009
Sabancı University Nanotechnology Application and Research Center	4 June 2010

Source: Turkish Official Journal (T.C. Resmi Gazete)

The efforts for the establishment of the National Nanotechnology Research Center (UNAM) located at Bilkent University started in 2005 with the application of a group of academicians to the SPO for funding of a nanotechnology center. Although it was named as “national” it is a research institute under the administration of Bilkent University. The first phase of the nanotechnology research center project was completed at the end of 2007 and its cost reached to 28 million TL. In May 2007 the research center project was turned into UNAM Material

Science and Nanotechnology Institute. The investments for the second phase of the project were expected to reach 60-70 million TL by the end of 2009[1]. With 62 laboratories in 9000 m² closed area UNAM is one of the centers of excellence in nanotechnology in Turkey. The mission of UNAM is defined as “training experts through a multidisciplinary graduate program and develop new and high technologies based on nanoscience to strengthen the competitiveness of Turkish products in international markets and, hence, to contribute to the improvement of living standards in Turkey”. SPO also provides funds to different universities and research centers for nanotechnology infrastructure and equipments. Gebze Institute of Technology, Istanbul Technical University and Sabancı University are also funded by SPO for their expenses on nanotechnology infrastructure.

In recent years the number of graduate studies in NST provided by Turkish universities has also increased. Bilkent University, METU, Hacettepe University, Anadolu University[2] and Istanbul Technical University provide master and PhD programs in nanoscience and technology. Among master and PhD programs, those provided by Hacettepe University specifically focus on nanomedicine. Hacettepe University has the advantage of combining its high level capabilities in medicine (including pharmacy, and bio-engineering), natural and engineering sciences. Furthermore some graduate programs in physics and chemistry also provide courses on nanotechnology.

As the interest in NST-related research in academia has increased the number of projects funded by public resources has increased in recent years as well. Searching for projects having nano prefix in their titles in TUBITAK web sources[3] reveals that by June 2010 such 337 academic projects are funded by TUBITAK; of these projects 176 have been completed. TUBITAK TEYDEB also provides funds

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[1] www.nano.org.tr, accessed on 27 June 2010

[2] Nano Bülten Sayı 09 http://www.nanott.hacettepe.edu.tr/nanobulten/09/nanobulten09.pdf , accessed on 13 June 2010

[3] http://mistug.tubitak.gov.tr/proje/index.php, accessed on 28 June 2010

for firms doing nanotechnology research and development; however no data is available at publicly open web pages or documents of TUBITAK regarding the number of industry projects funded in nanotechnology field.

Another important indicator of NST-related research and development activities is the number of patents assigned to Turkish institutes and firms. For patent research the methodology proposed by Huang et al. (2003; 2004) which is based on the search of certain keywords in titles and abstract of patent documents is preferred.

USPTO (US Patent Office) and Turkish Patent Office (TPO) databases were searched for 18 keywords (Appendix A) provided in these two studies. In USPTO database, 46 patents to which Turkish inventors participated were identified but none of these patents are assigned to Turkish institutes. In TPO database, by 3 March 2010, 162 patents including the selected keywords in their titles of abstracts were found; however only 39[4] of these patents are assigned to Turkish institutes or people resident in Turkey. Appendix A provides a list of these 39 patents. The list indicates that nearly half of these patents are assigned to either universities or public research institutes or individual researchers affiliated to Turkish universities. These results provide further evidence for the importance of nanotechnology research held in universities and the potential economic value of research outputs produced at universities in nanotechnology. On the other hand, a search for the number of nanotechnology patents by Huang et al. (2003; 2004) reveals that, between 1976 and 2004, 5363 USPTO and, between 1978 and 2004, 2328 EPO patents are assigned worldwide (Li et al., 2007).

In addition to aforementioned problems related to nanotechnology (i.e. no special support programmes or strong institutional initiatives and low level of patents), some other barriers to NST research in Turkey are (i) scarce financial resources for research activities and technological infrastructure; (ii) concentration of research facilities and activities at certain universities and centers in big cities;

[4] The number of patents found were actually 41. However 2 were excluded because nano-prefix used in these patent documents indicated a measure, i.e. nanometer which is not about nanotechnology.

(iii) low level of collaborations between academic disciplines to achieve transdisciplinary research; and (iv) low level of collaboration between universities and firms (TÜSİAD, 2008).

The following section will mainly focus on NST research activities in Turkish universities. This section aims to understand strengths and weaknesses of NST research carried out mainly in universities and, hence, to make some policy recommendations in order to improve NST research productivity, research collaborations and knowledge transfers among different actors of the nanotechnology innovation system in Turkey.

5.3 Bibliometric analysis of NST articles by Turkish universities

The most important problem in the bibliometric studies focusing on the emerging field of NST is the delineation of the field. This is not only because nanotechnology is an emerging technology field but also it is interdisciplinary. Many efforts have been spent for analyzing academic efforts and also patents in nanotechnology since the mid-1990s.

Braun et al. (1997) was the first study dealing with nanoscale research (Hullman and Meyer, 2003). For this study, authors (Braun et al., 1997) built a database of articles on the frequency of usage of the prefix-nano in the title of science and technology journal papers during the period 1986-1995. Tolles (2001) followed a similar way and searched the SCI database using “nano*” to analyze the international scientific standing of USA in nanotechnology. At first, searching a nano-prefix seemed a very useful approach for the delineation of the field but this method has the risk of inclusion of some terms or phrases such as nanosecond, nanogram, nanoplankton or some elements such as “NaNO2” or “NaNO3” which are not directly related to nanotechnology. Moreover due to NBIC convergence (as mentioned in Chapter 2) now there occurred a need to consider some terms and phrases which do not contain any nano-prefix but should be included in nanotechnology field.

The first attempt using a list of keywords and phrases instead of nano-prefix was held in a project prepared for th EU Commission; Noyons et al. (2003) summarize the report of the project which, using publication and patent data, aims to identify centers of excellence in nanotechnology across Europe. In this project, authors first started with a core set of publications of which some publicly known NST experts agreed on their representativeness. From titles and abstracts of these core publications noun phrases were extracted. However, the final list of the phrases for the delineation of the NST field was decided through the opinions and suggestions of a wider group of experts doing NST-related research. After 2005, the number of studies aiming at the delineation of the field of nanotechnology using text mining and bibliometric methods has increased. Among those Zitt ve Bassecoulard (2006), Porter et al. (2007) and Kostoff et al. (2007a) have come into prominence more than the others. Table 5.2 provides the number of NST publications from Turkey which are retrieved from ISI Web of Science (WoS) SCI-EXPANDED database on 24 June 2010 by using three different set of keywords proposed by Kostoff et al. (2007a), Porter et al. (2008) and Noyons et al. (2003).

Table 5.2 Number of NST publications of Turkish scholars retrieved from SCI-EXPANDED by using three different methodologies, 1985-2010

Years	*Number of publications**		
	Kostoff et al. (2007a)	*Porter et al. (2008)*	*Noyons et al. (2003)*
2010**	554	483	343
2009	1064	996	626
2008	896	826	538
2007	741	696	410
2006	608	544	320
2005	484	453	264
2004	474	459	230
2003	328	336	157
2002	257	279	137
2001	188	196	98
2000	144	143	60
1999	151	158	59
1998	111	116	42
1997	98	100	30
1996	104	83	36
1995	65	49	26
1994	27	35	14
1993	28	27	6
1992	35	30	15
1991	22	24	12
1990	5	3	3
1989	4	3	3
1988	4	2	3
1987	1	2	
1986	3	3	
1985	1	2	
Total	*6397*	*6048*	*3432*
Rate of change 2000-2009	*%639*	*%596*	*%943*

** Numbers include book reviews, editorials and brief notes*
***First semester*
Source: Own calculation from ISI- WoS

Among those three studies Kostoff et al. (2007a), which is carried out for the Office of Naval Research in the US and Porter et al. (2008) which is conducted by scholars in Georgia Institute of Technology is very similar not only in terms of numbers they produce but also the methodology. Porter et al. (2008) also compares its results with those provided by Kostoff et al. (2007a) because Kostoff et al (2006) research formulation served as the basis for Porter's study. Authors' comparison suggests that the overall nano-publication trend shows a very similar trajectory in both of these studies and country trends are quite aligned as well. However authors find that there are some second tier differences when the publications provided by these two methodologies are compared based on selected topical areas, authors and source journals. Our study shows that only 33 percent of nano documents provided by Porter et al. (2008) methodology are not covered by Kostoff et al. (2007a); the remaining 67 percent are the same in these two set of publications. Finally, in this research, for the analysis of the NST research in Turkish universities, the methodology and keywords provided by Kostoff et al. (2007a) for the delineation of the field was preferred. The reasons for this preference are (i) the number of articles retrieved by using Kostoff et al (2007a) is higher than the others provided in Table 5.2; and (ii) Kostoff et al (2007a) provide that Turkey was among the first 50 prominent countries of the world in terms of NST publications in the year 2005; on the other hand, Porter et al. (2008) do not provide any clue about the Turkey's presence in worldwide NST research. Since both Porter et al. (2008) and Kostoff et al. (2007a) have equal acceptance in the international academia, the selection of one over another would not hamper the reliability of the research.

This section summarizes how bibliometric data of nano articles published by Turkish scholars was retrieved from the ISI WoS- SCI EXPANDED database.

(1) For a ten year period from 2000 to the end of 2009, the bibliometric data including the full contents of the articles including the keywords provided by Kostoff et al. (2007a) in their title or abstracts, and having at least one author affiliated to Turkish institutes were retrieved from the ISI Web of Science databases on 11 January 2010 (for the query see Appendix B);

(2) Using pull-down menu on the web page the results were further refined to include only the original articles; in other words, book reviews,

editorials, and brief notes were discarded from the set of results and we were left with 4408 original articles.

(3) Full bibliometric records of these articles were exported as a text file from ISI WoS.

(4) These records were reformatted into a Microsoft Access 2003 database using a Visual Basic script.

(5) Each of these articles was given a unique number from 1 to 4408 and all variables included in bibliometric content (i.e. authors. institutes. addresses. titles and keywords) were linked to each other through this unique identifier.

(6) Data manipulation and analyses were performed through created tables and queries in this database. Most of these tables and queries were recreated from bibliometric software tool Sitkis (Schildt, 2005) which is also based on Microsoft Access.

(7) These different tables are used for simple counting of articles by year, institute or author; and queries allow matching different tables by the unique identifier in order to count the frequency of simultaneous occurrences of two different elements (i.e. networks of authors, networks of institutes) in the same document.

The tool, Sitkis, also allows the manipulated data to be exported to MS Excel and UCINET (Borgatti et al., 2002) compatible tables. The network measures, i.e. the standard centrality measures of degree, closeness, and betweenness were calculated using the social network analysis software UCINET and networks were drawn with NetDraw package embedded to UCINET.

5.4 Results from the bibliometric study

Global NST research literature has grown exponentially in the last two decades. The number of records regarding NST publications in the SCI / SSCI was

11265 in 1991 however it reached 64737 records in 2005 with an almost six fold increase (Kostoff et al. 2007b). Our bibliometric research shows that the total number of NST related publications in SCI-EXPANDED has already exceeded a hundred thousands in 2009. Therefore, before concentrating on NST research held in Turkish universities a brief review of the worldwide NST research is going to be provided.

Since the original research article is a good indicator of the new knowledge created in the academia, in the rest of the analysis, the number of research articles instead of all document types (i.e. review, editorial material, proceedings paper, meeting abstract and letter) will be considered. The analysis of the data retrieved rom SCI-EXPANDED for this research shows that the number of research articles reached to 91970 in 2009, a three fold increase as compared to 29648 in the year 2000. Although the number of research articles has exponentially grown in the last decade the most productive countries in NST field stay more or less the same. These are simply USA, China, Japan, Germany and France. Among those China has made a great effort in the last decade, and increased not only the number of articles but also the quality[5] of its publications which now appears to be comparable to France, Italy, Japan and Australia (Kostoff, 2008; Kostoff et al., 2007b). The results of the worldwide NST publications in this study confirm the findings of the previous studies that while shares of the US and Japan in global NST publications have dropped in the period from the early 1990s to 2005; the share of other countries such as China and South Korea grew rapidly over the course of the decade (Kostoff et al., 2007b; Kostoff et al., 2007c).

In spite of the increase in publications there is a huge concentration of publications in certain countries. In 2009 nearly 45 percent of original articles are published by the scholars linked to institutions in the USA and China; and the first five countries produce nearly 67 percent of those articles. These ratios were 40 percent and 70 percent, respectively in the year 2000 and 2005. Table 5.3 shows the

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[5] The quality of a publication is usually measured by the number of citations.

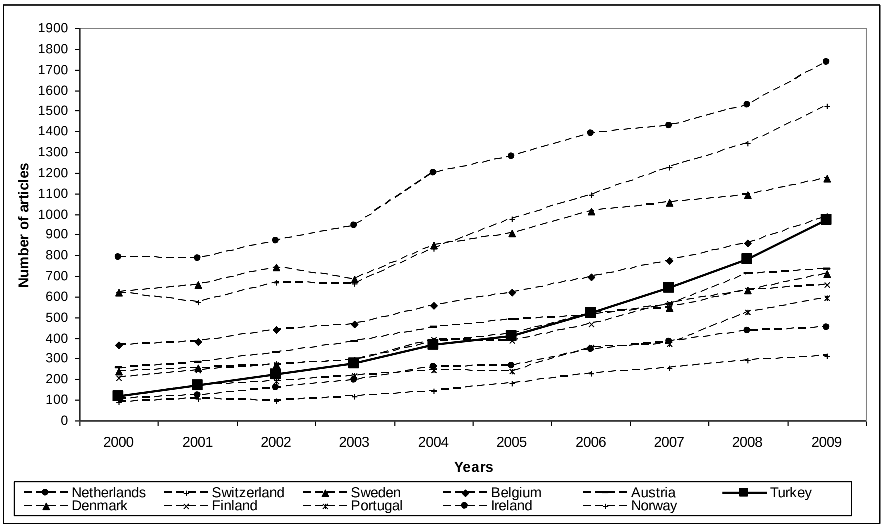
distribution of worldwide NST original articles in SCI-EXPANDED by countries and changes in trends in the last ten years.

Table 5.3 Distribution of worldwide NST original articles in WoS – SCI by countries

	2009	Rank	2006	Rank	2003	Rank	2000	Rank
PRC	23.65%	1	20.71%	2	15.94%	2	10.22%	4
USA	21.04%	2	24.16%	1	25.54%	1	26.63%	1
JAPAN	8.64%	3	10.12%	3	12.48%	3	13.83%	2
GERMANY	7.95%	4	8.68%	4	10.06%	4	11.77%	3
SOUTH KOREA	6.05%	5	5.31%	6	4.98%	6	3.66%	8
FRANCE	5.52%	6	5.76%	5	6.63%	5	7.57%	5
INDIA	5.21%	7	4.25%	8	3.55%	10	2.70%	12
ENGLAND	4.13%	8	4.49%	7	4.93%	7	6.23%	6
TAIWAN	3.41%	9	3.37%	9	2.62%	13	1.98%	16
ITALY	3.33%	10	3.32%	10	3.59%	9	3.55%	9
SPAIN	3.29%	11	2.92%	12	2.76%	11	3.06%	10
RUSSIA	3.09%	12	3.24%	11	4.31%	8	5.00%	7
CANADA	2.65%	13	2.85%	13	2.71%	12	2.86%	11
AUSTRALIA	2.14%	14	1.82%	14	1.65%	16	1.69%	17
IRAN	1.79%	15	0.62%	30	0.19%	45	-	-
SWITZERLAND	1.65%	16	1.67%	16	1.61%	17	2.10%	13
NETHERLANDS	1.62%	17	1.73%	15	1.74%	14	2.04%	15
BRAZIL	1.56%	18	1.40%	20	1.45%	19	1.56%	18
SINGAPORE	1.56%	19	1.51%	18	1.30%	20	1.29%	21
POLAND	1.43%	20	1.50%	19	1.54%	18	1.48%	19
SWEDEN	1.28%	21	1.55%	17	1.66%	15	2.09%	14
BELGIUM	1.08%	22	1.06%	22	1.13%	21	1.23%	22
TURKEY	**1.06%**	**23**	**0.79%**	**24**	**0.67%**	**28**	**0.39%**	**34**
ISRAEL	0.87%	24	1.11%	21	1.12%	22	1.37%	20
AUSTRIA	0.79%	25	0.78%	25	0.92%	23	0.86%	24
DENMARK	0.77%	26	0.79%	23	0.70%	26	0.81%	25
MEXICO	0.74%	27	0.71%	28	0.80%	25	0.78%	26
FINLAND	0.71%	28	0.71%	27	0.70%	27	0.70%	28
CZECH REPUBLIC	0.68%	29	0.63%	29	0.59%	30	0.68%	29
PORTUGAL	0.64%	30	0.54%	32	0.53%	31	0.38%	35
ROMANIA	0.61%	31	0.37%	38	0.36%	37	0.36%	36
UKRAINE	0.60%	32	0.78%	26	0.84%	24	0.92%	23
GREECE	0.58%	33	0.54%	33	0.52%	32	0.47%	32
SCOTLAND	0.57%	34	0.58%	31	0.62%	29	0.71%	27
EGYPT	0.56%	35	0.38%	37	0.41%	35	0.40%	33

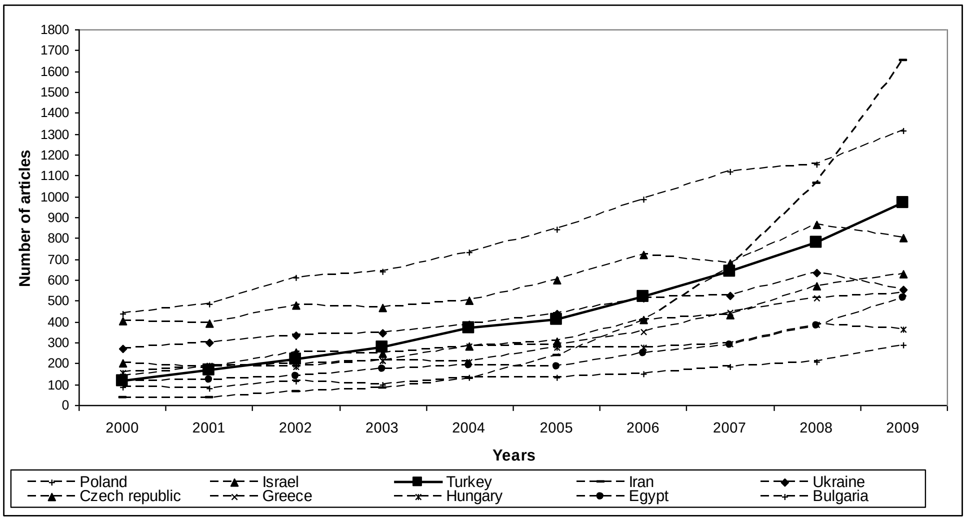
Source: Data retrieved from WoS SCI-EXPANDED.

Table 5.3 indicates that Turkey's presence in the worldwide NST research has improved for the last decade. In the year 2000, Turkey was on the 34th rank among the most prolific countries of NST research; however it went up to 23rd rank in 2009 as a country contributing 1.06 percent of NST publications in SCI-EXPANDED. Figure 5.1, Figure 5.2 and Figure 5.3 compare Turkey with some Western European countries, Eastern European and Middle East countries and those in Asia Pacific and Latin America respectively. These figures indicate that Turkey has increased its knowledge stock in the NST field more rapidly than some other countries which are economically and technologically more developed than Turkey such as small countries Austria, Finland, Denmark, Ireland, Portugal or Norway. On the other hand, Turkey lags behind some late-coming, transition or developing countries such as Czech Republic, Poland, Taiwan, Singapore, Iran or Brazil. This also indicates that there is a strong competition among countries in the race for catching up in the field of NST.



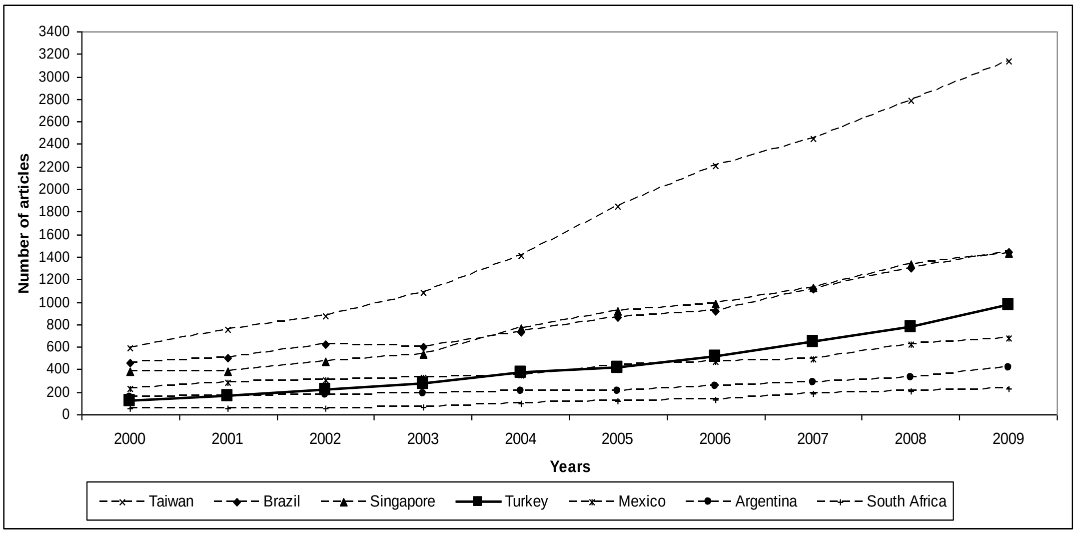
Source: Data retrieved from WoS, SCI-EXPANDED.

Figure 5.1: Turkey-Western European countries comparison of research articles



Source: Data retrieved from WoS, SCI-EXPANDED.

Figure 5.2: Turkey-Eastern Europe & Middle East countries comparison of research articles



Source: Data retrieved from WoS, SCI-EXPANDED.

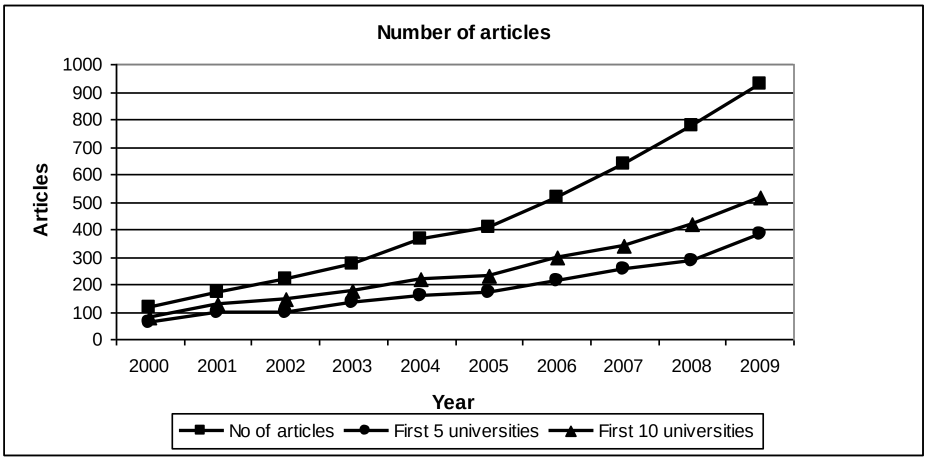
Figure 5.3: Turkey-Asian & Latin American countries comparison of research articles

The following part of the section will focus on the main characteristics of NST research at Turkish universities and institutes.

5.4.1 Main characteristics of nanoscale research at Turkish universities

During 1980s and 1990s the number of NST-related publications of Turkish scholars in the SCI-EXPANDED was very low (Table 5.2). However after the year 2000 an upward trend in publications became apparent. From 2000 to 2009 an almost eight fold increase (from 115 in the year 2000 to 928 in 2009) has occurred in the number of NST articles written by Turkish researchers. Not only the number of publications but also the number of Turkish institutes contributing to NST literature has increased. While the number of national institutes or organizations contributing to NST-related publications was only 37 in 2000 it increased to 107 in 2009; 90 of these 107 institutes were universities, and only 16 of these universities were private universities. The total number of public universities in Turkey was 94 and the number of private universities was 45 by April 5, 2010[6]. Thus, our data provides that nearly 79 percent of public universities contributed to NST-related research in Turkey.

Figure 5.4 indicates that the concentration in NST-related research has steadily decreased in the last 10 years. While in 2000 the first ten most prolific universities in Turkey generated 70 percent of NST-related articles this ratio decreased to 56 percent in 2009. Furthermore, the share of the most productive five Turkish universities in total number of NST-related articles decreased from 54 percent in the year 2000 to 41.2 percent in 2009. Thus in the last ten year NST-research in Turkey has become much more dispersed.



Source: Data retrieved from WoS, SCI-EXPANDED

Figure 5.4 Number of nanotechnology publications (SCI) of Turkish universities by year (2000-2009)

[6] www.yok.gov.tr

Analysis of the publication data also shows that the most important contributor to NST research in Turkey is universities. They contributed to 99.2 percent of research articles published in the ten year period from 2000 to 2009. On the other hand, public research institutes and governmental bodies contributed 3.3 percent of articles; among those institutes and organizations TUBITAK was more apparent. However, 2.4 percent of the NST articles in total were produced by different research institutes of TUBITAK; the share of the industry's contribution was only 1.1 percent[7].

Nano-institutions, as defined by Schummer (2007b), are those using the prefix 'nano' in their official names. The measurement of the contribution of nano-instiutions to the NST research in Turkey is important to understand to what extent the institutionalization of nanotechnology research has been achieved and also to assess the success of public incentives and funds provided for the establishment of research infrastructure. Analysis of 4408 articles in our data set shows that nano-institutions first appeared in 2004 in the addresses of Turkish scholars and their share in publications increased to nearly 11 percent in 2009.

Table 5.4 shows the most prolific universities of NST-related research in Turkey. The list of universities indicates a significant regional agglomeration in nanotechnology research. Five of the top six universities of the field are located in Ankara. Another interesting point that needs to be mentioned is that the number of publications falls significantly after Hacettepe University situated at the third place. The number of articles authored or co-authored by the scholars affiliated to METU is two times higher than the articles of Istanbul Technical University on the fourth rank.

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[7] Due to articles co-authored from different types of institutes the sum of ratios does not equal to 100.

Table 5.4 Top 40 institutions in terms of SCI publications in nanotechnology in Turkey, 2000-2009

Rank	*University*	*Total number of publications*	*Period I 2004-2000*	*Period II 2009-2005*	*Growth rate 2000-2009 (%)*
1	METU	590	201	389	93.53
2	Bilkent Univ	428	117	311	165.81
3	Hacettepe Univ	414	128	286	123.44
4	Istanbul Tech Univ	296	77	219	184.42
5	Gazi Univ	265	66	199	201.52
6	Ankara Univ	248	77	171	122.08
7	Dokuz Eylul Univ	199	60	139	131.67
8	Ege Univ	161	38	123	223.68
9	Istanbul Univ	142	36	106	194.44
10	Gebze Inst Technol	142	28	114	307.14
11	Ataturk Univ	128	41	87	112.20
12	Ondokuz Mayis Un	124	25	99	296
13	Cumhuriyet Univ	122	49	73	48.98
14	Anadolu Univ	109	20	89	345
15	Erciyes Univ	101	27	74	174.07
16	Koc Univ	101	20	81	305
17	Marmara Univ	98	21	77	266. 67
18	Selcuk Univ	98	11	87	690.91
19	Fırat Univ	97	25	72	188
20	Bogazici Univ	94	29	65	124. 14
21	Suleyman Demirel U.	91	9	82	811.11
22	Kirikkale Univ	87	16	71	343.75
23	Balikesir Univ	84	26	58	123.08
24	Karadeniz Tech Univ	84	17	67	294.12
25	Izmir Inst Technol	83	16	67	318.75
26	Inonu Univ	78	18	60	233.33
27	Cukurova Univ	77	9	68	655.56
28	Yildiz Tech Univ	76	14	62	342.86
29	Sakarya Univ	74	18	56	211.11
30	Eskisehir Osmangazi U.	72	8	64	700
31	Sabanci Univ	58	16	42	162.5
32	Gaziosmanpasa Univ	52	10	42	320
33	Mersin Univ	51	14	37	164.29
34	Onsekiz Mart Univ	49	7	42	500
35	Kocaeli Univ	47	8	39	387.5

Source: Data retrieved from WoS, SCI-EXPANDED.

These most prolific universities of NST research in Turkey are also the ones which have achieved a critical mass in terms of researchers. Table 5.5 shows the number of nano-scientists who are currently affiliated to these universities and have published at least three research papers in the last five years from 2005 to 2009[8]. METU and Hacettepe University have the highest number of NST researchers. Although the number of NST researchers currently affiliated to Bilkent University is a bit lower than the other universities this university has the advantage of hosting two nanotechnology research centers. Table 5.6 provides the list of ten most prolific researchers who contributed to NST-related research in Turkey in the last five year period. In this list, three nano-scientists from Bilkent University require attention due to their high number of articles. While the number of nano-scientists affiliated with Bilkent University is lower than the others these three nano-scientists produce very high number of articles. It might indicate that NST-research at Bilkent University is much more concentrated but in METU or Hacettepe University it is much more dispersed.

[8] For the empirical investigation of KTT activity, nano-scientists are defined as university-scientists who have at least three NST-related research articles published in WoS SCI (see Section 6.1 for details)

Table 5.5 Number of NST researchers affiliated to most prolific universities of Turkey, 2005-2009

University	*Number of NST researchers*
Middle East Technical University	45
Hacettepe University	41
Ankara University	33
Gazi University	31
Ataturk University	27
Bilkent University	26
Istanbul Technical University	26
Gebze Institute of Technology	23
Ege University	21
Dokuz Eylul University	19

Table 5.6 Top 10 authors of SCI publications in nanotechnology in Turkey, 2005-2009

Rank	*Author*	*Affiliation*	*Number of publications*
1	Özbay, Ekmel	Bilkent Univ. Dept. Phys. Bilkent Univ. Nanotechnol. Res. Ctr.	106
2	Sökmen, İsmail	Dokuz Eylul Univ. Dept. Phys.	41
3	Demir, Hilmi Volkan	Bilkent Univ. Nanotechnol. Res. Ctr.	40
4	Çıracı, Salim	Bilkent Univ. UNAM Inst. Mat. Sci. & Nanotechnol.	38
5	Yağcı, Yusuf	Istanbul Tech Univ. Dept. Chem.	38
6	Büyükgüngör, Orhan	Ondokuz Mayis Univ. Dept. Phys.	37
7	Denizli, Adil	Hacettepe Univ. Dept. Chem.	37
8	Toppare, Levent	METU Dept. Chem.	36
9	Erkoç, Şükrü	METU Dept. Phys.	33
10	Yakuphanoğlu, Fahrettin	Firat Univ. Dept. Phys.	30

5.4.2 Is nanoscale research in Turkey interdisciplinary?

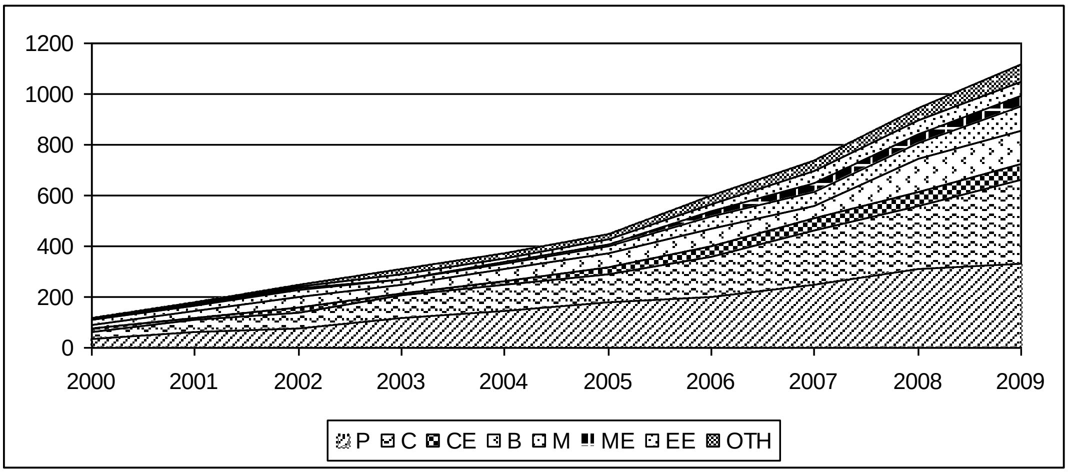
For further analysis of the main characteristics of NST research, disciplinary contributions to 4408 articles in our dataset are considered. For this aim, the disciplinary classification used by Schummer (2004) is followed (Table 5.7). In this research, we assume that the disciplinary affiliation of authors corresponds to their disciplinary knowledge contribution and here the 'discipline' is taken as a combined social and cognitive category.

Table 5.7 Disciplinary categories*

Abbreviation	*Discipline*
P	Physics; engineering physics
C	chemistry
B	biomedical sciences, including biomedical engineering, medicine, dentistry, pharmacology, pharmacy, biochemistry
M	material sciences and engineering, including special materials like ceramics, polymers etc.
ME	mechanical engineering incl. micro manufacturing
EE	electrical engineering incl. electronics, microelectronics, micro systems
CE	chemical engineering, incl. process engineering
IC	information and computer sciences
TG	general technology (unresolved affiliation on the departmental level)
OTH	other sciences mostly earth sciences, geology, mines, minerals, environmental science

*Adopted from Schummer (2004)

The analysis of the disciplinary origins of authors contributing to NST research in Turkey shows that physics and chemistry disciplines contribute nearly to 70 percent of the articles in our dataset. While the researchers in biological sciences contribute to13.6 percent of articles, 16 percent of articles are written by the researchers affiliated to engineering disciplines (Figure 5.5). While the shares of three disciplines namely chemical engineering and material science and engineering decreased from the year 2000 to 2009 other disciplines increased their shares in NST related research.



Source: Data retrieved from WoS, SCI-EXPANDED.

Figure 5.5 Disciplinary origins of authors contributing to NST research in Turkey

In science and technology policy discourse nanotechnology is presented as an intrinsically interdisciplinary field (Rafols and Meyer, 2007). Indeed, it is not only about the nanotechnology itself but about the way of making science in this new era. In recent years efforts to promote interdisciplinary scholarship and research have increased. Among those efforts special funds aimed at promoting cross-disciplinary collaboration, interdisciplinary training programs or hiring initiatives targeted at a faculty whose expertise spans traditional academic boundaries are apparent (Jacobs and Frickel, 2009). The underlying assumption of these policies and initiatives is that "cross-disciplinary research generates a higher rate of breakthroughs, is more successful at dealing with societal problems and fosters innovation and competitiveness" (Rafols and Meyer, 2007).

There are many academic efforts aiming to understand and analyze the interdisciplinary characteristics of nanotechnology (Meyer and Persson, 1998; Schummer, 2004; Rafols and Meyer, 2007; 2010; Porter and Rafols, 2009). Among those Schummer (2004) carried out a co-author analysis, which was based on the simple counting of the co-occurrences of disciplinary affiliations. Schummer defined two indices (i) multidisciplinarity and (ii) interdisciplinarity. In the study multidisciplinarity was measured by the number of disciplines involved and multidisciplinarity index ($M^{.05}$) was defined as the number of disciplines involved by authorships in at least 5% of the total number of articles.

$M^{.05}$ = count[c_i] if $c_i > 0.05$ and $c_i = n_i / N$

in which c_i was the relative size of discipline i, n_i was the number of papers in which at least one author of discipline i was involved, and N was the total number of papers in NST field.

On the other hand, in the same study, interdisciplinarity was measured by the relative number of papers co-authored by authors from more than one discipline. Two different interdisciplinarity indices were defined.

I^2 = number of papers co-authored by authors from 2 or more disciplines / the total number of papers in NST field.

I^3 = number of papers co-authored by authors from 3 or more disciplines / the total number of papers in NST field.

For the measurement of the extent of interdisciplinarity of nanoscale research in Turkey, the method proposed by Schummer (2004) was used in our thesis. Disciplinary boundaries are traditionally very strict in Turkey; and the low level of collaboration among people from different disciplines is a major barrier to the development of NST research in Turkey (TÜSİAD, 2008). Therefore, any study of interdisciplinarity in the field of NST in Turkey should consider how authors from different disciplines cooperate in a single research, in other words, how traditional disciplinary boundaries have been spanned in NST field. The answers to these questions are also important in order to determine science and technology policy needs aimed at reducing not only cognitive but also social boundaries between academic disciplines because the interdisciplinarity has become the new "mantra of science policy" since the mid-1990s (Rafols and Meyer, 2007; Bruce et al., 2004; Mentzer and Zare, 1999).

Table 5.8 Percentage distribution of articles in NST field according to the authors' disciplinary affiliations in Turkey, 2000-2009

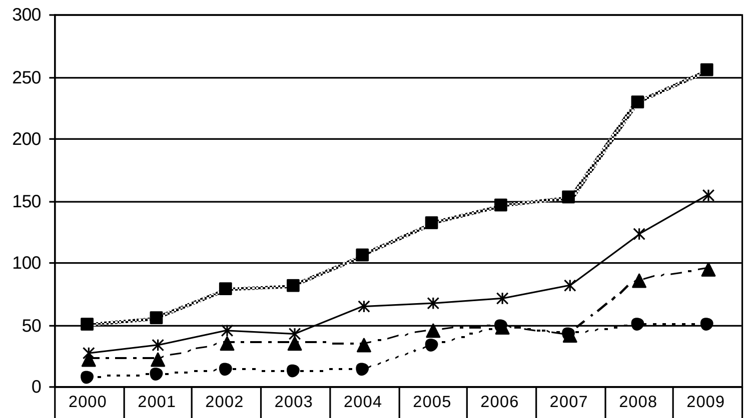
Years	*P*	*C*	*CE*	*B*	*M*	*ME*	*EE*	*OTH*	$M^{.05}$	I^2	I^3
2000	32.17	23.48	9.57	15.65	13.91	1.74	1.74	6.09	6	0.12	0.02
2001	37.50	27.98	5.95	14.88	10.71	2.38	3.57	3.57	5	0.19	0.02
2002	33.64	29.55	8.64	17.73	13.64	4.09	1.82	3.64	5	0.21	0.02
2003	42.12	32.97	4.03	12.45	6.23	1.47	6.59	6.96	6	0.19	0.01
2004	39.07	27.87	4.10	14.21	4.64	2.73	2.73	5.74	4	0.12	0.02
2005	43.03	28.61	5.13	13.69	6.85	2.93	3.91	4.89	5	0.16	0.02
2006	38.88	30.95	7.93	12.77	8.90	4.84	5.03	7.35	7	0.24	0.03
2007	38.52	34.12	7.55	7.39	8.96	5.66	7.23	6.92	8	0.31	0.03
2008	39.56	32.73	6.70	16.88	8.51	4.12	7.47	6.19	7	0.29	0.04
2009	35.99	35.24	6.79	14.01	10.56	4.09	5.93	7.76	7	0.28	0.04
Total	38.45	31.90	6.60	13.57	8.92	3.90	5.47	6.42	7	0.24	0.03

P: Physics; C: Chemistry; CE: Engineering Chemistry; B: Biology; M: Material Science and Engineering; ME: Mechanical Engineering; EE: Electronic Engineering; OTH: Other disciplines, i.e. environmental engineering, geology, mines, etc.
Source: Data retrieved from WoS, SCI-EXPANDED.

The multidisciplinarity index calculated for overall NST research in Turkey is the same with that provided by Schummer (2004) for worldwide NST research (Table 5.8). This result provides evidence that NST research in Turkey is indeed multidisciplinary as expected. On the other hand, our results provide that Turkish NST research is very weak in terms of interdisciplinarity. Schummer (2004) found I^2 index as 36.5 and I^3 index as 5.7 for worldwide NST articles published in 2002 and 2003 which are higher than those we found for Turkey (0.24 and 0.03 respectively). This low level of interdisciplinarity indicates that the disciplinary boundaries are still a very important barrier to research collaborations in Turkish academia and also emphasizes the importance of promoting collaborations among researchers affiliated to different disciplines.

Not only the collaborations among different disciplines but also collaborations among different institutes, countries and authors are also very important in modern science. There are many studies providing evidence that scientific collaborations not only increase the productivity of researchers which is measured by the number of articles (Lee and Bozeman, 2005) but also the impact of the articles measured by citations (Katz and Hicks, 1997, Van Raan, 1998; Guan and Ma, 2007). Katz and Hicks (1997), for example, use a database containing UK articles in the Science Citation Index (SCI) between 1981 and 1994 and find out that adding an author from the same institution to a paper earns an additional 0.76 citations, an additional author from another domestic institution earns 0.78 and from a foreign institution earns 1.60 additional citations per paper on average. On the other hand, for developing countries the role of international collaboration becomes an important issue and needs to be considered in the evaluation of any increase in productivity and impact of academic studies. Basu and Aggarwal (2001) provide evidence that international collaboration serves to increase both the overall productivity of Indian institutes and the average impact factor of their academic outputs. A similar study on Brazilian research outputs reveals that the average impact of an article written by one Brazilian researcher is just 0.79, the same ratio increases to 1.12 citations for articles written by more than one researcher affiliated to Brazilian institutes and to 3.39 citations when Brazilian authors collaborates with other research in foreign institutes (Leta and Chaimovich, 2002).

Our analysis of international collaborations in NST-related articles produced by scholars at Turkish universities indicates that although the number of international joint publications has increased in the last ten year period, the share of international joint publication among all NST articles decreased from 44 percent in 2000 to 28 percent in 2009. This is probably because of the increase in the number of national institutes which are not connected to international networks. The increase in the number of institutes contributing to NST field is promising in the sense that these institutes have developed their NST capabilities; however this may turn into a disadvantage if these new universities cannot build their own networks, which provide them access to high quality knowledge located abroad. Figure 5.6 shows that Turkish NST scholars collaborate more with their colleagues affiliated to European institutes than those linked to others located in various regions of the world. Findings of a detailed analysis of collaborations suggest that Turkish scholars are strongly linked to those scholars affiliated to institutes in USA, Germany, UK, France and Italy.



	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Number of articles (international collaboration)	50	55	78	81	105	131	145	152	228	255
Number of Artices (North America)	22	22	35	35	34	46	48	41	86	95
Number of articles (Europe)	27	34	45	43	65	67	71	82	123	154
Number of articles (OTHER)	7	9	13	12	13	33	48	42	50	49

Source: Data retrieved from WoS, SCI-EXPANDED.

Figure 5.6 Distribution of international joint publications of Turkish NST scholars by years and regions, 2000-2009

5.4.3 Collaborations and research networks

The most characteristic tendency of today's scientific production is the intensification of research collaboration (De Solla Price 1963; Hudson, 1996; Katz and Martin, 1997; Glanzel, 2002). In spite of some critics towards the assumption that multi-authorship and collaboration are synonymous terms (Katz and Martin, 1997) scientific collaboration is generally reflected by the co-authorship of publications and analyzed with bibliometric methods (Glanzel, 2002).

The analysis of co-authorship patterns in NST literature generated at Turkish universities indicates that the number of institutes collaborating with each other increased more than three times from the year 2000 to 2009 in line with the increase in the number of institutes. While, in the year 2000, 29 of 37 institutes collaborated, in 2009, 105 of 107 institutes collaborated with another institute. The sharp increase in the number of nodes[9] and links[10] indicated in Figure 5.7 also provides evidence for the increasing trend of collaboration in NST research in Turkey.

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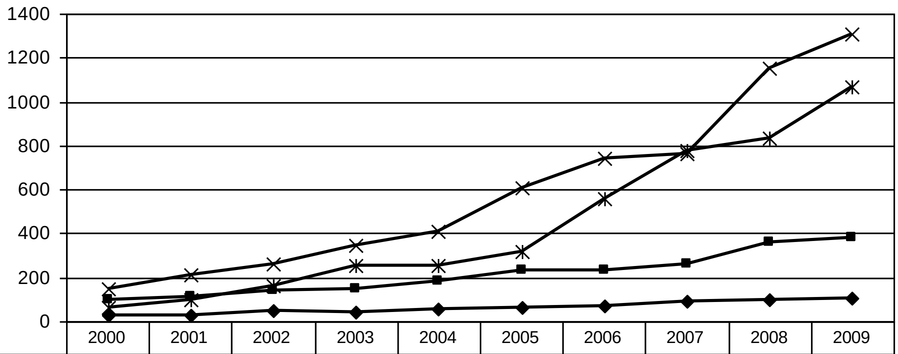
[9] The number of nodes is measured by the number of institutes / agents in collaboration.

[10] The number of links is measured by using co-authorship patterns: If one researcher from an institute / agent /node co-publishes an article with someone in another institute we can assume that these two researchers and these two institutes have a link.

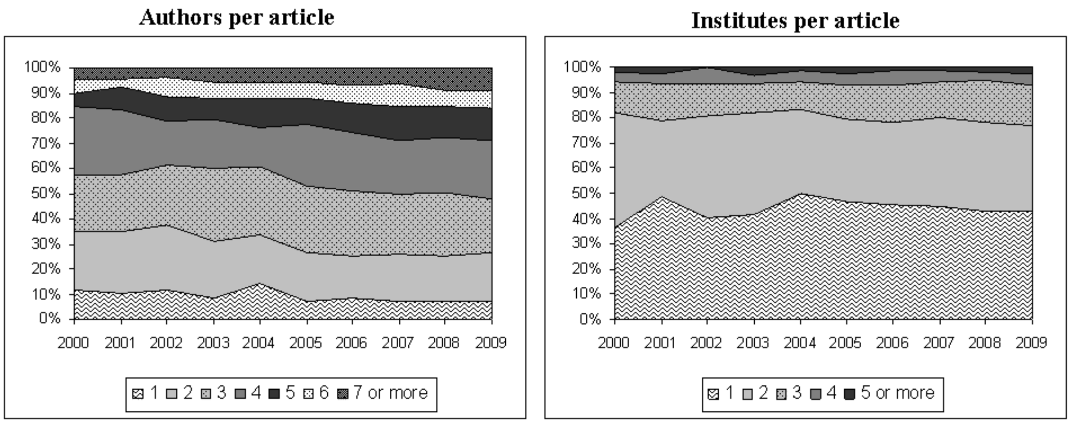


	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Nodes (Natl. Inst)	29	31	48	43	55	64	73	89	100	105
Nodes (All Inst)	98	114	142	147	184	231	235	263	361	385
Links (Natl. Collab)	66	98	166	254	258	318	562	778	834	1068
Links (Collab.)	145	211	259	346	410	610	742	766	1150	1309

Source: Our data collected from Web of Science, SCI-EXPANDED

Figure 5.7 Turkish NST research networks: Number of nodes and links, 2000-2009

However, the number of institutions and authors per article indicates that Turkish NST research has some weaknesses in terms of collaborations (Figure 5.8). In 2000, nearly 37 percent of research articles were authored by a single institute this ratio increased to 43 percent in 2009; and the percentage of articles co-authored by two institutes decreased from 45 percent to 34 percent in the same period. While the share of single-authored articles decreased from 11 percent to 7 percent, the share of articles with 5 or more authors increased from 16 percent to 29 percent in the ten year period from 2000 to 2009. This may indicate that authors would prefer to collaborate with other researchers in their own institutes. On the other hand, we found that the average number of authors collaborating per article was 3.38 in the year 2000 and increased to 3.83 in 2009. It is interesting to note that the average number of institutes per article, which was 1.9, did not change in 2009. These findings indicate that while the number of NST-related articles has significantly increased in the last ten years research collaborations and networks (in our case which is measured by co-authorship) have not improved among nano-scientists who are employed in different institutes / universities. In other words, the number of collaborators within universities has increased in this period 2000-2009, probably due to the increased number of nano-scientists, however, the pattern of research networks or collaborations have not changed. Hence, inter-institutional networking is still very low in NST-field.



Source: Data retrieved from WoS, SCI-EXPANDED.

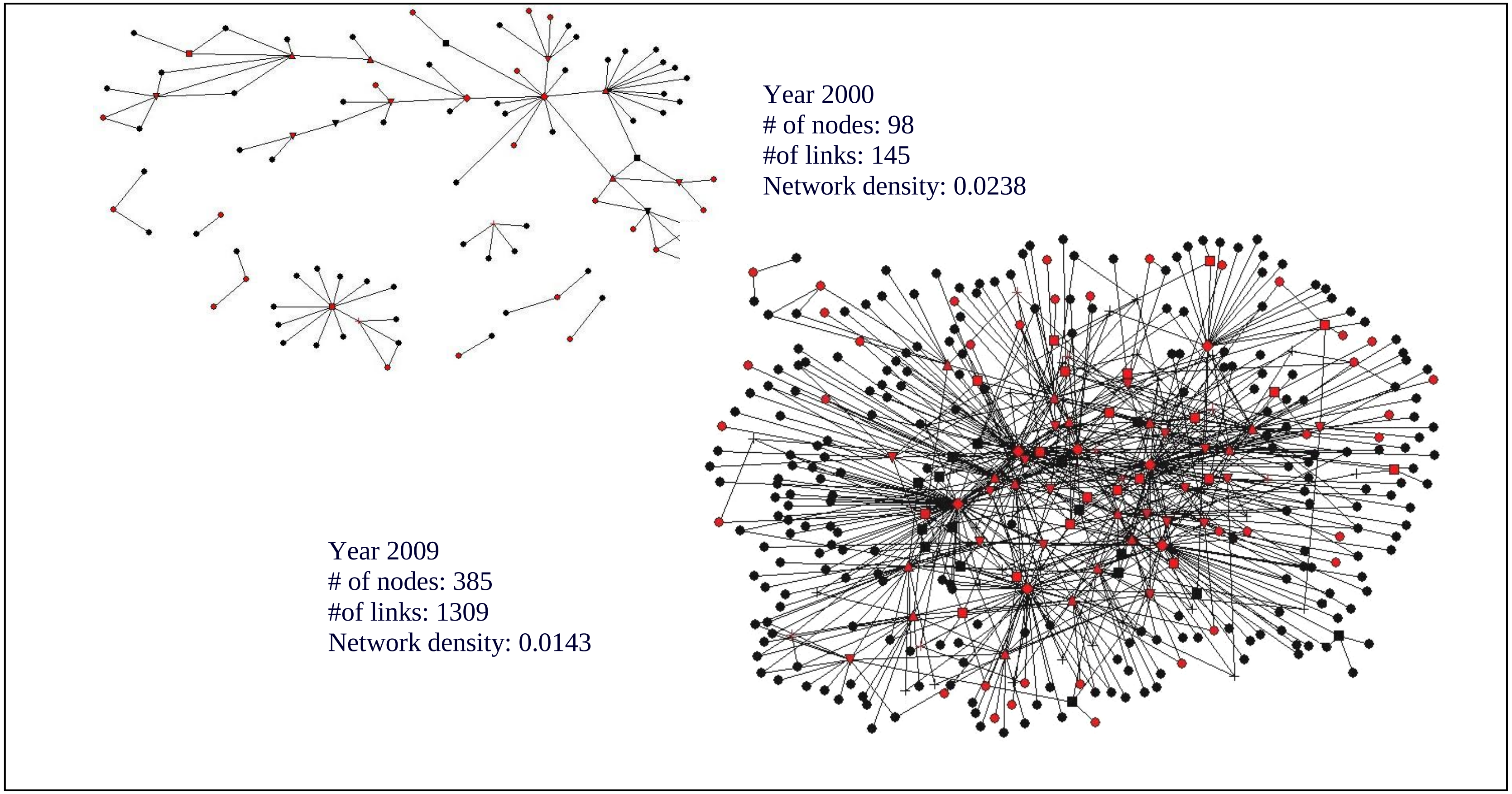
Figure 5.8 Collaboration per article measures, 2000-2009

For further analysis of Turkish NST research collaborations, social network analysis techniques and indicators (i.e. degree centrality) have been applied. Degree centrality "measures the extent to which a node connects to all other nodes in a social network" (Knoke and Yang, 2008). In network studies, it is proposed that nodes or agents with higher number of ties with other nodes may be advantaged since they occupy a more central position than those having lower number of ties and, hence, have more access to knowledge of other agents in the network. Degree centrality is measured in a non-directed network, in which the relations between nodes are bilateral, by the following formula:

$$C_D = \sum_{j=1}^{g} X_{ij} (i \neq j) \qquad \text{(Eq. 5.1)}$$

where C_D denotes degree centrality for node i and $\sum_{j=1}^{g} X_{ij}$ counts the number of direct ties that node i has to $g-1$ other j nodes. In this formula $i \neq j$ excludes i's relation to itself (Knoke and Yang, 2008).

Figure 5.9 indicates how NST research network of Turkish universities and institutes expanded in a ten year period from 2000 to 2009. The visual expressions of two networks in 2000 and 2009 show that while the number of links in the networks is increasing the network density figures are decreasing. Network density is simply expressed as the proportion of the number of links to the maximum possible number of links in a network. Hence, it is inversely related to the network size; the larger the social network the lower the network density because the number of possible links increases rapidly with the number of nodes included in the network.



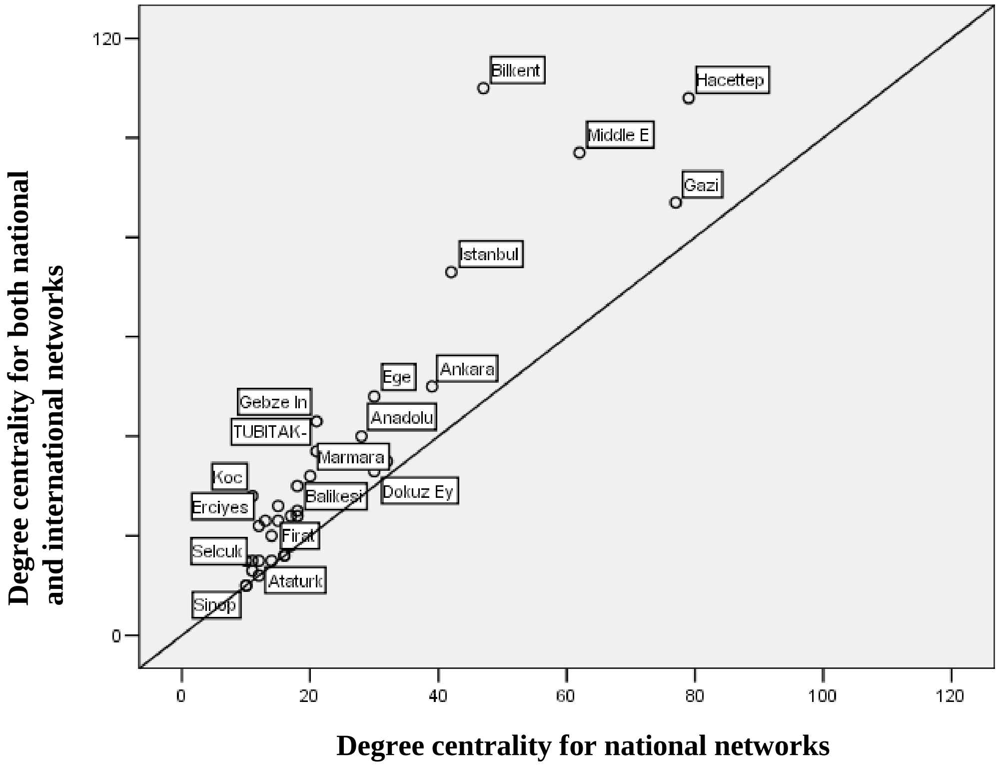
* Black nodes represent national institutes; and red ones for foreign institutes

Source: Data retrieved from WoS, SCI-EXPANDED.

Figure 5.9 NST research networks: a comparison 2000-2009

The mean degree centrality of NST research networks was 2.306 and the standard deviation was 2.597 in the year 2000. While, in 2009, mean degree centrality increased to 5.486 the standard deviation has increased to 12.622 with an almost five fold increase. This might indicate the presence of two different groups of institutions: (i) a large group of institutes with low degree centrality and (ii) a small group of institutes with higher degree centrality, or in other words, a small group of institutes which are well connected to others and a large group of institutes with low number of links to the other nodes in the network. Even though it is expected that in growing networks degree centrality measures are more heterogeneous; therefore, mean value is not representative (Kay, 2008), such a higher standard deviation indicates that NST research network follow a power law where there is a large number of institutes with a very low number of links. The cause of this heterogeneity in the network might be the fact that especially in recent years many universities entered into NST research network and they have not built their links with the others yet.

Another interesting point of Turkish NST research occurs when domestic network among Turkish institutes are separately considered. Degree centrality measures indicate that domestic NST research network is less heterogeneous than international networks. However, the detailed analysis focusing on certain institutes reveals that some research institutes have different characteristics in national and overall research networks. Figure 5.10 compares degree centralities of institutes in domestic research networks and whole research networks which include national and foreign institutes for the year 2009. It indicates that universities on the diagonal line have no international links however those slightly over the line have international links but their share in their network is comparatively low. According to this diagram, while Hacettepe, Gazi and Middle East Technical University have very central positions in domestic research networks, Bilkent University occupies the most central position when the whole NST research network is considered due to its higher number of international links. For example, in 2009, according to the degree centrality measure (which is 110) Bilkent University is the most central node in the network; however in the same year, it is at the fourth most central position in domestic research network after Hacettepe, Gazi and Middle East Technical University. Here the positions of Hacettepe and Middle East Technical University are remarkable because these two universities are well connected to national and international networks. Thus, they can play a brokerage role for knowledge flows from foreign institutes to some national institutes which are generally located in the periphery of networks with a small number of linkages to others (see also Gossart and Ozman, 2009).



Source: Data retrieved from WoS, SCI-EXPANDED.

Figure 5.10 Comparison of degree centrality measures of Turkish institutes, 2009

5.5 Conclusions and implications of the research

This chapter aims to understand the structure of NST-related research in Turkish universities. It is important to rationalize why university-industry relations in the NST field should be studied in Turkey for sustaining technological development which has been seen as an important force driving economic growth (Kuznets 1966; Abramovitz 1956; Solow, 1957). The analysis of the data retrieved from ISI WoS SCI-EXPANDED to characterize the NST research in Turkish research institutes indicates that Turkey's presence in worldwide NST research has become more apparent in recent years. There has been an exponential growth in the number of research articles published by Turkish NST scholars for the last ten years. Moreover, the NST research network has grown in the same period in terms of institutes, authors, links, national and international collaborations.

The overall NST research in Turkey presents an advantageous position for achieving technological change and, hence, may open up a window of opportunity for economic growth. However, the analysis of the main characteristics of nanoscale research carried out at Turkish universities indicates some drawbacks and barriers to the future development of the NST field in Turkey. The results indicate that, first of all, there is a high concentration of nanoscale research at certain universities. Although the intensity of concentration has been decreasing in the last five years, the most ten prolific universities in Turkey generated more than half of the NST related research articles in 2009.

Second, although NST-related research in Turkey is multidisciplinary, in other words, generated by the contribution of various disciplines, it is not interdisciplinary in the sense that articles are produced by collaborating academicians from the same disciplines. Third, analysis of research networks among universities in the NST field in Turkey also indicates that there is a small number of universities with a large number of links, on the other hand, a larger number of universities are not well networked with other universities in the field.

Fourth, in the recent years, with the increase in the number of institutes in the NST research networks, national collaborations have increased. However, the number of universities which have access to international research networks is still limited to some prolific universities of the country. Nonetheless, the international collaborations which allow accessing new knowledge located in other countries are important especially for countries which are new in the NST field with limited research capabilities. Last but not least, the most important contributor to the NST research in Turkey is universities; the share of industry's contribution is limited with the 1.1 percent of the total NST-related articles.

There is a race among countries which are not only the advanced but also developing ones (e.g. China, Brazil, India, Russia, South Korea) to become the leading countries of NST research; and scientific research carried out at universities is one of the most important components of these efforts. Any science policy design for nanotechnology in Turkey, therefore, needs to consider NST-related research activities at universities in order to become part of in this race. It is also important for university-industry interactions due to the fact that universities should have sufficient, high quality knowledge resources that are demanded by the industry. Nanotechnology-related science and technology policies, therefore, need to cover some measures to eliminate the aforementioned conclusions about the NST-related research at Turkish universities.

High concentration of nanotechnology research at certain universities or labs is a common phenomenon due to the nature of NST-related research. The role of instrumentation in scientific research in this field is very important; not only because of higher cost of instruments used in nanotechnology research but also the need for specialized research staff to use these instruments, especially SPMs. Therefore, the establishment of nanotechnology centers should consider the needs of specific regions and the agglomeration of industries in regions; and should be designed to support regional innovation systems. One or two universities in certain regions can be selected and supported to increase NST-related academic research, create new centers of excellence. Technological agglomeration in the sense of co-location of scientific and technological capabilities supports the development of nanotechnologies in a region; therefore, new organizational arrangements for sharing of facilities, equipment and skilled technicians across different disciplines, and in a wider range of institutions are required (Robinson et al., 2007). Research infrastructures which are mainly held by universities in Turkey might serve as an effective tool for the establishment of technological platforms on the regional basis.

The number of institutes per article and number of authors per article reveal that research collaborations are still weak in Turkish academia even in the field of NST which supposedly increases collaboration (Rafols and Meyer, 2007; 2010; Porter and Rafols, 2009; Porter and Youtie, 2009). In order to increase collaborations among institutes and authors science policy tools and support mechanisms are needed. For instance, during the application for public research fundings, universities or TUBITAK might consider whether and to what extent the prospected research project is open to collaboration; and whether the research projects which include academicians from different institutes, different disciplines and even from different regions might be preferred over the others. Supporting collaborative research from different national and international institutes and disciplines is an important policy tool and it is easy to apply without too much additional cost. Thus, in this way, collaborations across various institutes, disciplines or regions would accelerate the diffusion of NST research results; and might decrease the inequal distribution of NST-related knowledge and research skills.

Moreover, collaborations with countries such as USA, UK, Germany, France or Italy needs to be supported because co-authorship networks with the institutes located in these developed countries might affect positively not only the number of publications but also the quality of the research and knowledge flow to Turkish institutes through these research links. Indeed, there are many mechanisms launched by TUBITAK to support international mobility of scientists and their networking activities. However, our research indicates that, at least for the field of nanotechnology, except some researchers at certain universities (i.e. Bilkent, METU, Hacettepe) international research collaboration of Turkish nano-scientists is considerably low. Therefore, why these tools and mechanisms designed to support collaboration do not work should be investigated carefully and redesigned, if needed.

This problem might be due to the fact that research capabilities of some university-scientists do not suit well for the requirements to access international networks. In this sense, new strategies should be needed to improve these research capabilities; such as implementing mechanisms to encourage some universities to play the role of brokerage among Turkish and foreign scholars. As aforementioned Hacettepe and METU are good candidates for knowledge brokerage. However, if, for example, Bilkent University increases its collaboration with Turkish institutes and if Gazi University increases its links with the foreign institutes they may become successful knowledge brokers as well. In other words the development of policies that foster the tying down of international knowledge at national level is essential (Gossard and Ozman, 2009) for Turkey.

On the other hand, the weak contribution of the industry to NST research indicates a problem related to industrial R&D skills. This problem might be related to the fact that (i) industry does not have enough resources for doing nanotechnology -related R&D; or (ii) it does not have collaborations with university researchers to formalize and publish their research results in international journals. Nonetheless, the weak contribution of industry to NST research indicates that although co-publication of university and firm scientists is an important channel of university-industry collaboration, it is not effectively used by universities and firms in the NST field in Turkey.

However, in the literature, there are many studies emphasizing the importance of the integration with the science community from the perspective of firms. Cockburn and Henderson (1998) by using data on co-authorship of scientific papers between pharmaceutical company scientists and publicly funded researchers find that connectedness to open science community has a positive impact on firms' performance in drug discovery. Again Zucker et al (1998b) scrutinize the impact of co-authorships between university and firm researchers in biotechnology and find that for an average firm five articles co-authored by academic stars and the firm's scientists imply about five more products in development and 3.5 more products in the market. On the other hand, discoveries in biotechnology and nanotechnology are characterized by natural excludability[11] and, therefore, involve extensive tacit knowledge (Zucker et al 1998a; Darby and Zucker, 2004). Therefore, in the fields of biotechnology and nanotechnology, for a firm researcher, it is very important to carry out research in the laboratory together with university researchers, and would probably provide more opportunities for learning-by-doing and also will improve the knowledge and technology spillovers between universities and firms. Doing research at laboratory is very important in nanotechnology; however laboratories are heavily used by university researchers, and firm researchers are excluded from this realm of scientific knowledge production. Nonetheless, science-based technologies, especially biotechnology and nanotechnology, needs heavy usage of laboratory facilities and and specialized instruments which are not available at corporate labs. Hence, encouraging firm researchers to actively participate to research projects at university labs will increase the number of articles contributed by firm researchers; collaborations among university and firm researchers; and knowledge and technology spillovers between academia and industry.

As a final point, low patenting level in nanotechnology should be considered as an important indicator of bottlenecks in the commercialization of NST-related research carried out both at universities and firms. As discussed in Chapter 2, patenting issues in nanotechnology should be urgently included in national science and technology policies on nanotechnology. There is a very heavy patenting activity in nanotechnology; even a tiny research result is patented and the number of patents issued and the patent applications have been exponentially growing. However, most of these patents are acquired by multinational companies or universities in advanced countries; and unfortunately these patents would not be accessible by firms in

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[11] Scientific discoveries are achieved by small communities; and people out of these communities can be excluded from making use of these discoveries due to tacit knowledge developed during the process of discovery. Zucker et al (1997) argue that inherent in the discovery itself is its degree of natural excludability; i.e. if the techniques for replication are not widely known prior to the discovery, then any scientist wishing to build on the new knowledge must first acquire hands-on experience. Therefore, scientific discoveries with natural excludability can give rise to localized industrial effects where the information is sufficiently costly to transfer due either to its complexity or tacitness.

developing countries. Even for some developing countries which have good indicators in NST-related research (i.e. China, Brazil, India) the low number of nanotechnology patents is the most examined issue for catching up. Thus, the patentiability of research results produced at universities should be worked out and encouraged by science policies.

To summarize, in this chapter the NST-related research activites at Turkish universities were analyzed by using the articles in ISI WoS SCI-EXPANDED database which were published from 2000 to 2009 by at least with one scholar linked to Turkish institutes. The results indicate that in spite of some bottlenecks in NST related research activities, Turkey has an advantageous position in nanotechnology with the exponentially growing articles in the international literature. Moreover, high amount of investments has been made to establish new research facilities and to improve research infrastructure in the country. Among academicians there is a growing interest towards nanotechnology; and the number of master and PhD programs on interdisciplinary nanotechnology research has also been increasing. Thus, while NST-related research and knowledge capabilities have been growing in universities, how the issue of transfer of these capabilities from academia to industry can be achieved should be included in the agenda; and developing mechanisms facilitating university-industry collaborations should be among the targets of sciencen and technology policy design in nanotechnology in Turkey.

CHAPTER 6

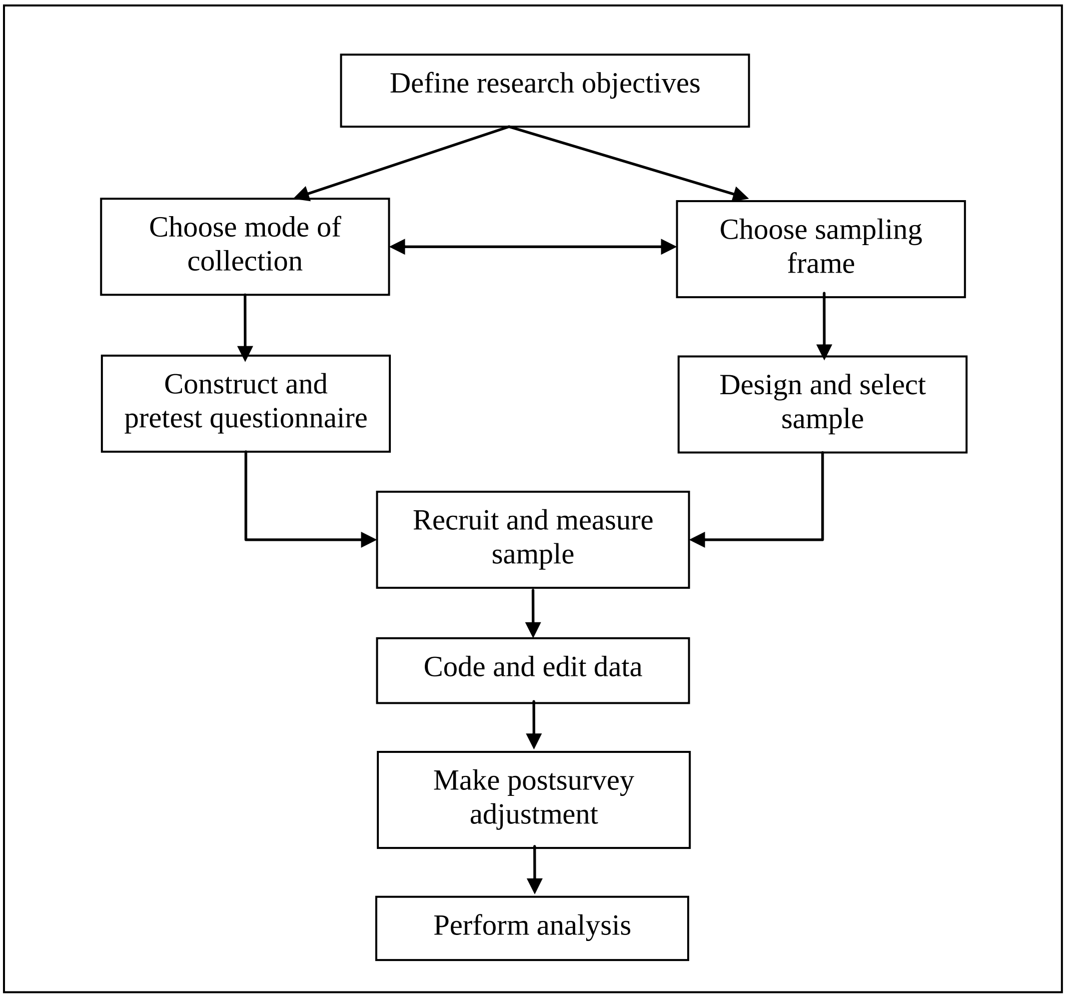
METHODOLOGY

In order to investigate the factors influencing university-industry KTT activity in the field of nanotechnology this thesis uses two sets of data collected from (i) university-scientists working on NST-related issues and (ii) firms conducting nanotechnology R&D or using nanotechnology in their products and production processes. To this end, we utilized two different methodologies for data collection and analysis. This chapter aims to present a detailed discussion of quantitative and qualitative methodologies used in this thesis. Section 6.1 reviews quantitative methodology used for data collection and data analysis in the first part of the research focusing on university-scientists. In Section 6.2, qualitative methodology utilized to collect data from firms and its analysis is discussed. Section 6.3 concludes the chapter.

6.1 Quantitative data collection and methodology

Sample surveys are widely used tools for the understanding of social phenomena. A survey is a systematic method for collecting information from a sample of entities for the aim of constructing quantititave descriptors of the attributes of the larger population from which the entities are drawn (Groves et al., 2009). Hence, a survey brings together three different methodologies which are sampling, question design and data collection to produce statistics about a target population (Fowler, 2009). Groves et al (2009) emphasize two important decisions that should be taken for a survey research; the first one is regarding the sample and the second regarding the measurement process, in other words, measurement instrument (in our case it is a ‘questionnaire’).

This chapter is organized around the scheme (Figure 6.1) describing the process of survey research in Groves et al (2009). Data collection and the analysis of the data are separately reviewed in two main sections. Section 6.1.1 focuses on the survey design and data collection. In this section, first the issues related to target population, sampling frame and sampling design are discussed; second some information regarding to the construction and the structure of the questionnaire is given; third, the way the survey was implemented and the data collected from the sample is reviewed; finally some information about data coding, editing and post survey adjustments are provided. Section 6.1.2 focuses on the analysis of the data. First, how the survey design potentially affects the data analysis is discussed from two perspectives, namely model-based and design-based; then binary response regression models, specifically, the Probit model is reviewed.



Source: Groves et al. (2009)

Figure 6.1 The survey process

6.1.1 Survey design and data collection

6.1.1.1 Sampling

Target population

The sampling procedure starts with the definition of the target population which is a set of entities (persons, firms, households, etc) to be studied (Groves et al., 2009). Defining the target population is one of the most important part of the study because the choice of target population affects the statistics that result from data (Lohr, 1999).

In this survey, the target population is described as scientists who are involved in NST research at Turkish universities (nano-scientists). However, identifying nano-scientists is not an easy task due to the fact that there is no easy definition of 'nano-scientist' or 'nanotechnologist'. Therefore, the bibliometric data regarding 4408 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 was used. Details regarding how this data is collected, retrieved and manipulated were presented previously in Section 5.3.

As mentioned in Section 5.3, first a database including the bibliometric data of 4408 articles was constructed and various analyses regarding the articles, institutes and authors were performed through created tables and queries in this database. For this aim a bibliometric software tool Sitkis (Schildt, 2005) was used. In this process, a table that includes the names of authors and the total number of articles linked to these authors was also created. The created table included 5806 different names of scientists and the number of articles linked to these names. However, the researchers identified with this method are involved in nanotechnology to different degrees; the distribution of the number of articles is highly left-skewed with a longer left tail of authors having only one article. In other words, 3741 (nearly 64.5 %) scientists in the list are linked to only one article in our database. Most of these researchers are affiliated with foreign institutes and included in the list just because they are co-authors of Turkish NST-related articles. Moreover, nearly 80% of researchers in the list have less than three articles.

For the description of the target 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. The number of such nano-scientists is 1134. The very recent studies of Palmberg (2008) and Nikulainen and Palmberg (2010), which aim to understand university-industry relations in nanotechnology in Finland, apply a similar methodology for the identification of survey population.

Sampling frame

The second step was the formation of the sampling frame. A sampling frame is a list of target population members which have a chance of being included in the sample (Groves et al., 2009; Lohr, 1999; Fowler, 2009). Ideally the sampling frame is a list of all units in the target population; however a sampling frame cannot always be perfectly linked to population members. For the sampling frame, target population of 1134 researchers who have at least three NST articles in the list were taken for further research. Since the names of researchers and their affiliations cannot be matched by the software tool which was used in this process a manual research procedure was handled. The steps we followed:

1- Each of 1134 names in the list were searched in the original data set including the addresses of the institutes to which a scientist was affiliated

2- If the name of a scientist and the corresponding address of the institution to which the researcher was affiliated matched along the data set the researcher’s address was added to the list. Then, web site of the university was checked to confirm that this researcher was the member of that university indeed. If so, her/his full name, title, phone number and e-mail address were added to the list.

3- For a nano-scientist if we found more than one institution we first checked whether there was more than one person with the same name and initials or the same person had worked for more than one institute. If there was more than one person with the same name and initials we checked the addresses and the number of articles for each person. For each person, again the web site of the university s/he affiliated with was used to find out her/his full name, title, phone number and e-mail address.

4- If the names of the researchers could not be found at the web sites of the universities they were affiliated with we googled the web for the name of the researcher. If we found the name in another university we checked her/his CV details and publications for confirmation. If there was no doubt that the person we found was the one we looked for then the new address, phone, and e-mail details were added to the list.

5- As a final stage, researchers who could not be found through the web research, who had not completed their PhD research yet; who had not worked for the universities but for government or private sector companies; and those affiliated to foreign institutes / universities were excluded from the final list.

At the final stage, we are left with a list of 703 researchers with full name, title, postal address, phone and e-mail address. This list of 703 researchers was, at the same time, the sampling frame of the survey. A sample of nano-scientists was selected from this sampling frame through the use of probability sampling.

Sampling strategy: disproportionate stratified sampling

In probability sampling, each member of the sampling frame has a known probability of selection and a chance method is used to choose the members to be included in the sample (Lohr, 1999). There are various probability sampling techniques and each of these techniques has some advantages and disadvantages. The basic form of probability sampling is the simple random sampling (SRS). This technique ensures that each population element has an equal probability of selection; and it can be applicable even when the survey designers have no available information on the population structure (Lehtonen and Pahkinen, 1995). However, SRS cannot guarantee against the possibility of obtaining a really inappropriate sample; i.e. one that is not representative of the whole population (Lohr, 1999). For example, when taking a SRS of size 100 from our population of 703 nano-scientists it is theoretically possible to obtain a sample with scientists who all have published exactly 3 NST articles. In order to obtain a representative sample of the population the most convenient sampling technique is stratified sampling with selection probability proportional to size.

In the stratified sampling technique, the target population is divided into non-overlapping subpopulations called strata; and they are regarded as separate populations in which sampling can be performed independently (Lehtonen and Pahkinen, 1995). In this technique, the population of N sampling units is divided into h strata with N_h sampling units in the hth stratum; the values of $N_{1,} N_{2,........} N_h$ are known by the survey designer; and $N_1 + N_2 + ... + N_h$ must be equal to N which is the total number of units in the entire population (Lohr, 1999).

There is a special kind of stratified sample called proportionate stratified sampling in which the number of sampled units in each stratum is proportional to the size of the stratum in the entire population. In other words, the selection probability π_{hj} of the jth element in the stratum h equals to n_h / N_h which also equal to n / N where n is the total number of elements in the sample; n_h is the number of sampled elements in the stratum h; N is the size of the total population and N_h is the size of the stratum h (Lohr, 1999; Tryfos, 1996). Although the probability that the jth element to be selected for the sample equals to n / N, which is the same as in an SRS, this technique prevents many of the bad samples that could be drawn in an SRS

(Lohr, 1999); and it guarantees that the estimators are no less precise than those obtained from a simple random sample of the same size. Hence, it is nearly always better than a simple random sampling of the same size (Tryfos, 1996).

The power of the stratified sampling comes from the advantages provided by auxiliary information used to improve the efficiency of the estimation (Lehtonen and Pahkinen, 1995). Auxiliary information can be used for stratification to lower the variance within each stratum. If different strata have very different means for a characteristics which is estimated and the auxiliary variable(s) used to define strata is highly correlated with this characteristics stratification can increase precision substantially. Thus, the ideal stratification scheme creates strata that are internally homogeneous and externally heterogeneous (Carrington et al., 2000).

We are aware of these theoretical considerations related to stratified sampling. However, for our case, there was no previously available information which could provide guidance to achieve an allocation that maximizes the precision of the estimator of the population mean (Kalton, 1983). The auxiliary information we have about our population is restricted to the number of NST articles which indicate only to what extent these academicians are involved in nanoscale research and which is not enough to make some estimations about the intensity of their relations to the industry.

On the other hand, for some special purposes disproportionate stratified sampling is very helpful in surveys. One use of the disproportionate stratification in the survey sampling design is to allocate a sufficient sample size to certain strata or to a certain subpopulation (Fowles, 2009; Lehtonen and Pahkinen, 1995; Kalton 1983). In fact, using disproportionate stratification is a widespread method of over sampling rare and elusive populations in a survey. In recent years, the number of studies focusing specifically on rare or elusive populations or oversampling such populations, such as minorities, racial or ethnical subgroups, and people with an illness or employees in different industries has increased (Sudman and Kalton, 1986). Moreover theoretical studies discussing how these rare or elusive populations can be sampled or oversampled have also increased (i.e. Kalton, 2009; Kalsbeek, 2003; Sudman et al, 1988; Kalton and Anderson, 1986). Hence, in many cases varying the selection probabilities allows a survey to better achieve its goals, i.e. oversampling a group of people because it is easier to collect data from these people than others (Carrington et al., 2000).

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, a disproportionate stratified sampling method was used to select nano-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 6.1.

Table 6.1 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 hereafter 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 6.2). In this way, a rare population of academicians who are much more interested in nanoscale research could be oversampled.

Table 6.2 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	

Moreover, within these two strata a second level of stratification was also applied to ensure that the selected nano-scientists are distributed proportionately across the geographical regions. For the proportionate allocation of independent samples selected from Group 1 and Group 2 scientists across the geographical regions, level 2 NUTS (Nomenclature of Territorial Units for Statistics) aggregation was used. On this level of aggregation Turkey was divided into 12 regions and the details of the cities included in each NUTS 2 level regions can be found in Appendix C. Table 6.3 provides the probability of selection ratios across groups and regions. After these strata are determined the certain number of elements is selected through random sampling from each stratum.

Table 6.3 Probability of selection ratios across groups and regions

NUTS	*GROUP 1 Prob. of selection* (n_h/N_h)	*GROUP 2 Prob. of selection* (n_h/N_h)	*TOTAL Prob. of selection* (n_h/N_h)
TR 1	0.47	0.19	**0.24**
TR 2	0.40	0.19	**0.21**
TR 3	0.50	0.19	**0.27**
TR 4	0.48	0.19	**0.27**
TR 5	0.48	0.17	**0.27**
TR 6	0.38	0.18	**0.22**
TR 7	0.55	0.24	**0.30**
TR 8	0.22	0.28	**0.26**
TR 9	0.33	0.20	**0.22**
TR A	0.25	0.17	**0.19**
TR B	0.57	0.20	**0.30**
TR C	0.75	0.13	**0.25**
TOTAL	**0.47**	**0.19**	**0.26**

In this survey, the logic behind the selection of the target population and the formation of the sampling frame is mainly based on the idea that the number of articles published by academicians is a fundamental indicator of how much a university scientist is interested or involved in nanoscale research. As a natural extention of this logic, it can be argued that the authors in the highest 25 percent are those who are the most involved in NST. This group of academicians is also prominent figures of nanoscale research in Turkey. For example, investigating the lists of scientific committee members of the last three NANOTR[1] conferences shows that while 19 percent of the academicians in the highest 25 percent serve as a scientific committee member at least for one of these conferences, the same ratio is only 6.6 percent for Group 2.

Moreover, following a disproportionate sampling strategy also provide us some cost-related advantages. We have a given budget which allows us to carry out a certain number of surveys across all regions of the country. Given our budget constraint, an optimal allocation seems to oversample the group of academicians who have the highest number of NST-related articles published in a given five year period from 2005 to 2009. If the probabilities of selection were constant across strata and we wanted a sample of the same amount of nano-scientists sampled from Group 1 that constituted nearly 25 percent of the entire population we would need to collect 108 additional questionnaires from the second stratum of academicians with less than 8 articles. Hence, such a sampling design would cause a 60 percent increase in our budget; however the information gained in return from the academicians added to the sample would be very limited compared to this increase in the budget.

Although this sampling design allows us to better achieve our objectives under the budget constraints we have, it brings some discussion about how this sampling design and unproportionately weighted subpopulations in the entire sample would affect the statistics we derived and the inferences we made about the whole population. This issue will be discussed in a following section (see 6.1.2.1).

[1] NANOTR is acronym of national conferences on nano-science and nanotechnology in Turkey which have been organized since 2005.

6.1.1.2 Questionnaire

The questionnaire was developed on the basis of a thorough review of the literature on university-industry knowledge and technology transfer. In the last two decades, the number of empirical studies focusing on different aspects of the university-industry interactions and knowledge and technology transfer between universities and firms has been considerably increased; and some of these empirical studies used specially designed questionnaire surveys to gather data (i.e. Schartinger et al., 2001; D'este and Patel, 2007; Landry et al., 2007; Arvanitis et al., 2008; Bekkers and Freitas, 2008; Boardman and Ponomariov, 2009). However, among those studies only a few of them focus on the field of nanoscience and nanotechnology (Palmberg, 2008; Nikulainen and Palmberg, 2010).

Previous empirical studies provide a large number of examples of survey questions. However, there was no previous research addressing the university-industry interactions in Turkey by using a survey questionnaire. Therefore, a considerable effort has been spent in order to develop a reliable and valid questionnaire to measure the university industry interactions in this new technology field.

Questionnaire design: Reliability and validity

Reliability and validity are two important measures to be considered during the questionnaire design. There is a considerable literature on how a reliable, valid and efficient questionnaire can be designed (Fowles, 2009; Bethlehem, 2009; Philips and Stawarski, 2008; Robson, 2001; Singleton and Straits, 1999). During the questionnaire design, the guidelines provided by these resources were followed in order to have a good quality questionnaire. However, to increase reliability and validity of the questionnaire some further efforts were also made. For our case, three different kind of validity can be considered; these are content validity, face validity and construct validity.

The content validity refers to the extent the content of the questionnaire is representative of the concept that the researcher is attempting to investigate (Gliner and Morgan, 2000). The assessment of the content validity involves a review of the survey's content "to ensure that it includes eveything it should and does not include anything it shouldn't" (Litwin, 1995). The process of establishing content validity starts with the definition of the concept that a researcher wants to investigate and continues with a thorough exploration of the available literature (Gliner and Morgan, 2000; Carmines and Zeller, 1979). Content validity cannot be measured with statistics; therefore, it is presented as an overall opinion of a group of experts on to what extent the items in the questionnaire are representative of the investigated concept (Gliner and Morgan, 2000; Litwin, 1995).

In this research, the content validity of our survey was reinforced by reviews of the questionnaire items carried out by dissertation committee members and by two additional academicians[2] who have both practical and theoretical knowledge of the research issue; also by initial interviews based on a pilot questionnaire with university scientists who are involved in nanoscale research at METU.

On the other hand, face validity refers to the appearance of the questionnaire; in other words it concerns whether it seems to be valid or professionally designed for those who are surveyed (Goodwin, 2008; Del Greco et al., 1987). Face validity does not actually describe the content but it is a selling point for the questionnaire (Gliner and Morgan, 2000). It is about whether the respondents understand the questions and find the answers provided in the questionnaire appropriate (Chrispin et al., 1997). The face validity of the questionnaire was improved through the discussions with the dissertation committee members, other faculty members, and doctoral students. Moreover, we worked with a professional research company for face-to-face interviewing of nano-scientists; and their experts were helpful to assess and reinforce the face validity of the questionnaire. At the end, comments and suggestions were incorporated and a final

[2] Ayşe Gündüz Hoşgör from METU and Dilek Çetindamar from Sabancı University.

version of the questionnaire was prepared, and five pilot interviews with the selected nano-scientists from our list were carried out.

The last type of validity related to the questionnaire is the construct validity. This type of validity is defined as the most important yet most difficult and complex way of assessing the validity of a questionnaire. Construct validity is related to hypothetical concepts that cannot be observed directly (Gliner and Morgan, 2000). It is a measure of how meaningful the questionnaire used in a survey is in the practical use (Litwin, 1995). In other words, this type of validity is linked to the hypotheses about the concepts (or constructs) measured in the questionnaire; and it can be measured with the extent to which the predetermined hypotheses about the logical relations between variables are confirmed by the data collected through the questionnaire (Del Greco et al., 1987; Babbie, 2007; Scholtes et al., 2011). The key construct of this research is the nano-scientists' relations with the industry and its various forms; hypothesis testing in the following chapters indicates that our questionnaire could achieve a construct validity.

On the other hand, reliability refers to the ability of a test to produce consistent results whenever it is applied (Morrison et al., 2011); in other words it is related to the issue of whether respondents are consistent or stable in their answers (Groves et al., 2009) and it suggests that the same data would have been collected whenever the survey is repeated (Babbie, 2007). Therefore, reliability decreases the measurement error.

Reliability is assessed in three forms: (i) test-retest; (ii) alternate-form (equivalence) and (iii) internal consistency (Litwin, 1995; Fink, 2006). The test-retest is the most commonly used indicator of the reliability and it is measured by applying the same set of questions to the same set of respondents at two different times in order to decide on how the reproducible the results are (Litwin, 1995). In the second form, the questions and answers are reworded differently as to produce two different questionnaires measuring exactly the same items. These two different questionaires can be completed by different groups or people or by the same set of people at two different times. The compasion of the results produced by these two questionnaires provides a measure of reliability (Fink, 2006; Litwin, 1995). Finally, internal consistency measures how the questions in the questionnaire are internally consistent and it is often measured by a statistics called Cronbach's alpha. If there is more than one question measuring a single construct in the questionnaire, the calculated Cronbach's alpha indicates how the answers given to these questions are intercorrelated.

The first two measures of reliability were not preferred in this survey due to time constraints both we and the respondents had. To get an appointment from nano-scientists was very difficult due to their limited time; therefore, asking for another appointment for testing and retesting the responses of the same nano-scientists with the same test or with a reworded questionnaire did not seem a proper option of measuring reliability. Therefore, these techniques could not be applied to confirm the reliability of the questionnaire. On the other hand, internal consistency seemed much more appropriate to measure the reliability of questionnaire for our case. Cronbach's alpha coefficients for all scale questions in this questionnaire (Table 6.4) are above 0.75 showing that the internal reliability of the questionnaire is considerable high.

Table 6.4 Cronbach's alpha coefficients of questionnaire

Questions*	*Items measured in questions*	*Cronbach's alpha coefficients*
Questions 1&2	Forms of interaction	0.88
Question 4	Motivations for interactions	0.90
Question 6	Obstacles to interactions	0.75
Question 10.3	Intensity of relations	0.80
All scale questions		0.85

* For questions see Appendix D

The structure of the questionnaire

The questionnaire used in this survey (Appendix D) includes ten different sections, except an introductory part asking some personal information such as academic title, the year in which the nano-scientist got her / his PhD degree, the university and field of the PhD degree, the scientific field, the department and the university in which the nano-scientist is currently employed and gender. The logic behind the grouping of the questions in ten different sections is to keep the questions about the same topic close together and make answering to the questions easier for respondents (Bethlehem, 2009).

The first three sections include questions aiming to measure how frequently academicians are connected to the industry using different channels of KTT. These three sections were designed to include the measures of dependent variable, namely university-industry interaction, and therefore, were put before the other questions measuring independent variables. This preference is mainly because of the fact that the order of questions may affect the responses; for example, an issue addressed in earlier questions may make respondents think of an issue which will be asked in a later question and affect their responses (Babbie, 2007; Bethlehem, 2009). Therefore, questions measuring dependent variables are placed before those measuring independent variables in order to ensure that responses given to the dependent variable are not affected by the responses given to the independent variables.

In section 4, nano-scientists are asked about the factors motivating or encouraging them to have connections with the industry. On the other hand, section 5 asks the impacts of university-industry interactions on the academic activities at the universities. In section 6, academicians are asked about the factors or challenges which negatively affect university-industry interactions. In these three sections, academicians are given some statements and asked to give their answers on a five-point Likert scale. While section 7 is focusing on the general academic activities of the respondents; i.e. total number of articles in SCI, the number of academic projects completed or the time shared for educational and research activities, section 8 includes questions specifically addressed to NST-related research activities. In section 9, the respondent is asked about the nanoscale research activities at the university she / he employed and the support of the university in fostering university-industry interactions. Finally, section 10 focuses on the network activites of the respondents and how they perceive the strenght of the university-industry interactions among other academicians they know or work with.

Along the entire questionnaire respondents are asked to complete 21 open-ended questions which in most occassions require very short answers, e.g. the number of articles, patents or projects completed. Other questions are closed-questions with various response formats. In seven questions, the simplest response option, i.e. “yes” or “no”, is prefered. On the other hand, respondents are asked to provide their opinions, beliefs or attitudes in 70 sub-questions on a five-point Likert scale. The questionnaire is provided in Appendix D.

6.1.1.3 Interviewing, editing and coding of the questionnaires

Three main methods of administering survey questionnaires can be identified: (i) self-administered questionnaires in which respondents are asked to complete the questionnaire themselves; (ii) face-to-face interviews for which interviewers visit respondents to ask the questions orally and record their answers; and (iii) telephone interviewing (Babbie, 2007; Singleton and Straits, 1999). Each method has some advantages and disadvantages; and the choice of data collection mode in a survey research depends on research objectives, unit of analysis, sampling plan or the budget of the research (Singleton and Straits, 1999).

In this research, face-to-face interviewing was selected as the mode of data collection. The main motivation behind this choice is to increase the response rate and to decrease the time spent for the data collection process. Face-to-face interviewing is the most expensive data collection mode but it ensures higher response rates and often results in better quality data (Bethlehem, 2009; Groves et al., 2009; Singleton and Straits, 1999). Moreover, interviewers' ability in clarifying, probing and motivating respondents to provide complete and accurate responses can decrease the percentage of unanswered questions in a survey (Groves et al., 2009). In this research, after a research fund provided by TUBITAK was granted, the problem related to the expense of face-to-face interviewing was overcome and the interviews were carried out by the experienced interviewers of a professional research company in 12 NUTS regions of the country.

In this process, first, the lists of Group 1 and Group 2 nano-scientists were provided to the company (Veri Araştırma, İstanbul) experts with the contact information (university, faculty, phone number and e-mail address) of the nano-scientists. We informed the company experts about the aim of the research, the target population, sampling design and questionnaire development process; and they were actively involved in sample selection process; especially the assessment of the face validity of the questionnaire and provided some consultancy in the sampling selection and questionnaire development processes, i.e. wording of the questionnaire, the order of questions. Moreover, a separate training program was organized for the interviewers who would carry out the field work. The content of the training programme covered (i) what the main objectives of the research were; (ii) who would be interviewed and how they were selected; (iii) how they would introduce themselves to the respondents and provide a brief information about the survey; (iv) the main sections and organization of the questionnaire; (v) explaination of each question; (vi) explaination of concepts; (vii) answering the questions of interviewers about the interviewing process. During this training session the interviewers had become familiar with the questionnaire; and also they were instructed to follow the wording of the questions exactly and to record the responses exactly.

The sampled academicians were first contacted on the phone and given brief information about the content of the survey, the main objectives and the university and the academicians who were carrying out this research and asked for an appointment to carry out a 20-30 minutes long interview. For this aim, a text document providing a guideline to the interviewers in their first contact with the respondents was prepared and provided to the company experts. Moreover, a letter addressing the academicians who would be contacted was prepared and sent to their e-mail boxes. This letter provided information about the university and research center carrying out the research (METU-TEKPOL); the organizations supporting the research; an accurate and brief decription of the aims of the research; the confidentiality of the responses and the identity of the respondents; how long answering a questionnaire roughly takes their time; and finally the name of the contact person if they have questions or concerns about the survey. After the appointment was arranged, the interviewer visited the respondents at her / his office and the questionnaire was completed. Finally, 181 interviews with the sampled academicians were conducted from 15th of May to the end of June in 2010. Completed questionnaires were returned to the research company for coding, editing and processing. The respondents were contacted again by the field work supervisors of the company after the completion of the questionnaire to ensure that the interviewing was properly completed; and for incompleted information if there was any in the questionnaire. Hence, a completed and edited 181 questionnaires were coded by the company staff and provided to us in a MS Excel document on July 20, 2010.

In the final stage of data collection, we controlled every single questionnaire completed and checked whether the responses were coded correctly. Some responses were coded again; some were edited; some were rescaled in a different way; and some new measures were created using the existing ones. Response and nonresponse rates for each question were reviewed; nonresponses were edited in a proper way as different from the original coding. Moreover, some questions were excluded from the data set due to high nonresponse rate. Finally after a two-month work we got a final set of collected data to run the statistical analysis.

6.1.1.4 Ethical issues

In recent years, ethical issues have been increasingly concerned in social surveys. Ethical guidelines protecting human subjects in research are mainly based on the Belmont Report published in 1979 which advanced three principles for the conduct of research involving human subjects; namely beneficence, justice and respect for persons (Groves et al., 2009; Fowles, 2009; Punch, 2003). Although these principals are mainly related psychological, medical or other health related research involving human subjects, the emphasis on ethical considerations has also affected social scientists to be more attentive to the ethical manner in which the research is carried out.

During the design and implementation stages of this survey, two ethical principals were always considered, (i) informing respondents; and (ii) protecting respondents. Each person contacted on the phone for appointment or interviewed for the completion of the survey were informed about the name of the university, department, academicians and other researchers involved in the research; the organizations supporting the research; the purposes of the research; and most importantly they were provided assurance that cooperation is voluntary and they could skip any questions they do not want to answer. The interviewers were instructed about this important ethical issue. Moreover, the persons who were contacted for the appointment or interviewed were provided a written statement that their responses and identities would be protected with respect to confidentiality. Therefore, the questionnaire was designed not to include any question providing any clues about the identity of the respondent. In this sense the anonymous nature of the research was assured.

Finally it should be mentioned that, all information and documents related to the survey design including questionnaires and letters addressing the respondents were submitted to the Practical Ethics Research Board at the Middle East Technical

University to check whether the survey does follow the ethical principals; hence, a written confirmation was provided by the Board.

6.1.2 Analysis of the survey data

The analysis of the survey data becomes much more complex in the cases where sample observations are not selected with equal probabilities. Some sampling techniques which are more complex than SRS; i.e. multi-level stratified sampling, multi-stage sampling techniques, or sampling with unequal probabilities, increase the weights of certain groups of population elements in the final sample. There is a debate on whether the sampling design should be considered as relevant for inference in regression (Lee and Forthofer, 2006; Lohr, 1999). Here two main approaches can be detected: model-based and design-based (randomization). We want to discuss these two approaches and present the arguments leading us to choose one of these approaches for the analysis of the data.

In this section first design-based and model-based approaches will be discussed and then the data analysis method used in this dissertation, namely binary probit regression model will be reviewed.

6.1.2.1 Design-based vs. model-based inference

Instead of an SRS, in this survey a more complex sampling design mainly based on unproportionate stratified sampling was employed. Due to this sampling design, a group of people, i.e. university scientists with higher number of NST-related articles, are given a higher probability of selection; hence, the sampling weights of the observation units in this group are higher than those of the rest. The sampling weight for an observation unit is equal to the reciprocal of the probability that this observation unit is selected to be in the sample (Lohr, 1999), or in other words, $w_i = 1/\pi_i$. Sampling weights are used by survey statisticians to compensate the effects of the sampling design, i.e. stratification and clustering, or nonresponse. Although using weights is widely accepted for descriptive inference their usage is a subject of a long standing debate among theorists on the appropriateness of using weights for analytical inference that seeks to describe causal systems (Kalton, 1989; Pfeffermann, 1993). The aim of this part is to provide an answer to the question of whether the sampling weights should be used in analytical modelling employed in this research.

Design-based approach

Design-based inference is based on the concept of randomization; therefore, it is also called as randomization approach (Lohr, 1999; Smith, 1984). Design-based approach treats the survey outcomes (y values) as fixed rather than random; hence, randomization mechanism is dictated by the chosen sampling design. From this parameter to be estimated and the sampling weights, defined as the inverse of the probability of selection, are included in the estimate of $\bar{y}_u$ to achive design unbiasedness (Little, 2007; Lee and Forthofer, 2006; Binder and Roberts, 2003; Smith, 1984). Thus, key differentiating points for design-based approach can be summarized as (1) the population of interest is the finite population which the sample is selected from, (2) the variability is generated by the sampling design and (3) sampling weights play a crucial role in estimations (Bertolet, 2008).

More formally, let consider U is a finite population of N identifiable elements, $U = \{1,2,3,........, \text{N}\}$. For a given sampling design p(s), s_n possible number of size n can be drawn from the population. Under such a sampling design it is possible to allocate all the population elements with an indicator variable I_i which is equal to 1 if the ith element of the population is included in the sample and zero otherwise: $I_i = \{I_1, I_2, ..., I_i, ..., I_N\}$. Then, $\pi_i = P(I_i = 1)$, where π_i is the probability, under p(s), that the ith element is included in the sample (Faiella, 2010; Bertolet, 2008). The sampling weight is defined as $w_i = 1/\pi_i$. In design-based approach sampling weights are important not only to achieve unbiasedness but also because of the fact that design-based analysis gains information about the non-realized samples from the sampling weights and the sampling structure (Bertolet, 2008).

The main discrepancy between design-based and model-based approaches lies on the definition of variance. In design-based approach, variance is the average squared deviation of the estimate from its expected value, averaged over all samples that could be drawn from using a given sampling design (Lohr, 1999). Moreover, the formulas of variance differ across the variety of sampling plans. There are some methods developed for estimating variances of complex survey estimators required for hypothesis testing and for deriving confidence intervals; namely Taylor series method, balanced repeated replication (BRR), jackknife-repeated replication (JRR) or the bootstrap method (Lee and Forthofer, 2006; Lohr, 1999).

Model-based approach

In model-based approach, a stochastic model describes the relationship between y_i and x_i that holds for every observation in the population. In model-based inference, it is assumed that for the N dimensional distribution of $Y = \{Y_1, Y_2, ..., Y_i, ...Y_N\}$ for an element i there is an associated value Y_i that is randomly generated by the model. On the other hand, the actual finite population values $y = \{y_1, y_2, ..., y_i, ..., y_n\}$ are regarded as realizations of random variables, Y_i. In other words, it is assumed that there is a conceptual infinite population of Y values and the observations $(y_1, y_2, ..., y_n)$ are independent realizations from this population. Therefore, it is often called a superpopulation model. In model-based inference, randomness is introduced directly into the y values, and thus any sampling design used for obtaining the n units in the sample can be ignored

(Bertolet, 2008; Binder and Roberts, 2003; Lohr, 1999; Särndal et al., 1992; Hansen et al., 1983; Smith, 1984).

Two important advantages of the model-based approach can be emphasized. The first one is that if the model is correctly specified the unweighted estimator performs better (Faiella, 2010); and second, it is aligned with mainline statistics approaches in other fields (i.e. econometrics); therefore, analysts can rely on a huge literature covering model building and diagnostics (Faiella, 2010; Little, 2004).

In the design-based vs. model-based debate there is a wide spectrum of opinions on the role of sampling weights. On the one side, there are modellers who view the weights as irrelevant and on the other there are survey statisticians who incorporate the weights into every analysis (Pfeffermann, 1993). For example, Hoem (1989) argues that the worries and computing exercises in order to introduce sampling weights can be superfluous where the researcher is really involved in modelling human behaviour rather than calculating descriptive statistics in finite populations. Fienberg (1989) from a similar perspective emphasizes that sampling weights, as they are usually constructed, are at best irrelevant to a likelihood –based approach to statistical inference. On the other end of this discussion there are survey statisticians arguing that hypothetical model parameters should be replaced by the descriptive population parameters; i.e. Kish (1965); Kish and Frankel (1974); Fuller (1975); Shah et al. (1977).

Between these two ends of the discusion there are a large group of researchers who argue that if the sampling design is informative[3] ignoring sampling designs have severe effects (e.g. bias of point estimators and poor performance of test statistics and confidence intervals) on the inference process (Pfeffermann, 1993) and may cause model misspecification (Lee and Forthofer, 2006). There are a

[3] There is a number of studies discussing the definition of informative sample or informativeness (Binder et al. 2005; Pfeffermann, 1993; Smith, 1989; Sugden and Smith, 1984; Smith, 1984; Little, 1982; Scott, 1977). A sampling design is informative if it is dependent on unknown values of outcome variable or dependent variable Y. In other words, if the selection probability of an element in the population is related to the unknown response variable Y, it is argued that the sampling design is informative about the modelled outcome.

number of studies focusing on these effects of ignoring the informative sampling design. For example, DeMets and Harperin (1977), Holt et al.(1980), Nathan and Holt (1980), Nathan and Smith (1989) provide evidence that the OLS estimator is biased when the sample is selected on a design variable Z which is correlated with the dependent variable Y. Moreover, Chambers and Boyle (1985 as given in Pfeffermann, 1993 and Lohr, 1999); Prentice and Pyke (1979, as cited in Lohr, 1999); Scott and Wild (1989) show that ignoring the informative sampling design in logistic regression models only affect intercept term; in such a case the estimate of the intercept term has a large bias.

Although the effects of sampling design on the estimations are rarely dealt with in econometric textbooks, Wooldridge (2009; 2001) adverts on exogeneous and endogeneous stratification and how the stratified sampling design affects the estimators. He mentions that, in cases where stratification is based on exogeneous variables the estimators are unbiased and efficient; and normal procedures can be applied; however if the sampling is endogeneous some special econometric methods are needed (Wooldridge, 2009). Wooldridge uses Hausman test for the exogeneity of the stratified sampling (Wooldridge, 2001). Moreover Maddala (2001), again, emphasizes that in the logit model, the coefficients are not affected by the unequal sampling; and he adds that "even for probit and linear probability model, although one cannot derive the results analytically, it appears that the slope coefficients are not much affected by unequal sampling rates". Thus, if the primary interest of the researcher is to estimate the coefficients of the independent variables in a binary choice model the sampling design has no effect in the model-based analysis.

In this part we discussed the possible effects of the sampling design we followed in the survey on especially analytic inferences. There is a controversy among the design-based and model-based approaches. However, we preferred to follow a model-based approach and the usual econometric procedures. Since the design variable (number of NST publications) is fully known and is assumed to be conditionally independent from the response variable Y (as previously explained in sampling design) we decided to ignore the unproportionate stratified sampling design in the analysis of the data.

6.1.2.2 Methods for data analysis: Binary probit models

The information collected from this survey is used to determine the importance of various factors on the intentions of nano-scientists affiliated to Turkish universities to engage in relations with the industry by estimating binary probit models.

Binary probit model is one of the discrete regression models in which the dependent variable y is binary; i.e. it can only assume two variables, which are denoted as 0 and 1 (Maddala, 1983). For our case, y can be defined as one if a nano-scientist is linked to industry or zero otherwise. Regression models for binary dependent variables (for other discrete dependent variables as well) allow us to explore how each explanatory variable affects the probability of the event occuring; therefore, they are called as probability models (Long and Freese, 2006; Liao, 1994).

Binary probit is a latent variable model for binary dependent variables. A latent variable model assumes a latent or unobserved variable, y^* ranging from $-\infty$ to ∞ that generates the observed y 's (Long, 1997). The response variable y_i^* is defined by the following regression equation

$$y_i^* = \beta' x_i + u_i \qquad \text{(Eq. 6.1)}$$

where i indicates the unit of observation, x is the explanatory variable, β is the parameter to be estimated and u is the random disturbance term. y_i^* is unobservable and what we observe instead is a dummy variable y. The link between y_i^* and observed y_i can be defined as follows:

$$y_i = 1 \quad \text{if } y_i^* > \tau \qquad \text{(Eq. 6.2)}$$

$$y_i = 0 \quad \text{otherwise}$$

where τ is the threshold or cutpoint.

A latent variable model assumes that a continuous latent variable y^* underlies the binary categories. For example, in our case, the observed y is the status a nano-scientist's having a relationship with the industry; and y can only be observed in two cases: a nano-scientist is linked to the industry, or s/he is not. However, the intensity of the relationship is not the same for all nano-scientits; some have more intense relations with the industry but some do not. Therefore, we can assume that there is an underlying continuum of possible responses to the question of whether a nano-scientist is linked to the industry. All possible answers on this continuum are the values of y^* which generates the observed value (Long and Freese, 2006; Long, 1997).

From Eq. 6.1 and Eq. 6.2, for a given value of x_i

$$\begin{aligned} \text{Prob}\,(y_i = 1) &= \text{Prob}\,(y_i^* > 0) \\ &= \text{Prob}\,(\beta' x_i + u_i > 0) \\ &= \text{Prob}\,(u_i > -\beta' x_i) \\ &= 1 - F(-\beta' x_i) \qquad \text{(Eq. 6.3)} \end{aligned}$$

where F is the cumulative distribution function of u (Maddala, 1983). If the distribution of u is symmetric, then $1 - F(-\beta' x_i) = F(\beta' x_i)$ and we can write

$$\text{Prob}\,(y_i = 1) = F(\beta' x_i) \qquad \text{(Eq. 6.4)}$$

Due to some serious problems OLS (ordinary least squares) procedure is not preferred for the estimation of β from the Eq. 6.4. The first problem is about the error term. In a linear probability model the value of the dependent variable has a nonstochastic component and a random component which is the error term. In the binary choice models, nonstochastic component in an observation i is its expected value in that observation, and it can be easily computed because it takes only two values (0 and 1). In such a model, error term also takes only two values and, therefore, does not have a normal distribution. Hence, the OLS is not, in general, fully efficient; but some nonlinear procedures are more efficient than OLS procedure (Maddala, 1983). Second, the error term is inherently heteroskedastic because the error variance varies with the values of the explanatory variables. Third problem is that the predicted probabilities can be greater than 1 or less than 0. Therefore, the linear probability model may make some nonsense predictions that an event will occur with probability greater than 1 or less than 0. Thus, instead of OLS Maximum Likelihood (ML) estimation is used. Likelihood function is

$$L = \prod_{y_i=0} F(-\beta' x_i) \prod_{y_i=1} F(\beta' x_i) \qquad \text{(Eq. 6.5)}$$

The functional form of F in the likelihood function depends on the assumptions about the disturbance term, u. If the cumulative distribution of u is logistic, we have a logit model. On the other hand, if u is assumed to be distributed normally with Var(u) = 1, then we have a probit model (Maddala, 1983; Liao, 1994; Long, 1997, Long and Freese, 2006). In the probit model,

$$\text{Prob}(y=1) = F(\beta' x_i) = \int_{-\infty}^{\beta' x} \frac{1}{\sqrt{2\pi}} \exp\left(-\frac{t^2}{2}\right) dt \qquad \text{(Eq. 6.6)}$$

Probit and logit models give similar results due to the fact that the cumulative normal distribution and logistic distribution are very close to each other. However, in cases where extremely large number of observations are concentrated heavily in the tails of the distribution the estimates from logit and probit models differ substantially; and for these cases, logit models have been proved to be more appropriate (Liao, 1994). Unless the sample presents such a heavy tailed distribution, choosing one model over another does not make a difference in terms of results. However, the estimates of β from these two methods are not directly comparable because of the different variances of u_i assumed; Amemiya (1981) propose a ratio of $1/1.6 = 0.625$; it suggests that the estimates of β obtained from logit model should be multiplied by 0.625 to be compared with those obtained from the logit model (Maddala, 1983; Liao, 1994). Nonetheless, probit model is more favored by the economists due to the normality assumption for error term u (Wooldridge, 2009).

The interpretation of the parameter estimates in a probit regression model is an important issue. In binary response models, what is required is to explain the effects of the explanatory variables on the response probability, P($y_i = 1$). However, the estimated parameters give information about the direction of the relationship between the dependent and explanatory variables but not on its intensity. Measuring the effects of explanatory variables on y is a complicated procedure due to the nonlinear nature of F (Wooldridge, 2009; Maddala, 2001). One useful way of interpretation in both logit and probit models is to examine partial effect of the explanatory variables on the response probability (Wooldridge, 2009; Maddala, 2001; Maddala, 1983). This partial change in the probability with respect to an explanatory variable is also called the marginal effect (Long, 1997; Liao, 1994); and it obtained by taking the partial derivative of the Eq. 6.7

$$\frac{\partial P(y=1)}{\partial x_k} = \frac{\partial F(\beta' x_i)}{\partial x_k} = \phi(\beta' x_i)\beta_k \qquad \text{(Eq. 6.7)}$$

Hence, the marginal effect provides us the expected amount of change in the probability of event occuring for a given unit of change in x_k. The sign of the marginal effect is determined by β_k but its magnitude depends on the values of the other variables and their coefficients. Marginal effects can be computed in two ways. One method is to compute marginal effects at the mean of the explanatory variables. In the second method, first the marginal change for each observation in the sample is computed and, then their average value is calculated (Long 1997; Long and Freese, 2006). In this research, we compute marginal effects at the mean of explanatory variables. However, we have to note that the marginal effect for dummy variable is calculated as the discrete change in probability as the dummy variable going 0 to 1.

Another issue to be reviewed in this section is the goodness-of-fit statistics for binary choice models. In OLS, the coefficient of determination R^2 is the standart measure of fit and it measures the proportion of variance explained by the model. However, there is no such a clear common measure for models with categorical outcomes (Long, 1997). Instead, several measures, which are called pseudo-R^2 have been proposed [4]. Although such measures of goodness-of-fit are widely used in the literature we are aware of that these measures provide very limited information for models with categorical dependent variables. Therefore, the information provided by pseudo -R^2 should be assessed within the context of theoretical framework used, past research and estimated parameters of the model. In our analyses, we use McFadden pseudo-R^2 (McFadden, 1973)[5] and Hosmer-Lemeshow (HL) statistic[6] (Hosmer and Lemeshow, 1980; Lemeshow and Hosmer, 1982) as the measures of goodness-of-fit.

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[4] They are called ‘pseudo’ because they are not measured in terms of variance because in logit or probit models the variance is fixed; thus, they are measured in terms of log likelihood. These pseudo-
R^2 s are similar to R^2 in many sense, such as the value of pseudo-R^2 s ranges between 0 and 1, and higher values indicate better model fit.

[5] McFadden pseudo-R^2 suggests an analogy of R^2. In this measure the total sum of squares used in R^2 is exchanged with the log likelihood for model M_α without regressors and the residual sum of squares in R^2 is exchanged with the log likelihood for model M_β with regressors. In the case $M_\alpha = M_\beta$ McFadden pseudo-R^2 equals 0 (Long, 1997).

[6] Hosmer-Lemeshow test statistics compare predicted probabilities with the observed data. In order to compute the test statistic, first the model is fit and, predicted probabilities are computed. Second these predicted probabilities are sorted from the smallest to the largest value. Then, the number of observations is divided into G groups (generally G is set as equal to 10). Since the predicted probabilities are sorted from the smallest to the largest the first group has the n number of smallest values of predicted probabilities. Then, within each group, the mean prediction and the mean number of observations is computed. Finally, Hosmer-Lemeshow test statistic is computed as Pearson chi-square statistic with G-2 degrees of freedom (Long and Freese, 2006). Non-significant chi-square (p>0.1) indicates that the model does fit well.

6.2 Qualitative data collection and analysis

The fundamental aim of this research is to understand the dynamics behind the tendency of nano-technology firms in Turkey to interact with universities. Since university-industry interaction is a very complex process which has not yet been fully investigated among high-technology firms in Turkey, using qualitative methods is more appropriate to understand the process in which firms interact with universities and use the knowledge obtained from universities in their innovations. Hence, in this research, a case study method (Eisenhardt, 1989; Yin, 2009; Gerring, 2007; Gillham, 2000) has been adopted.

A case study is the investigation of a single case or multiple-cases to answer specific questions; and, therefore, it seeks a range of different kinds of evidence collected through methods such as archives, interviews, questionnaires or observations (Eisenhardt, 1989; Gillham, 2000). However, qualitative methods in a case study research are fundamental (Gillham, 2000) due to the advantages they provide for the collection of detailed and multi-dimensional data.

Qualitative methods produce detailed data about a small number of cases. The selection of qualitative instead of quantitative methods is based on a trade-off between breadth and depth. While quantitative methods use standardized survey instruments which limit the collected data to pre-determined categories, qualitative methods allow investigation of selected cases in depth (Patton, 2002). Miles and Huberman (1994) suggest that qualitative methods have some certain strenghts; (i) it provides local groundedness, in the sense that a case can be understood in its own context; (ii) due to a rich and holistic approach qualitative methods have a strong potential for revealing complexity; and (iii) flexibility of qualitative methods further help to understand how and why things happen.

Nanotechnology is very new for Turkish firms, therefore, the number of firms interested in nanotechnology is very small but their levels of engagement with this technology and their technological capabilities widely differ. Hence, we have a mixture of firms, some are dedicated nanotechnology start-up firms; some are established manufacturing firms from different industries but use nanotechnology in order to improve their traditional products such as textile, ceramics or chemicals. In order to capture the variation among firms in size, industry or R&D intensity, and the impact of these varieties on the attitudes of firms to establish relations with universities we decided to use qualitative methods for data collection and analysis. Therefore, the second empirical research of this dissertation which aims to understand the factors influencing nanotechnology firms in Turkey to enter in relations with universities is based on 21 firm-level case studies based on qualitative semi-structured interviews.

Section 6.2.1 presents how the sampling frame that is the list of nanotechnology firms is constructed. Section 6.2.2 discusses the semi-structured interview technique used in the research; in section 6.2.3 data collection phase is reviewed. Section 6.2.4 discusses the qualitative data analysis methods used in this research.

6.2.1 Sampling

While quantitative methods depend on larger samples selected randomly, qualitative ones focus on relatively small number of cases (Patton, 2002). Therefore, in qualitative methods purposeful sampling instead of random sampling is preferred. In purposeful sampling, the researcher selects certain cases because they are expected to inform an understanding of the research problem or central phenomenon in the research (Creswell, 2007). Eisenhardt (1989) suggests that case studies should be selected with theoretical sampling if the aim of the researcher is to build theory from case studies. In theoretical sampling, cases are selected from a population for the likelihood that they will offer theoretical insights (Eisenhardt and Graebner, 2007). In qualitative methods random selection of samples is not preferable; case or cases are choosen on the basis of predetermined objectives of the research.

In the sampling design of this qualitative research, our primary aim was to reach a considerably large part of the firms developing nanotechnology or using any form of nanotechnology in their products or processes. Therefore, after we first prepared the list of firms, we aimed to construct a sample of firms that could reflect the diversity in the firm population.

Nanotechnology is a new and steadily growing field of technology; moreover it is a candidate general purpose technology (for an extended discussion, see Chapter 2), in the sense that it is used by firms across different sectors from low technology textile industry to high technology electronics industry. Due to this ambiguity, in Turkey, there is no ready-to-use or accessible list of firms which carry out nanotechnology related-R&D or use nanotechnology in their products and processes. Therefore, different sources of information were utilized for establishing a list of nanotechnology firms to use in this research.

We started with the nanotechnology report published by TÜSİAD (2008) which provides a list of 21 established or start-up firms, in Turkey, which develop nanotechnology or use it in their production process. In order to enlarge this list of nanotechnology firms, we carried out an exhaustive search over internet: (i) we searched over the web pages of each "Technology Development Zones" (Teknoloji Geliştirme Bölgesi)[7] to find out nanotechnology start-ups; (ii) we searched for the list of publicly funded firms (by TUBITAK -TEYDEB or Ministry of Science, Industry and Technology) and their projects which were, to some extent, accessible over internet; (iii) we searched for industry magazines and newspapers to detect new product and process innovations including the keywords 'nano' or 'nanoteknoloji'; and finally (iv) we made a general search over internet with using

[7]Technology Development Zones (Teknoloji Geliştirme Bölgeleri) have been established by a law (No: 4691) enacted in 2001. The aim of this law is to support the foundations of certain sites located nearby universities where high technology entrepreneurs, researchers and academicians are provided some benefits to develop their industrial products and commercialize their research outcomes. The primary aim of the establisments of these regions is to promote university-industry relations.

keywords such as ‘Türkiye’, ‘nano’, ‘nanoteknoloji’, ‘firma’, etc. After this intensive search over internet, we had a longer list of Turkish firms doing nanotechnology related R&D or using nanotechnology in their productions. However, some new firms were also added to the list along the period we conducted interviews; because interviewees sometimes provided us information about nanotechnology firms in the market.

At the final stage we had a list of 44 firms which either develop nanotechnology or use certain nanotechnologies developed out of firm in their productions. However, during the period we were contacting the firms for arranging an interview, we noticed that same people were the founders / partners / employees of more than one firm. During phone conversations, it was mentioned by firm managers that for various reasons (i.e. having access to public funds, partnering with international firms, or distributing resources across projects) they founded more than one start-up firms. When we considered such cases, the number of firms which could be interviewed was reduced to 40.

Firms’ founders / executive managers or R&D managers who were responsible for nanotechnology-related activities in the firm were contacted first on the phone; if they were not reached on phone we sent e-mails to communicate with them. We told about who we are, the objectives and the scope of the research, how collected data would be used; and then asked for a face-to-face interview. Some firms rejected our interview request. Finally, we carried out 21 interviews with different nanotechnology firms in our list. In other words, more than 50 percent of Turkish nanotechnology firms present in our list were interviewed.

Table 6.5 provides the number of fims in our list and those we interviewed in two groups. The first group (Group A) includes firms which are established firms with more than 50 employees, not dedicated nanotechnology firms but operate in various industries such as textile, chemicals, electronics, ceramics, etc. In the second group (Group B), there are start-up firms which are mostly developing nanotechnology-related product or processes. Some of the firms in Group B are founded by nanotechnology academics affiliated to Turkish universities. These firms founded by nano-scientists or those having nano-scientists among their founders/ partners are classified as Group B1 and the rest under Group B2.

Table 6.5 Distribution of interviewed sample across groups of firms

Group	*All firms in the list*	*Interviewed sample*	*Percentage*
A	15	8	**53 %**
B	25	13	**52 %**
B1	14	7	**50 %**
B2	11	6	**54 %**
TOTAL	**40**	**21**	52.5%

We succeeded reaching half of the firms in our list; however our primary purpose in sampling strategy was to capture the diversity among firms. As shown in Table 6.5, we contacted and collected data from different groups of firms; and the firms across groups were equally distributed. Therefore, we can argue that our sampling design has produced a representative sample and also reflects to the diversity in the population.

6.2.2 Semi-structured interviews

Interviews are guided conversations; the researcher guides the discussion by asking specific questions and encouraging the interviewee to answer the questions in-depth in order to collect information about the the topic she / he is interested in. Therefore, it is expected that research interviews are somewhat structured. However the degree of structure changes depending on the aim of the research.

Semi-structured interview is preferred in this research due to its advantages. This method provides flexibility which is balanced by structure and, therefore, increase the quality of the data obtained (Gillham, 2005). A structured interview is built up from mainly two types of questions: main questions and probes or follow up questions. Main questions are used to start the conversation and to direct the interviewee to the main discussion or topics of the interview. Probes, on the other hand, are asked to complete or clarify the answers of respondents or to request for more detailed or in-depth responses (Rubin and Rubin, 1995; Gillham, 2005).

As emphasized by Gillham (2005), semi-structured interviewing needs in-depth preparation before conducting the interviews. Therefore, we first reviewed the literature focusing firms' interactions with universities; and the main topics were detected. Moreover, empirical studies or reports focusing on the main characteristics of nanotechnology firms; the main challenges of these firms and their relations to academia were specifically examined. Finally, the main questions of the interview were identified; these questions guided our conversation with firms. In other words, these questions were the basis of the interview guide serving as a framework for the main body of the semi-structured interview (Arksey and Knight, 1999).

However, as mentioned in the previous section, the firms we interviewed are characterized by a huge variety, not only in their relations to nanotechnology related activities, but also in size, sector or organizational structure. Thus, semi-structured interviewing provided us all the flexibility to handle these varieties of firms; but increased the time we needed to prepare for the interviews. Prior to each interview, we reviewed publicly available secondary material about the interviewee firm to be familiar with the case. Thus, we added probes to our interview guide to collect more information about the specific characteristics of the firm. However, during some interviews we needed to ask further questions to get in-depth information about firms' relations to universities. The interview guide which includes main questions is provided in Appendix E.

6.2.3 Interviews and data collection

High level R&D responsibles who had accepted to be interviewed were first contacted on the phone and given brief information about the content of the interview, the main objectives, and the university and the academicians who were carrying out this research and asked for an appointment for a face-to-face interview. In each firm, high level manager who is responsible for nanotechnology-related R&D efforts, i.e. general managers, founders of start-up firms, managing partners, R&D managers, and project managers, were contacted by me.

After the appointment was arranged, I visited the respondent at her / his office; and following the pre-determined guideline, interviews were conducted. However there were two exceptional cases in which firm managers were interviewed on the phone. The lenght of interviews changed from firm to firm from 40 minutes to 3 hours. Only 8 interviews were recorded with interviewees' permissions; however in the rest field notes were taken. After each interview with or without voice recording, the collected data was immediately transcribed. All interviews (Appendix E) were completed in almost one-year period from June 2010 to May 2011.

Ethical issues are also involved in interviews. Since interviews include human interaction ethical issues directly affect the interviewee and, hence, the knowledge produced during interviews (Klave, 2007). Likewise in our questionnaire survey, during the qualitative interviews two ethical principals were considered: (i) informing respondents; and (ii) protecting respondents. Firm managers were informed about the name of the university, department, academicians and other researchers involved in the research; the organizations supporting the research; the purpose of the research; and most importantly they were provided assurance that they could skip any questions they do not want to answer. Moreover, they were informed that their responses, firm names or other firm related identifying information would be protected with respect to confidentiality.

6.2.4 Qualitative data analysis

In qualitative methods, data analysis begins while the interviewing is still under way. After the completion of each interview we examine the data and find out the concepts and themes (Rubin and Rubin, 1995), of course not always in a systematic manner. However, after all interviews are completed, a more-detailed and fine-grained analysis of the data is required. There are various ways of qualitative analysis of interview data.

In this research, thematic analysis is utilized for data analysis. Thematic analysis is a process for encoding qualitative information; it enables researchers to use the information collected through qualitative methods in a systematic manner (Boyatzis, 1998). In thematic analysis the researcher identifies themes and patterns in interviews. It is the simplest but most popular method of data analysis. In this method, the researcher, first, transcribes the interviews and through reading transcripts (or listening to voice records) searches the data for related categories, patterns or themes (Holloway, 1997).

Thematic analysis of the data starts with thematic coding. Coding is a way of indexing or categorizing the data in order to establish a framework (Gibbs, 2007). For coding the data, we carefully re-read transcribed text of each interview and we identified one or more passages of text exemplifying similar theoretical or descriptive ideas with the same code[8]. During the analysis of qualitative data, a

[8] For instance we use similar codes of INFORMAL, COMM, RES, ACAD and CONS to code KTT channels used by the interviewed firms. We identified themes of 'human capital', 'social capital', 'organizational factors', 'impact of KTT activity' from the theory and the previous research in this dissertation. For instance, in human capital theme we use such codes: 'research experience in industry', 'research experience in academia', 'being familiar to academic language and codes' and 'following academic publications', 'following academic conferences'.

theory-driven code development approach (Boyatzis, 1998) is followed. Boyatzis argues that in this approach the themes emerge from theory; and therefore, codes are in the language of the researcher's field.

Hence, we had some essential themes and codes which we derived from the literature; and some of these themes and codes were embedded into the interview guide. In the interviewing period some of these categories or themes were reconfirmed; some lost their importance or some new categories, themes or codes appeared. Therefore, before a detailed thematic analysis we had some categories in our mind; but after a careful reading of the texts of transcibed data we added new ones. Finally we categorized the collected data according to different themes; and linked these categories to provide answers to our research questions. This way of analysis is also classified as cross-case analysis (Miles and Huberman, 1994) in which information collected from various cases are analyzed in a systematic manner for explanatory aims and theory building.

6.3 Conclusions

This chapter reviewed two different methodologies for data collection and analysis. We first presented (in Section 6.1) how the data used for the quantitative analyses of factors influencing nano-scientists to engage in university-industry KTT activity is collected and analyzed. We first described the target population and formed a sampling frame. Second, the sampling strategy based on disproportionate stratified sampling, its advantages and disadvantages were discussed. Then, how the questionnaire was designed and controlled for validity and reliability was briefly stated. The sampling strategy we used was based on unequal probability selection; and brought some concerns about whether the sampling design should have been considered in estimations. After a brief discussion of design-based and model-based approaches we stated our preference for model-based approach due to the fact that the design variable is fully known and is assumed conditionally independent from the response variable. In the last section, we briefly discussed binary probit models which were used to estimate the impacts of various factors on the intensions of nano-scientists affiliated to Turkish universities to engage in university-industry KTT activity.

In the second part of the chapter (Section 6.2), we discussed qualitative data collection process and methodology which was used to understand the factors affecting nanotechnology firms to interact with universities. A multiple case study approach was utilized to collect information from firms which conduct nanotechnology R&D or use any form of nanotechnology in their products and production processes. Hence, we obtained qualitative data which was collected from 21 cases through semi-structured interviews.

A multiple-case study approach and qualitative methods provide our research, first of all, flexibility to explore the differences among firms. The target population is very limited in numbers albeit they var extremely in certain characteristics such as size, industry, R&D capacity and organizational structure. Some of these firms are established firms operating in a wide spectrum of manufacturing sectors; i.e. textile, ceramics, electronics, chemicals etc. Their primary concern is not to develop specific nanotechnologies but use nanotechnology to improve their main products. On the other hand, there are start-up firms focusing fundamentally on nanotechnology R&D; they are dedicated nanotechnology firms which aim to develop a certain form of nanotechnology. Second, qualitative methods allow in-depth analysis of selected cases; and exploration of various factors influencing nanotechnology firms to engage in university-industry KTT activity and its consequences in a context dependent manner and from a wider perspective.

In Chapter 7 and Chapter 8, we present and discuss findings of the quantitative and qualitative research respectively.

CHAPTER 7

WHO, AT UNIVERSITIES, INTERACT WITH THE INDUSTRY: AN EMPIRICAL INVESTIGATION OF UNIVERSITY NANO-SCIENTISTS

In this part, the information collected through the questionnaire survey is used to determine the importance of various invidividual and organizational factors on the proclivity of nano-scientists affiliated to Turkish universities to interact with industry. In Section 7.1 we discuss how KTT activity is measured in this study; and indicate how the dependent variable(s) is constructed. Respondents are asked about how frequently they interact with industry through any 18 different forms of KTT activity; but the number of activities is reduced to five through some methods including factor analysis following principal component analysis (PCA). A brief discussion of model selection, empirical specification of the model, explanatory variables used in the model and related hypotheses is carried out in Section 7.2. It is followed by a section which makes use of descriptive statistics for the individual and organizational features of what to examine the Turkish context of NST-related academic research. Section 7.4 presents the results of the empirical analysis of the individual and organizational factors which influence the intentions of Turkish NST academics to engage in university-industry KTT activities. This section is followed by similar analyses for the determinants of engaging in informal KTT activities in section 7.5; and research related KTT activities in section 7.6. In Section 7.7 we discuss the findings of the research, and its STI policy implications.

7.1 Measuring KTT activities: Construction of dependent variable(s)

In Chapter 3, we reviewed the literature focusing on the variety in university-industry interactions. The variety in the form of interactions between universities and firms has been considered by scholars especially in questionnaire surveys addressing both individual researchers and firms. For example, Inzelt (2004), based on a review of the empirical literature identifies 18 different forms of interaction; Bekker and Freitas (2008) ask the perceived importance of 26 different KTT activities between universities and firms; and Arvanitis et al. (2008) explore the use of 19 single form of KTT activities and 3 channels of commercializing technology developed at universities (i.e. patenting, licensing and spin-offs). A list of studies using various forms of KTT is provided in Chapter 4 (see Table 4.2).

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. Percentage distribution of respondents who are engaged in commercial forms of KTT activity is presented in Table 7.1. Results indicate that only 7.18 percent of respondents have engaged in any one of these three forms of commercial-based KTT activity.

A university spin-off is defined as “a new company founded to exploit a piece of IP created in an academic institution” (Shane, 2004b). While in this definition the key point is an IP owned by the institution, Wright et al. (2008) argue that at some institutional contexts IP is not necessarily owned by the university and many university companies do not build upon formal and codified knowledge embodied in patents, therefore, start-ups by academics based in university which do not involve institution’s IP but individual academics’ own IP or knowledge should be included as a university spin-off. In this research, we prefer to take the definition of university spin-off in Wright et al. (2008) due to the fact that university IP is not a relevant case for most of the start-up companies by academics based in universities in Turkey. To measure academic entrepreneurship, respondents are asked about whether they have founded a company or been a partner of a company in order to commercialize their inventions originated from university labs.

Table 7.1 Percentage of respondents engaging in direct forms of KTT activity (COMM)

	0=No	*1=Yes*
Joint patents	96.13	3.87
Licensing	96.69	3.31
Entrepreneurial activity	96.13	3.87
Commercial KTT activity	92.82	7.18

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; 2=rarely; 3=sometimes; 4=frequently; 5=very frequently). Among those 15 questions, four questions measure how frequently respondents consult firms in their nanotechnology related R&D projects. Table 7.2 provides percentage distribution of respondents' consulting firms on the basis of the intensity of the engagement.

Table 7.2 Percentage of respondents engaging in consultancy (CONS)

	1=Never	*2=Rarely*	*3=Sometimes*	*4=Frequently*	*5=Very Frequently*
CONS	**61.33**	**17.68**	**12.15**	**6.08**	**2.76**
R&D projects based on public funds	*69.61*	*13.81*	*8.84*	*5.52*	*2.21*
R&D projects based on EU funds	*90.06*	*6.08*	*3.31*	*0.55*	*0.00*
R&D projects based on other international funds	*93.92*	*3.87*	*1.66*	*0.55*	*0.00*
R&D projects based on firms' internal funds	*81.77*	*12.15*	*3.31*	*2.21*	*0.55*

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 (i.e. Arvanitis et al., 2008; Cohen et al. 2002 For the aim of decreasing the number of KTT channels between universities and firms, the factor analysis following principal component analysis (PCA) with Varimax rotation and the Kaiser criterion (i.e eigenvalue greater than one) was used. (For details of PCA see Appendix F). Factor analysis was performed using STATA 11.0; and finally 3 principal components were identified. These components are (i) informal / interpersonal forms of KTT (or INFORMAL); (ii) research-related KTT activities (or RES); (iii) academia-related KTT activities (or ACAD). All three components explain almost 76 percent of the total variance (Table 7.3).

Bartlett's test of sphericity and Kaiser-Meyer-Olkin (KMO) measure are the most common methods to assess whether the dataset is adequate for factor analysis. The Bartlett's test of sphericity tests the hypothesis that variables in the dataset are not intercorrelated; and the rejection of the null hypothesis (i.e. the variables are uncorrelated) is an indication that the data are adequate to factor analysis. The KMO measure, on the other hand, compares the magnitudes of the observed correlation coefficients to the magnitudes of the partial correlation coefficients; and an acceptable level of the measure is 0.5 or greater. Both Bartlett's test and KMO measure indicate that our dataset is clearly adequate for principal component factor analysis.

Table 7.3 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**		
SAN-TEZ (Master/PhD theses supported by firms)		**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[1]**		
Bartlett's test of sphericity	**835.96[2]**		
Variance explained by each component	**6.15**	**1.12**	**1.08**
Proportion of variance explained by each component	**55.91%**	**10.18%**	**9.82%**

[1]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
[2]p-value= 0.000 (H0= Variables are not intercorrelated)

Table 7.4 provides percentage distribution of respondents engaging in (i) informal / interpersonal forms of KTT (INFORMAL); (ii) research-related KTT activities (RES); and (iii) academia-related KTT activities (ACAD) on the basis of the intensity of the engagement.

Table 7.4 Percentage of respondents engaging in INFORMAl, RES and ACAD forms of KTT activity

	1=Never	*2=Rarely*	*3=Sometimes*	*4=Frequently*	*5=Very Frequently*
INFORMAL	**13.26**	**16.57**	**30.94**	**28.73**	**10.50**
Conferences, seminers	*24.02*	*19.55*	*3184*	*18.99*	*5.59*
Supervising students employed at firms	*56.67*	*18.33*	*16.11*	*7.22*	*1.67*
Informal relations with graduates at firms	*29.83*	*27.62*	*25.41*	*12.71*	*4.42*
Informal relations with firm researchers	*29.83*	*31.49*	*26.52*	*9.39*	*2.76*
RES	**35.36**	**26.52**	**25.97**	**8.84**	**3.31**
Ad-hoc research for firms	*58.56*	*26.52*	*11.05*	*2.21*	*1.66*
Special tests and analyses	*58.56*	*19.34*	*16.57*	*3.87*	*1.66*
Joint research projects	*59.67*	*22.65*	*14.36*	*2.76*	*0.55*
Firms' accession to university labs	*52.22*	*27.78*	*12.78*	*4.44*	*2.78*
ACAD	**64.64**	**20.44**	**12.15**	**2.21**	**0.55**
SAN-TEZ	*77.09*	*11.17*	*10.06*	*1.12*	*0.56*
Joint publications with firm researchers	*80.34*	*13.48*	*5.06*	*1.12*	*0.00*
Joint thesis supervision with firms researchers	*83.43*	*11.05*	*4.42*	*1.10*	*0.00*

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. SAN-TEZ (Master/PhD theses jointly supported by firms and the Ministry of Science, Industry and Technology)
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 chapter is to investigate the factors influencing the propensity of nano-scientists to engage in university-industry KTT activity. 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 7.5 provides how different forms of KTT activity are constructed and defined on a binary scale.

Table 7.5 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.

Table 7.6 shows that almost 46 percent of nano-scientists at Turkish universities have engaged in ‘KTT Activity’ through any one of these five forms of activities (INFORMAL, RES, CONS, COMM or ACAD). 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 (RES), 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 (i.e. joint thesis supervision, joint publications or SAN-TEZ).

Table 7.6 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

7.2 Model specification, explanatory variables and hypotheses

7.2.1 Model specification

The models estimated in this study are based on both RBV and STHC approach which are both presented and discussed in Chapter 5. Although the theoretical and conceptual frameworks provided by these two approaches are not originally developed for explaining KTT between universities and firms, they have recently been successfully used in empirical investigation of the factors which influence university-industry interactions both at the individual and organizational level. Both of these approaches predict that individuals or universities will tend to interact with the industry as long as they have idiosyncratic resources, capabilities and skills which can be deployed and mobilized during KTT activity; and these resources, capabilities, skills; and their mobilization will increase the likelihood of interactions between universities and firms.

Formation of KTT linkages between universities and firms is a very complex process with various agents and factors to explore. Therefore, we argue that theoretical conceptualization of university-industry KTT activity requires a multi-level model which includes individual and organizational levels. Both RBV and STHC approach provide such a multi-level framework for the investigation of KTT activities. There are many examples of empirical studies focusing on multi-level agents and factors. O'Shea et al (2007), for example, focus merely on MIT as a case and consider all the characteristics either on the levels of individual, organizational or external environment to explore the university's spin-off activities. D'Este and Patel (2007), Landry et al. (2006; 2007), Boardman and Ponomariov (2009), Boardman (2009), Ponomariov (2008) and Edler et al. (2011) all follow a multi-level model which include both individual and organizational level factors influencing the decision of an individual university researcher to engage with the KTT activity. Hence, the model on which we will base our analysis include not only capabilities, resources and skills embodied in individual nano-scientists hired by Turkish universities but also resources and organizational capabilities of universities.

At the individual level, the factors behind a university-researcher's tendency to collaborate with other academics have long been studied in the literature (Hicks and Katz, 1996; Katz and Hicks, 1997; Melin and Persson, 1996; Melin, 2000; Bozeman and Corley, 2004). Focusing on individual motivations of university-scientists to collaborate is due to the fact that collaboration choices of these scientists remain very much within their control given the environment provided by the academia (Bozeman and Corley, 2004). Based on a similar reasoning, the number of studies taking the university researcher as the unit of analysis to explore KTT activities has recently been increased. On the other hand, at the organizational level, there is a consensus in both theoretical and empirical literature that resources and capabilities that universities possess play a critical role in the formation of KTT links between universities and firms. Moreover, including both individual and organizational level resources, capabilities and skills in the model seems more critical for empirical investigation of university-industry interactions in the field of nanotechnology. First of all since it is an emerging technology field, tacit knowledge embodied at successful researchers (Darby and Zucker, 2004) and the necessary skills for the mobilization of tacit knowledge is the key to the formation of links. Second, instrumentation of science and technology has reached to the peak in the field of nanotechnology; inventions 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, organizational resources such as physical resources (i.e. labs, equipments, devices) and human resources (i.e. experts in using these special tools and devices) play an important role in the formation of university-industry interactions in the field of nanotechnology (Palmberg, 2008; Merz and Biniok, 2010). Third, although the peer effect has not been studied much in the literature Bercovitz and Feldman (2003; 2008), Stuart and Ding (2006) and Tartari et al. (2010) provide evidence for the positive impact of the peers' in the formation of university-industry KTT links. This is explained by the fact that researchers learn how to interact with firms from their colleagues who have strong linkages to the industry (Bercovitz and Feldman, 2003; 2008). Hence, the impact of peer effect on the formation of university-industry KTT linkages is also examined in this study. Figure 7.1 provides a schematic representation of our multi-level model for investigating who, at universities, interact with private firms.

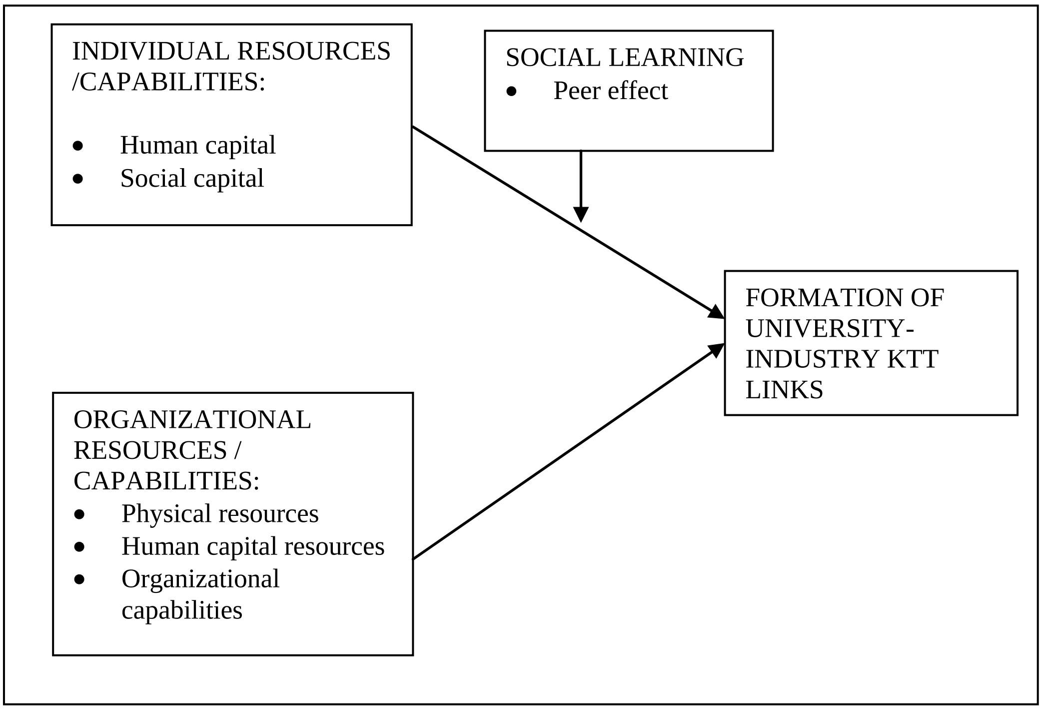

Figure 7.1 A multi-level model for the formation of university-industry KTT links

This model will be tested for the propensity of nano-scientists at Turkish universities to engage in university-industry *KTT Activity* (see Table 7.5), which encompass all KTT activities, as well as for two different forms of KTT activity, namely 'informal contacts' (INFORMAL) and 'research activities' (RES) which are the most common forms of interactions between nano-scientists and firms in Turkey (Table 7.5).

7.2.2 Explanatory variables for measuring human and social capital of nano-scientists and hypotheses

Following STHC approach (Bozeman et al. 2001) and the concept of "intellectual human capital" as proposed by Zucker et al. (1998a; 1998b) and Zucker and Darby (2007) the notion of human capital used in this study is not limited with formal / informal education and training but expanded to include tacit knowledge, skills and know-how embodied in individual researchers as well as social capital endowments.

In the case of university-industry KTT activity, human capital and social capital seems to be one of the most critical resources / capabilities to be mobilized in university-industry relations; and therefore, in many cases, it is advanced that human and social capital positively influence the formation of KTT links between universities and firms (i.e. Murray, 2004; Corolleur et al., 2004; Stuart and Ding, 2006; Boardman, 2008; Boardman and Ponomariov, 2009; Haeussler and Colyvas, 2011).

In this study, human and social capital of the nano-scientists at Turkish universities are proxied by a number of indicators including research experience, scientific productivity, patenting, applied research activities, accessing funding opportunities and intensity of academic networks.

a) Research experience:

The first indicator is the research experience of a scientist; and it is measured by the number of years between 2010 and the year of PhD completion. It is expected that more experienced university scientists will have more accumulated more 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. Therefore, university-scientists with longer research experience are expected to have more accumulated human and social capital. Some recent empirical studies provide evidence for the positive influence of university scientists' experience on their tendency to engage in university-industry KTT activity.

Landry et al. (2007) use the same indicator (i.e. the number of years passed since PhD completion) we use in this research 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 experience, seniority or tenure status is an indication of human and social capital, and thus, have strong influence over being engaged in KTT activity. Thus, we hypothesize that

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

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

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

b) Scientific productivity

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

Knowledge is also a key component of human capital endowments; therefore, it is expected that university scientists who have greater knowledge in the NST field are more likely to interact with the industry. A number of variables were constructed in order to measure the impact of knowledge embodied in nano-scientists a number of variables are operationalized.

a) Number of NST-related publications

The first variable used in this research in order to measure the scientific productivity and knowledge resources of nano-scientists is the number of NST-related publications in SCI. The number of NST publications is calculated by us using bibliometric data which were retrieved from ISI WoS SCI. The number of publications is a clear indicator of academic research carried out by academics; therefore, those with more publications are thought to have a larger supply of findings and outcomes needed by the industry. Zucker et al. (1998b) introduce the notion of "star scientists", who have higher number of scientific publications into the literature. They advance that collaboration with "star scientists" of biotechnology contributes to the innovation activities of firms due to the fact that intellectual human capital of university biotechnology scientists increases firms' human capital endowments. Moreover, the number of publications also increases the reputation of the academics, and the visibility of their works (Haeussler and Colyvas, 2011).

The relationship between research productivity and university scientists' tendency to engage with commercial or 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 entrepeneurs. Moreover, they find out that their productivity does not decrease following the formation of the firm. 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.

The emprical studies reviewed here provide strong evidences for the relationship between the scientific productivity measured by the number of publications and tendency of univerisity scientists to engage in KTT activity. Therefore, we hypothesize that

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

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

Number of patents:

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) use both patents and publications as the indicators of human capital and 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.

Scientists with patents are supposed to have a larger supply of potentially commercializable research findings and experience in applied research and, hence, bring much more resource endowments to firms in case of collaborations. All these factors make such academic patentors much more visible and attractive for firms; and positively influence academics' tendency to interact with the industry. Our respondents are asked about the number of patents and patent applications in question 2.1 (see Appendix D). Consequently, we hypothesize that

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

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

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

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). However, since industrial funding for academic research has been traditionally low in Turkey; in order to measure the degree of scientific outcomes' industrial applicability we directly asked nano-scientists about how much their research outcomes meet the needs of industry; and responses are collected on a five-point Likert scale (question 8.4, see Appendix D) .

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 4A: 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.

Hypothesis 4B: 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 INFORMAL KTT activity.

Hypothesis 4C: 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 RESEARCH-related KTT activity.

c) 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. On the other hand, STHC approach (Bozeman et al., 2001) suggests that when scientists have industry funding, their respective professional networks and resources broaden to work with companies (Boardman and Ponomariov, 2009).

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' (question 7.4, see Appendix D). Hence, we hypothesize that

Hypothesis 5A: 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.

Hypothesis 5B: 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 INFORMAL KTT activity.

Hypothesis 5C: 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 RESEARCH-related 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 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 this study we measure the impact of government research grants on the formation of KTT linkages with the varibale, 'the number of publicly funded research projects carried out by a nano-scientist in the last 5 years' (question 7.3 see Appendix D). Thus, we hypothesize that

Hypothesis 6A: 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.

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

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

d) 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).

The importance of social capital to our research is based on its capacity to create a web of resources available to each member of the social network. In this sense, Bourdieu (1986) defines social capital as "the aggregate of the actual and potential resources which are linked to possession of a durable network"; Knoke (1999) argues that social actors create or mobilize their network connections to gain access to other social actors' resources. According to Nahapiet and Groshal (1998), social capital comprises both the network and the sum of actual and potential resources / assets which may be mobilized through this network.

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 a university scientist 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[1] 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 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.

In this study, instead of using the number of collaborators in publishing (or co-authors) we directly asked respondents the intensity of their personal contacts with other NST-related researchers (question 10.3.1, see Appendix D). This is preferred due to the fact that co-publishing does not always mean an actual collaboration; and scientists co-publish with various reasons (Katz and Martin, 1997). Moreover, with using co-publishing data, a vast amount of informal contacts would have been ignored. Therefore, the respondents are asked about how frequently they personally contact other nano-scientists at Turkish universities; and responses are given on a five-point Likert scale (1: never and 5: very frequently).

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

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

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 7A: 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.

Hypothesis 7B: 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 INFORMAL KTT activity.

Hypothesis 7C: 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 RESEARCH-related KTT activity.

7.2.3 Explanatory variables for measuring peer effect and hypotheses

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 emphasizes 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. In order to measure a possible peer effect respondents are asked about how strongly their peers are linked to the industry (question 10.1, see Appendix D); and the responses are given on a five point Likert scale (1= Not very strong, 5= Very strong). Hence, we hypothesize that

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

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

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

7.2.4 Explanatory variables for organizational resources/capabilities and hypotheses

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.

a) Physcial resources:

In RBV of the firm, physical resources include the physical technology used in a firm, a firm's location and equipments (Barney, 1991). Although firms' physical resources are widely referred as an important source of firm diversification (Chatterjee and Wernerfelt, 1991), in the empirical literature investigating university-industry relations these resources 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 too expensive to be built up in the individual firms; and the human resources to use all these equipments are limited to be hired in the industry, universities having large NST-related physical resources are in a 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. In order to account for the presence of physical resources, respondents are asked whether there exists a NST-related research center, laboratory or research group in their universities (question 9.1, see Appendix D) the respondes are collected in a binary scale (0=No, 1=Yes). Hence, we hypothesize that

Hypothesis 9A: 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.

Hypothesis 9B: 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 INFORMAL KTT activity.

Hypothesis 9C: 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 RESEARCH-related KTT activity.

b) 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; 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. Author (Ponomariov, 2008) explains in such a way that a more prestigious scholarly environment may provide greater incentives to scientists to engage in basic and peer-review research and, hence, scientists consider interactions with industry as somewhat distracting to their research activities.

In this study we measure human capital of universities with two variables (i) total number of citations received by university 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). Both of these variables are based own our calculations from the bibliometric data which were retrieved from ISI WoS SCI. 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 opportunites 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 10A: The higher the number total citations to a university's NST-related publications is, the greater is the likelihood of a nano-scientist employed at this university to engage in KTT activity.

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

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

Hypothesis 11A: 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.

Hypothesis 11B: 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 INFORMAL KTT activity.

Hypothesis 11C: 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 RESEARCH-related KTT activity.

c) 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 Thurby (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, in this research, the respondents are asked about how much their university administration support them in the formation of relations with the industry (question 9.4, see Appendix D) and providing solutions to problems that might occur during the relations with firms; and responses are given on a five-point Likert scale (1: not very much; 5: very much).

After the review of the empirical studies supporting the argument that the attitude of university administration, university policies, strategies and routines have positive impact on the university-industry interactions we hypothesize that

Hypothesis 12A: 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.

Hypothesis 12B: 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 INFORMAL KTT activity.

Hypothesis 12C: 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 RESEARCH-related KTT activity.

Finally, Table 7.7 provides a list of all hypotheses provided in the previous part.

Table 7.7 Research hypothesis

1	*The greater the research experience of a nano-scientist is, the higher is her/his likelihood to engage in KTT activity [INFORMAL and RESEARCH-related KTT activity]*
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 [INFORMAL and RESEARCH-related KTT activity]
3	The greater the number of patents of a nano-scientist is, the higher is her/his likelihood to engage in KTT activity [INFORMAL and RESEARCH-related KTT activity]
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 [INFORMAL and RESEARCH-related KTT activity]
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 [INFORMAL and RESEARCH-related KTT activity]
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 [INFORMAL and RESEARCH-related KTT activity]
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 [INFORMAL and RESEARCH-related KTT activity]
8	Nano-scientists with peers who have stronger industrial ties are more likely to engage in KTT activity [INFORMAL and RESEARCH-related KTT activity]
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.
10	The higher the number total citations to a university's NST-related publications is, the greater is the likelihood of a nano-scientist employed at this university to engage in KTT activity [INFORMAL and RESEARCH-related KTT activity]
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 [INFORMAL and RESEARCH-related KTT activity]
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 [INFORMAL and RESEARCH-related KTT activity]

7.2.5 Control variables

Two control variables are used in the models to account for the effects of some 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. The respondents are mostly employed at either "faculty of natural sciences" or "faculty of engineering". It is expected that researchers at engineering faculties are more likely to interact with the industry. To control the effect of academic discipline or university department, the dummy variable "faculty of engineering" (which takes the value of 1 if a university-scientist is employed at the engineering faculty, 0 otherwise) is included in the models.

To control the effects of factors motivating university scientist to interact with the industry is considerably important for policy design. There might be numerous factors that motivate individual nano-scientists to engage in KTT activity (question 4, see Appendix D); however not all of these motivations have a clear impact over the propensity of these scientists to engage in KTT activity. Identifying motivations or group of motivations which have a clear impact over the formation of university-industry linkages might be very useful in developing initiatives to support the conditions that motivate nano-scientists to engage in industry-related activities. Therefore, we capture the differences in terms of individual motivations to interact with the industry with two variables "motivations for commercialization" and "motivations for obtaining firm contribution". Since these variables are identified as a result of the factor analysis following PCA, they are continuous variables of predicted factor loadings (for details Section 7.4.6).

7.3 Descriptive statistics for profiling nano-scientists at Turkish universities

7.3.1 Academic discipline, experience and gender

Two-thirds of respondents are currently affiliated to natural science faculties of the universities. While one-quarter of the academics are employed at engineering faculties the rest equally distributed in medical science faculties and research institutes. As it can be expected there is a strong relationship between a scientist's faculty / scientific discipline and her having a linkage with the industry. Table 7.8 shows that while almost 55 percent of respondents who are affiliated to engineering faculties have an intense interaction with firms, more than half of the academics affiliated to natural sciences faculties do not engage in any form of KTT activity. Chi-square test indicates that there is a significant association between a nano-scientist's being engaged in KTT activity and the type of faculty she/he affiliated with.

Table 7.8 Percentage distribution of respondents by faculties

	Total	*KTT Activity=0*	*KTT Activity=1*
Natural Sciences	66.85	58.68	41.32
Engineering	25.41	45.65	54.35
Medical sciences[1]	3.87	71.43	28.57
Research Institutes	3.87	14.29	85.71
Chi-square test[2]	$\chi^2(3) = 7.65^{***}$		

[1]Medicine, pharmacy, dentistry
* p<0.1, ** p<0.05, and *** p<0.01

The average research experience of respondents which is measured by the number of years after the PhD completion is 15 years. The comparison of groups with and without KTT activity indicates that there is no significant difference between these two groups in terms of research experience (t-test, p=0.26). Table 7.9 shows that 38 percent of respondents have maximum 10 years of research experience and nearly 11 percent of them have more than 30 years of experience (Table 7.9).

Table 7.9 Respondents research experience by the periods of PhD completion

	Total (%)	*KTT Activity=0 (%)*	*KTT Activity=1 (%)*
1970s	10.56	31.58	68.42
1980s	15.00	55.56	44.44
1990s	36.11	56.92	43.08
2000s	38.33	57.97	42.03
Chi-square test	$\chi^2(3) = 4.53$		

* p<0.1, ** p<0.05, and *** p<0.01

[2] Chi-square test of indepence is used to test the null hypothesis that there is no statistical association between two categories (Conder and Foreman, 2009).

The respondents of the questionnaire are predominantly professors (45.3 percent). They are followed by associate professors (32 percent) and assistant professors (nearly 18 percent). It can be expected that as an indicator of academic success and experience title of the respondents exert a positive impact on the formation of KTT activity; however, according to Mann-Whitney U test, there is no evidence that academic title of the respondent significantly affects her/his tendency to interact with the industry (Table 7.10).

Table 7.10 Respondents by academic title

Academic Title	*Total (%)*	*KTT Activity=0 (%)*	*KTT Activity=1 (%)*
Prof.	45.30	52.44	47.56
Assoc. Prof.	32.04	62.07	37.93
Asst. Prof.	17.68	43.75	56.25
PhD	4.97	55.56	44.44
Mann-Whitney U test[3]		$z = 0.133$	

* p<0.1, ** p<0.05, and *** p<0.01

Almost three-quarters of respondents completed their PhD education in a Turkish university. Only 25 percent of the respondents have a PhD diploma from the foreign institutes which are mainly located in the USA or European countries (Table 7.11). However, chi-square test indicates that there is no difference between these two groups having PhD degrees from Turkish or foreign institutes in terms of their tendency to have a KTT link with the industry.

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[3] Mann-Whitney U test is a nonparametric test used to determine whether two independent samples are identical. Since it is a nonparametric test it does not require the assumption that populations are normally distibuted. Therefore it can be used with ordinal, interval or ratio data. The null hypothesis (H_0) tested by Mann-Whitney U test is that two population are identical (Anderson et al., 2005).

Table 7.11 Respondents by country of PhD diploma

PhD Diploma	*Total (%)*	*KTT Activity=0 (%)*	*KTT Activity=1 (%)*
From a foreign institute	25.41	52.17	47.83
From a Turkish institute	74.59	54.81	45.19
Chi-square test	$\chi^2(1) = 0.096$		

* p<0.1, ** p<0.05, and *** p<0.01

Table 7.12 shows that the respondents are predominantly male (72.4 percent). However, this ratio is almost the same with the share of males in our complete list of 703 nano-scientists affiliated to Turkish universities. Our research indicates that among Turkish NST academics males are dominant. However, there is no significant difference between males and females in terms of their tendency to interact with industry.

Table 7.12 Respondents by gender

Gender	*Total (%)*	*KTT Activity=0 (%)*	*KTT Activity=1 (%)*
Female	27.62	58.00	42.00
Male	72.38	52.67	43.33
Chi-square test	$\chi^2(1) = 0.41$		

* p<0.1, ** p<0.05, and *** p<0.01

7.3.2 Scientific production, research activities and funding

There is a significant variation in respondents' total number of scientific articles published in the last five years; it ranges from 3 to 438. The average number of scientific articles is almost 28 with a higher standard deviation (38.29). However, between the two groups of respondents with or without engagement in KTT activity there is no statistically significant difference in terms of total number of scientific publications ($t= 1.065$, $p>0.1$).

On the other hand, the average number of NST-related articles of respondents published in the last five years is nearly 8 (Table 7.13) but the deviation (standard deviation 6.2) in number of articles is not that much probably due to the stratified sampling strategy used in this study. Nonetheless, there is no significant difference between the groups of nano-scientists who engage with the industry and who do not in terms of the number of NST-related articles. However, the average share of NST-related articles in the total number of scientific publications is 41 percent (Table 7.13).

Table 7.13 Respondents' scientific productivity (averages)

Articles in SCI	*Mean*	*Std. Dev.*	*KTT Activity=0*	*KTT Activity=1*
Number NST articles	8.2	6.22	8.06	8.37
Total number of articles	27.82	38.29	30.61	24.53
Share of NST articles in total	0.41	0.24	39.03%	43.11%

The number of publicly funded research projects provides reliable information on the available resources for the individual researchers' scientific activities. The results indicate that nearly three-quarters of the respondents have engaged in at least one publicly funded research project (Table 7.14). While 67 percent of respondents have conducted one to five publicly funded research projects, almost 9 percent have accessed public funds with more than 6 research projects. On the other hand, chi-square test indicates that the groups with or without engagement in KTT activity significantly differ in terms of the number of publicly funded research projects. While only 33 percent of the nano-scientists who have no access to publicly funded research projects have engaged in KTT activity, 77 percent of those who carried out 6-10 publicly funded research projects have KTT link to private firms. Thus, it indicates that publicly funded research projects can be used as an effective policy tool to increase university-industry interactions.

Table 7.14 Number of publicly funded research projects by respondent

Publicly funded research projects	*Total (%)*	*KTT Activity=0 (%)*	*KTT Activity=1 (%)*
0	23.76	67.44	32.56
1-5	67.40	52.46	47.54
6-10	7.18	23.08	76.92
10 +	1.66	66.67	33.33
Chi-square test		$\chi^2(3) = 8.45^{**}$	

* p<0.1, ** p<0.05, and *** p<0.01

Educational activities, i.e. courses and thesis supervision, seem the most important time consuming academic activity for our respondents. On average, nano-scientists spend nearly half of their total weekly work hours for educational activities. While they spend 38 percent, on average, for research activities, 11 percent is spent for other activities i.e. administrative activities. Table 7.15 shows that the groups of academics who are engaged in KTT activity and who do not differ in the amount of time allocated for various academic activities.

A more detailed analysis of time allocated for research activities provides that while more than 70 percent of respondents allocate less than 40 percent of their weekly work hours for research activities, only 5 percent have a chance to spend more than 70 percent of their time for research. As expected the percentage of time spent for research activities significantly vary with the academic titles of respondents (one way anova test for equal variances, $F=12.26$, $p<0.001$).

Table 7.15 Share of respondents' time across various academic activities

Percentage of time spent for	*Mean*	*Std. Dev.*	*KTT Activity=0*	*KTT Activity=1*	*t-test*
Educational activities	0.51	0.013	0.51	0.52	-0.35
Research	0.38	0.013	0.39	0.38	-0.55
Other	0.11	0.009	0.10	0.11	-2.28

As indicated in Table 7.16 respondents predominantly fund their scientific research activities with government grants and internal funds provided by their universities; on average half of the respondents' research budget is met by government grants and 41 percent by internal resources provided by universities. However, data not reported here shows that there is no significant difference between nano-scientists employed at public and private universities in terms of the share of government research funds in their total research budget. While the share of internal university funds in total individual research budget is significantly lower among academics of private universities the share of international funding is significantly higher (26 percent). The results indicate that nano-scientists in private and public universities exhibit some significant differences in terms of their portfolios of funding resources.

Table 7.16 also provides that there is an association between the share of private funding in total research budget of a nano-scientist and her/his tendency to interact with the industry. Moreover the share of internal university funding in total research budget of nano-scientists significantly differs between groups of nano-scientists with and without KTT activity. While the share of private funding positively associates with university-industry KTT activity, internal university funding has a negative effect.

Table 7.16 Respondents' sources of funding

Research funding	*Mean*	*Std. Dev.*	*KTT Activity=0*	*KTT Activity=1*	*t-test*
Private funding	0.01	0.04	0.008	0.02	-2.41**
Public funding	0.50	0.33	0.47	0.53	-1.27
University internal funding	0.41	0.34	0.46	0.34	2.45**
International funding	0.07	0.17	0.05	0.09	-1.58
Other sources	0.01	0.04	0.01	0.01	-0.76

* $p<0.1$, ** $p<0.05$, and *** $p<0.01$

An analysis of the association between the shares of funding obtained from various resources in the total research budget of a nano-scientist and her/his being engaged in KTT activity provides that the share of private funding is strongly associated to the formation of informal and research-related university-industry links (Table 7.17). Our data (not reported here) shows that nearly 17 percent of NST academics have an access to private funds and almost 58 percent of those academics have a strong linkage to the industry.

Table 7.17 Respondents' sources of funding by the forms of KTT activity

Research funding	*INFORMAL = 0*	*INFORMAL= 1*	*t-test*
Private funding	0.007	0.03	-2.96***
Public funding	0.49	0.51	-0.36
University internal funding	0.47	0.35	1.90*
International funding	0.05	0.1	-2.18**
	RES=0	*RES=1*	*t-test*
Private funding	0.009	0.05	-4.34***
Public funding	0.50	0.52	-0.35
University internal funding	0.43	0.28	1.9*
International funding	0.06	0.14	-2.06**

* p<0.1, ** p<0.05, and *** p<0.01

7.3.3 NST-related academic activities

Respondents do not have a long experience in NST research. The mean value of NST experience is 7.15 years (Table 7.18). Nearly 54 percent of the respondents have mentioned that they have been involved in NST for five years or less. On the other hand, the share of respondents who have a minimum ten-year of interest in NST is around 14 percent. The results provide that there is a significant relationship between NST experience of respondents and their tendency to interact with the industry (t-test, p=0.66).

Table 7.18 Respondents' NST-related experience

NST experience	*Total*	*Std. dev.*	*KTT Activity=0*	*KTT Activity=1*	*t-test*
Years	7.15	0.4	6.48	7.96	-1.85*

The respondents are asked about the share of NST-related research in their total academic activities and responses are given on a five-point Likert scale (1: not very much and 5: very much). 42 percent of the respondents have mentioned that the share of NST in their whole academic activities is considerably high in comparison to 37 percent for whom NST is only a tiny part of their academic activities (Table 7.19). On the other hand, Mann-Whitney U test indicates that two groups of respondents with or without engagement in KTT activity significantly differ in terms of the share of NST in total academic activities. Hence, Table 7.18 and 7.19 indicate that doing more nanotechnology is associated positively with the university-industry KTT activity. The results confirm the importance of human capital in the formation of KTT linkages between nano-scientists and private firms. Nano-scientists who are more experienced and more intensively work on nanotechnology might probably have valuable human capital endowments and, a large network in the NST community (social capital).

Table 7.19 Percentage share of respondents by the intensity of NST-related research

Share of NST in total academic activities	*Total*	*KTT Activity=0*	*KTT Activity=1*
Not very much	18.33	78.79	21.21
Not much	18.89	64.71	35.29
Moderate	21.11	50	50
Much	26.11	40.43	59.57
Very much	15.56	39.29	60.71
Mann Whitney test		$z = -3.81^{***}$	

Applied research is proved to be important for the formation of university-industry interactions (i.e. Landry et al., 2007; Arvanitis et al., 2008). In order to measure the tendency of nano-scientists to carry out applied research and its impact on the university-industry interactions, respondents are asked about the extent to which their research meets the needs of industry. The responses are given on a five-point Likert scale (1: Not vey much; 5: very much). Table 7.20 shows that almost 63 percent of respondents have indicated that their NST research considerably meets the needs of the industry. However 18 percent of respondents deal with some sort of NST research which does not have industrial applications. Mann-Whitney U test provides strong evidence for the relationship between being engaged with the industry and applied research activities of respondents.

Furthermore, almost two-thirds of the respondents have mentioned that they have at least one completed research of which outcomes can be commercialized with some efforts; and two groups of academics with or without linkages with the industry significantly differ in carrying out scientific research with commercializable outcomes (chi-square, p=0.08).

Table 7.20 Industrial applicability of respondents' NST research outcomes (%)

How much meets the needs of industry	*Total*	*KTT Activity=0*	*KTT Activity=1*	*INFORMAL=0*	*INFORMAL=1*
Not very much	5.92	80	20	90	10
Not much	12.43	80.95	19.05	80.95	19.05
Moderate	18.93	46.88	53.12	50	50
Much	47.93	51.85	48.15	62.96	37.04
Very much	14.79	28	72	32	68
Mann Whitney test		$z = -3.31^{***}$		$z = -2.94^{***}$	

* p<0.1, ** p<0.05, and *** p<0.01

7.3.4 Networks of nano-scientists and their peers

Majority of the respondents have mentioned that they have a considerably intense relations with the other nano-scientists affiliated to Turkish universities. Nearly 68 percent of academics personally interact with other academics on an occasional or more frequent basis (Table 21(a)). Mann-Whitney U test provides that there is a significant relationship between a respondent's tendency to interact with the industry and the intensity of her/his relations with other nano-scientists employed at Turkish universities. Furthermore, respondents' having engaged with INFORMAL or RESEARCH-related forms KTT activities is strongly related to the intensity of their domestic academic links (Table 7.21(b)).

Table 7.21(a) Respondents by the intensity of relations with other nano-scientists in Turkish academia (%)

Intensity of relations with other academics in Turkey	*Total*	*KTT Activity=0*	*KTT Activity=1*
Never	8.29	66.67	33.33
Rarely	23.76	67.44	32.56
Sometimes	31.49	68.42	31.58
Frequently	29.28	37.73	62.27
Very frequently	7.18	0	100
Mann Whitney test		$z = -4.53^{***}$	

* p<0.1, ** p<0.05, and *** p<0.01

Table 7.21(b) KTT active respondents by the intensity of relations with other nano-scientists in Turkish academia (%)

Intensity of relations with other academics in Turkey	*INFORMAL =1*	*RES=1*
Never	26.67	6.67
Rarely	25.58	9.30
Sometimes	31.58	1.75
Frequently	50.94	15.09
Very frequently	84.62	61.54
Mann Whitney test	$z = -3.93^{***}$	$z = -3.5^{***}$

* p<0.1, ** p<0.05, and *** p<0.01

One-fourth of the respondents have no connections with the international academia. However half of the respondents have mentioned that they interact with nano-scientists from international academia on occasional or more frequent basis. Mann-Whitney U test shows that there is a significant difference between two groups of respondents with or without linkages with the industry in terms of their intensity of relations with the international academia (Table 7.22(a)). Similarly, a strong relationship exists between having engaged with INFORMAL and RESEARCH-related interactions with the industry and the intensity of international academic links (Table 7.22(b)).

Table 7.22(a) Respondents by the intensity of relations with nano-scientists in international academia (%)

Intensity of relations with international academia	*Total*	*KTT Activity=0*	*KTT Activity=1*
Never	26.52	72.92	27.03
Rarely	23.20	57.14	42.86
Sometimes	30.39	49.09	50.91
Frequently	15.47	39.29	60.71
Very frequently	4.42	12.50	87.50
Mann Whithey test		$z = -3.75^{***}$	

* p<0.1, ** p<0.05, and *** p<0.01

Table 7.22(b) KTT active respondents by the intensity of relations with nano-scientists in international academia (%)

Intensity of relations with international academia	*INFORMAL =1*	*RES=1*
Never	22.92	10.42
Rarely	38.09	4.76
Sometimes	40	5.45
Frequently	57.14	28.57
Very frequently	75	50
Mann Whitney test	$z = -3.4^{***}$	$z = -2.69^{***}$

* p<0.1, ** p<0.05, and *** p<0.01

However, the links between respondents and specialists employed at government agencies is not very strong. Nearly 42 percent of the respondents have mentioned that they have no connections with the specialists employed at government agencies. Only 28 percent of nano-scientists have interacted with those specialists on occasional and more frequent basis (Table 7.23). The test results provide that there is a strong relationship between a respondent’s intensity of interpersonal relations with specialists in governmental organizations and her/his tendency to interact with the industry (Mann-Whitney U test, p<0.001).

Table 7.23 Respondents by the intensity of relations with governmental organizations (%)

Intensity of relations with governmental organizations	*Total*	*KTT Activity=0*	*KTT Activity=1*
Never	41.99	67.11	32.89
Rarely	29.83	53.70	46.30
Sometimes	16.02	34.48	65.52
Frequently	9.94	38.89	61.11
Very frequently	2.21	25	75
Mann Whitney test		$z = -3.44^{***}$	

* p<0.1, ** p<0.05, and *** p<0.01

It is expected that peers have an influence on a university researcher's tendency to interact with the industry as examined previously in Section 7.3.3. This influence might be either in the form of social learning (i.e. scientists may learn how to interact with the industry from their peers) or in the form of benefiting from industrial networks of the peers. Therefore, the respondents are asked about how strong are their peers' relations with the industry; and responses are given on a five-point Likert scale. Nearly 60 percent of the respondents have mentioned that their peers' links with the industry are not strong. Only 14 percent of the respondents have peers with strong industrial linkages. However, Mann-Whitney U test provides that there is a strong relationship with an academics' tendency to interact with the industry and the intensity of her/his peers' KTT linkages with the industry (Table 7.24).

Table 7.24 Respondents by the strength of their peers industry links (%)

Intensity of peers' industrial links	*Total*	*KTT Activity=0*	*KTT Activity=1*	*INFORMAL=0*	*INFORMAL=1*
Not very strong	12.80	52.38	47.62	61.9	39.1
Not strong	47.56	60.26	39.74	65.38	34.62
Moderate	25.61	47.62	52.38	59.52	40.48
Strong enough	10.98	33.33	66.67	33.33	66.67
Very strong	3.05	20	80	20	80
Mann Whitney test		$z = -2.02^{**}$		$z = -2.19^{**}$	

* p<0.1, ** p<0.05, and *** p<0.01

7.3.5 University resources and capabilities

Nanotechnology is simply defined as the understanding and control of matter at dimensions between approximately 1 and 100 nanometers; and it needs special instruments (i.e. AFM and STM) and powerful computers. Therefore, the instruments, laboratories, devices and computational systems at universities are the keys for NST-related research. Moreover, since the use of these instruments requires special knowledge, competences and experiences, the presence of these instruments and laboratories at the universities is a good indicator of the NST-related human capital located at these universities.

Almost 60 percent of respondents have mentioned that there are NST-related research centers, research groups or laboratories at their universities (Table 7.25(a)). Chi-square test provides evidence for the strong relationship between having interactions with the industry and university's NST-related resources and capabilities (Table 7.25(b)). It also indicates that the groups of academics affiliated to universities where NST-related research centers, groups or laboratories exist are significantly differ in their tendency to engage in INFORMAL and RESEARCH-based interactions with firms.

Table 7.25(a) Respondents by their universities NST-related physical capabilities (%)

NST research center/group / lab.	*Total*	*KTT Activity=0*	*KTT Activity=1*
No	40.33	72.60	27.40
Yes	59.67	41.67	58.33
Chi-square test		$\chi^2(1) = 16.79^{***}$	

* p<0.1, ** p<0.05, and *** p<0.01

Table 7.25(b) Respondents engaging in INFORMAL or RESEARCH-related KTT activity and their universities' NST-related physical capabilities (%)

NST research center/group / lab/graduate prog.	*RES= 0*	*RES= 1*	*INFORMAL=0*	*INFORMAL=1*
No	95.45	4.55	78.79	21.21
Yes	83.48	16.52	50.43	49.57
Chi-square test	$\chi^2(1) = 5.63^{**}$		$\chi^2(1) = 14.14^{***}$	

* p<0.1, ** p<0.05, and *** p<0.01

46 percent of respondents who have mentioned that there is a NST-related research center, group or laboratory in their university have worked in at least one of these NST-specific organizations. The average period for working in these NST-specific organizations is 41.64 months or nearly 3.5 years. Moreover, chi-square test also indicates that there is a strong relationship between working in a NST-specific organization at universities and having interactions with the industry.

Some empirical studies (i.e. Thursby and Thursby, 2002; DiGregoria and Shane, 2003; Friedman and Silberman, 2003) provide evidence for the influence of university policies and strategies on the various forms of university-industry relations. To measure the support provided by university administrations to improve university-industry interactions respondents are asked about how much the administrations of their universities are supportive of KTT and responses are given in a five-point Likert scale. Table 7.26 shows that while 43 percent of respondents have mentioned that their universities support them in their relations with the industry nearly 38 percent find university administrations not very supportive. Mann-Whitney U test provides no evidence for the relationship between university support and the tendency of academics to engage interactions with the industry.

Table 7.26 Respondents by their universities' support for KTT activity

University Support	*Total*	*KTT Activity=0*	*KTT Activity=1*
Not much supportive	14.47	65.22	34.78
Not supportive	23.27	54.05	45.95
Moderate	18.87	50	50
Supportive	35.22	44.64	55.36
Much supportive	8.18	61.54	38.46
Mann-Whitney test		$z = -1.07$	

* p<0.1, ** p<0.05, and *** p<0.01

7.3.6 What motivates NST academics to interact with the industry?

Understanding why university scientists engage in university-industry KTT activity is important for the analysis of the formation of university-industry links. However, the number of empirical studies focusing on this issue is very limited. While some empirical studies provide evidence for the importance of royalty income as a motive for licensing-based university-industry interactions (Jensen and Thursby, 2001; Bercovitz and Feldman, 2008; DiGregoria and Shane, 2003), some argues that universities and individual academics engage with the industry to increase research funds (Meyer-Krahmer and Schmoch, 1998; D'Este and Perkmann, 2011).

Our results provide that most important motives for nano-scientists at Turkish universities to interact with the industry is related to increasing funds for research. Nearly 93 percent of respondents have mentioned that "providing industrial financial support for graduate students along their research" is important or very important to interact with the industry. On the other hand, for 92 percent of respondents "additional resources and funds for academic research" is important or very important to engage with the industry (Table 7.27).

In order to decrease the number of motivations influencing the decisions of NST academics to interact with the industry, a factor analysis following PCA is used. KMO measure and Bartlett's test of sphericity proves that our dataset is appropriate for factor analysis. With the principal component factor analysis with varimax rotation, we identified three final motivations for academics: (i) motivations related to academic duties; (ii) motivations related to commercialization of research results and (iii) motivations to obtain firm contributions for the improvement of research results (Table 7.28).

Table 7.27 Motivations of respondents to engage in university-industry KTT activity

Motivations to interact with the industry	*Not very important*	*Not important*	*Neither unimportant nor important*	*Important*	*Very important*
Providing industrial financial support for graduate students along their research	1.1%	2.4%	3.3%	46.7%	46.5%
Additional resources and funds for academic research	2.1%	3.5%	2.6%	38.4%	53.5%
Additional resources for the improvement of labs and technical equipments at universities	0.6%	4.9%	6.7%	42.0%	45.9%
Testing the academic research findings in practice	1.5%	4.1%	6.2%	57.3%	31.0%
New ideas from the industry for academic research	6.5%	4.9%	4.5%	62.7%	21.4%
Access to firms' equipments and technology	2.1%	6.2%	11.7%	46.5%	33.5%
Business opportunities for the commercialization of academic research findings	1.5%	7.0%	13.6%	46.9%	30.9%
Exchange of information and experience with firm researchers	1.1%	3.6%	18.8%	50.8%	25.7%
Additional insights and perspective from the industry to the technology field, product and / or findings	4.4%	7.3%	13.6%	55.0%	19.7%
Patenting academic research findings	1.1%	9.2%	18.8%	42.8%	28.1%
Licensing university patents	3.2%	9.1%	17.6%	46.5%	23.6%
Increasing job prospects for graduates	0.8%	5.3%	23.1%	44.0%	26.9%

Table 7.28 Principal component factor analysis of motivations for KTT activity

	Factor 1 Academic duties	*Factor 2 Commercialization*	*Factor 3 Industry contribution*
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**[1]		
Bartlett's test of sphericity	**1071.97** [2]		
Variance explained by each component	**6.33**	**1.23**	**0.92**
Proportion of variance explained by each component	**52.75%**	**10.25%**	**7.67%**

[1]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

[2]p-value= 0.000 (H_0 = Variables are not intercorrelated)

The comparison of the mean values of three groups of motivations (Table 7.29) indicates that there is a significant difference between two groups of academics who have linkages with the industry and who do not in terms of the mean importance of motivations related to academic duties and commercialization of research outcomes. Table 7.29 may indicate that nano-scientists with KTT linkages with the industry seem more sensitive to all three forms of motivations. For both groups of nano-scientists with and without KTT links with private firms the support (especially financial support) provided by firms to academic research conducted at universities is very important. While nano-scientists who have engaged in KTT activity have a higher motivation to commercialize their research results, those without KTT activity do not give much importance to motivations related the commercialization of research results. One STI policy implication of this result might be that nano-scientists without KTT linkages with industry can be motivated by some initiatives to increase financial support of the industry to academic research not by the initiatives related to commercialization of research outcomes.

Table 7.29 Three groups of motivations

Motivations	*Mean*	*Std. Dev.*	*KTT Activity=0*	*KTT Activity=1*	*t-test*
Academic duties	4.12	0.05	4.01	4.26	-2.50**
Commercialization	3.87	0.06	3.70	4.08	-3.24***
Firm contribution	3.93	0.06	3.83	4.04	-1.90*

7.4 Determinants of the formation of university-industry KTT links

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

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

Table 7.30 provides a brief definition of explanatory variables; and Table 7.31 shows descriptive statististics. Correlations between explanatory variables are given in Table 7.32 and finally Table 7.33(a) provides the estimation results. Models presented in Table 7.33(a) differ only in terms of including INDFUND or NPUBGRANT or both of these variables[4]. For three models 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 physical resources and organizational capabilities have significant effecta over individual scientists' proclivity to interact with industry.

[4] To examine the impacts of NPUBGRANT and INDFUND variables over the formation of KTT linkages between nano-scientists and private firms is important for this study due to some STI policy implications. However, we detected a multicollinearity problem between these variables and, therefore, we include them separately in Model 1 and Model 2.

Table 7.30 List of explanatory variables and their definitions

Variable	*Description*
EXP	Number of years between 2010 and the year of 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 7.28)
MOTIVEFIRM	Predicted factor loadings for motivations related to firm contribution (Table 7.28)
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 in Appendix B.

[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 7.31 Descriptive statistics for explanatory variables

Variable	*Variable Type*	*Obs.*	*Mean*	*Std. Dev.*	*Min.*	*Max.*
EXP [Research experience]	Continous	180	15.05	9.69	0	39
NSTPUB [NST publications]	Discrete	181	8.2	6.22	3	37
NPATENT [# of patents]	Discrete	181	0.51	2.01	0	20
NPUBGRANT [Publicly funded projects]	Categorical	181	0.87	0.6	0	3
INDFUND [Industry funding]	Continous	172	0.01	0.04	0	0.3
APPL [Applied research]	Ordinal	169	3.53	1.07	1	5
NTWK [Social networks]	Ordinal	181	3.03	1.07	1	5
PEER [Peer effect]	Ordinal	164	2.44	0.95	1	5
TOTCIT [Total citations]	Discrete	181	492.89	485.87	4	2260
INTCOLLAB [International links]	Continous	181	0.37	0.24	0.03	1.23
NSTINST [NST research inst./lab]	Dummy	181	0.6	0.49	0	1
UNIVSUPP [University support]	Ordered	159	2.99	1.22	1	5
MOTIVECOMM [Motiv. Commercialization]	Continous	173	2.57	0.96	0.08	4.42
MOTIVEFIRM [Motiv. Firm contribution]	Continous	173	2.97	0.93	-0.72	4.88
ENGINEERING [Faculty of Engineering]	Dummy	181	0.25	0.44	0	1

Table 7.32 Correlation table for explanatory variables

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

* Correlation is significant at 5%

** Correlation is significant at 1%

Table 7.33(a) Probit regression results: 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 7.33(b) Marginal 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)

7.4.1 Human capital and social capital of scientists

The number of NST-related publications of an invidual university-scientist correlates (NSTPUB) negatively and significantly ($p<0.1$) with her/his propensity to engage in KTT activity. Negative but significant coefficients on the discrete variable of publication numbers indicates that university scientists with higher number of NST publications have a lower probability of interacting with the industry. Table 7.33(b) 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 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 1A. Among previous studies, while Lowe and Gonzalez-Brambila (2007) and Stuart and Ding (2006) provide evidence for the positive impact of the number of publications on academic entrepreneurship, Landry et al. (2007) and Haeussler and Colyvas (2011) demonstrate that number of publications positively affect the tendency of university scientists to interact with the industry. Zucker et al (1998a), on the other hand, suggest that in biotechnology as well as in nanotechnology (Darby and Zucker, 2004) scientific knowledge is mainly tacit embodied in individual scientists and, therefore, interacting with star scientists with higher number of publications improve firms' innovation capacity.

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. While scientific production system and the role of universities in the society is changing the academic reward system is also changing (Etzkowitz et al., 2000), especially in advanced countries; patents or disclosures have become additional indicators of academic success. However, the number of publications is still the fundamental indicator of academic success and reputation; and patent numbers cannot supplement but instead support the role of publications. Meyer (2006a) and Azoulay et al. (2009) provide evidence for the positive impact of patenting on publications.

On the other hand, in Turkey the influence of the academic reward system, which is simply based on the number of publications, is crucial. 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 breakthrough discoveries aimed to increase their international publications rather than for improve their relations with the industry. On the other hand, a high number of NST articles might be a consequence of intensive basic research rather than applied research and, therefore, nano-scientists who have high numbers of NST articles relying on basic research would not able to engage in KTT activity due to the nature of their research. Thus, if it is the case, the number of NST-related articles of a nano-scientist is expected to be correlated negatively with her/his proclivity to engage in KTT activity.

Table 7.33(a) 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 7.33(b)) 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. Hence, we cannot reject the hypothesis 3A indicating that the greater the number of patents of a nano-scientist is the higher is her/his likelihood to engage in KTT activity.

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. Together with the estimation results for NSTPUB, we can suggest that not star scientists with higher number of scientific publications but 'inventor-authors' who both publish and patent have a higher tendency to interact with firms. Average number of publications among patent holding nano-scientists in our sample is around 10. 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 impact (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 7.33(b) demonstrate that an additional point 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 4A: 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 association 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 7.33(b) 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 by the STHC approach in the sense that nano-scientists who are highly engaged in publicly funded research projects deal more with research activities than other university-scientists and have access to new knowledge resources and networks. Hence, all of these opportunities help nano-scientists to improve their human capital endowments.

Estimation results for the influence of the intensity of personal contacts with other nano-scientists at Turkish universities support our hypothesis 7A 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 7.33(a) 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 7.33(b) 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.

Finally, estimation results in Table 7.33(a) indicate that research experience of a nano-scientist (EXP) has no significant impact on her/his tendency to interact with industry. Experience is a good indicator of human and social capital of individual scientists and, therefore, it is widely used in the empirical literature to measure individual skills, competences and know-how. Moreover, there are number of studies which provide strong evidence for the positive and significant impact of experience or seniority on the formation of university-industry relations (Landry et al., 2007; Boardman, 2008; Boardman and Ponomariov, 2009; Link et al., 2007; Haeussler and Colyvas, 2011; Azagro-Caro, 2007). However, our research results do not support the hypothesis 1A which indicates that the greater the research experience of a nano-scientist is, the higher is her/his likelihood to engage in KTT activity.

7.4.2 Peer effect

Although recent studies suggest that social learning 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 7.33(a) 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 percentage point (Table 7.33(b)). 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 (PEER) and the formation of KTT linkages is not very strong. Our results provide only a very weak evidence to support the hypothesis 8A.

7.4.3 Organizational resources / capabilities

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 (Table 7.33 (b)) also state that the presence of nano-equipments at universities increases the probability of a nano-scientist's being engaged in KTT activity by 27.8 – 32.5 percentage point. Hence, our study provides strong evidence to support hypothesis 9A 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.

The essence of nanotechnology is to observe, control and manipulate the entities at the nanoscale which can merely be sensed by special microscopies, devices and powerful computer programs. Therefore, physical resources in the form of laboratories or centers equipped with special nano-devices are the key for universities and academics to have accumulated NST knowledge. The presence of equipments has a considerable impact on the formation of university-industry relations due to the demand comes from firms to use these equipments for test and analyses in the innovation process. Hence, these results create some important policy implications with applicable strategies to improve university-industry interactions in the NST field.

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 (Table 7.33(a)). Therefore, our results provide a weak evidence to support the hypothesis 10A and reject the hypothesis 11A which indicates that the higher the number of international links per NST publication is the greater is the likelihood of a university-scientist employed at this university to engage in KTT activity.

In this research, we use two variables (TOTCIT and INTCOLLAB) to measure the research quality of universities which mostly coincides in the empirical literature with human capital resources of universities. Although the results are confusing in some extent, 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 probably 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 7.33(b) 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 percentage point. 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)

7.4.4 Control variables

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.

On the other hand, we are aware of the reverse causality problem related to some variables (i.e. NPATENT, INDFUND or APPL). For instance, in our models, the number of patents (NPATENT) is included as a factor explaining the presence of a nano-scientist's link to private firms but it might be a consequence. In other words, a nano-scientist might produce more patents due to the fact that she/he has stong ties with the industry. However, due to the limitations of the cross-sectional study we could not deal with this problem.

In summary, the estimation results provide strong evidence supporting the hypotheses 3A (NPATENT), 4A (APPL), 7A (NTWK), 9A (NSTINST) and 12A (UNIVSUPP); and considerably weaker support for the hypotheses 6A (NPUBGRANT) and 10A (TOTCIT). However, the effect of a nano-scientist's number of NST publications (NSTPUB) and university's international links (INTCOLLAB) are statistically significant but in the opposite direction of that we hypothesized (hypothesis 2A and hypothesis 11A respectively). Additionally, our results do not support hypotheses 1A, 5A and 8A.

Hosmer-Lemeshow statistic (Table 7.33(a)) suggests that the model does fit well (p>0.1). However, McFadden R^2 provides very limited information for measuring fit. As emphasized in Section 6.1, pseudo-R^2 measures for non-linear models with categorical variables are different from R^2 measures used in OLS. In our case, it is better to assess the goodness-of-fit for our models within the context of theoretical framework used, past research and estimated parameters of the model.

Hence, our results indicate that first, our model largely explains the factors influencing the formation of KTT links between university nano-scientists and firms; and second, both individual human and social capital characteristics of nano-scientists; and university's organizational resources and capabilities influence the propensity of nano-scientists to engage in university-industry KTT activity.

Our sampling strategy is based on disproportionate stratified sampling. The total population of 703 nanoscientists is divided into two groups; Group 1 includes nanoscientists with 8 or more number of nanoscience and nanotechnology articles and Group 2 includes nanoscientists with 3 to 7 articles. Due to our sampling strategy, Groups 1 nanoscientists have higher probability of selection than those in Group 2. Therefore, the binary probit estimations are repeated for each group separately. The results indicate that number of patents (NPATENT) has no significant impact on the proclivity of Group 1 nanoscientists to engage in KTT but has a significant and positive coefficient for Group 2 nanoscientists. While industrial funding (INDFUND) has a significant and positive impact on the formation of KTT links between Group 1 nanoscientists and firms; it has no impact over the propensity of Group 2 nanoscientists to interact with firms. Similar differences are also observed in explanatory variables related to public grants (NPUBGRANT) and the degree of being engaged in applied research (APPL). However, the numbers of observations are very small in each group to establish reliable estimations of the probabilities for nanoscientists to engage in KTT activity. The estimation results are provided in Appendix G.

7.5 Determinants of the formation of university-industry INFORMAL KTT links

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 7.5) activity we use probit regression analysis. The basic statistical model to be estimated is as follows:

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

Table 7.34(a) provides the estimation results. Three models presented in this table differ only in terms of including INDFUND or NPUBGRANT or both of these variables. For these three models a number of variables related to individual and organizational resources / capabilities have statistically significant effects. At first glance, it can be argued that, on the individual side, number of NST-related publications and patents, doing applied research, the percentage of industrial fund in total research budget and having an intense relationship with other nano-scientists at Turkish universities influence the tendency of university nano-scientists to engage in INFORMAL KTT activity. On the other hand, university's physical resources and organizational capabilities have significant effect over individual scientists' proclivity to interact with industry through INFORMAL channel.

Table 7.34(a) 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 7.34(b) Marginal effects[6]: INFORMAL KTT Activity

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

7.5.1 Human capital and social capital of scientists

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 (hypothesis 2B). 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 7.34(b)).

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 7.34(b)) 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 7.34(a) 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 7.34(b) 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 7.34(a) 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 7.34(b) 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 7.34(b) 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 7.34(a) 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. Hence, for hypothesis 1B our estimation results provide no support.

7.5.2 Peer effect

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.

We hypothesized earlier that a university nano-scientist with peers who have stronger industrial ties has a greater tendency to engage in INFORMAL KTT activities. However, only Model 1 provides support for the relationship between peer effect and the formation of INFORMAL KTT linkages. Therefore, we have very limited evidence to support the hypothesis 8B.

7.5.3 Organizational resources / capabilities

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. Therefore, the estimation results (Table 7.34(a)) provide strong support for the hypothesis 9B which indicates that a nano-scientist employed at the university with nano-equipments (research centers, labs, working groups) is more likely to engage in INFORMAL KTT activity.

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. Hence, we can reject the hypothesis 11B which indicates that the higher the number of international links per university's NST publication is, the greater is the likelihood of a nano-scientist employed at this university to engage in INFORMAL KTT activity. 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 7.34(b) 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.

7.5.4 Control variables

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.

In summary, the estimation results generated by three models provide evidence that support hypotheses 3B (NPATENT), 4B (APPL), 5B (INDFUND), 7B (NTWK), 9B (NSTINST), and 12B (UNIVSUPP); and offers considerably weaker support for the hypotheses 8B (PEER) and 10B (TOTCIT). On the other hand, we reject the hypotheses 1B (EXP), 2B (NSTPUB), 6B (NPUBGRANT) and 11B (INTCOLLAB). Thus, these results suggest that both individual human and social capital characteristics of nano-scientists and university's organizational resources and capabilities influence the propensity of nano-scientists to engage in university-industry INFORMAL KTT activity.

7.6 Determinants of the formation of university-industry RESEARCH-related KTT links

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:

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

Table 7.35(a) provides the estimation results. Three models presented in the table differ only in terms of including INDFUND or NPUBGRANT or both of these variables. For three models a number of variables related to individual and organizational resources / capabilities have statistically significant effects. At first glance, it can be argued that, on the individual side, number of patents, percentage of industrial fund in total research budget and having an intense relationship with other NST academics in Turkey influence the tendency of university nano-scientists to engage in RESEARCH-related KTT activity. On the other hand, university's physical resources have a positive and significant effect over individual scientists' proclivity to engage in RESEARCH-related forms of KTT activity.

Table 7.35(a) 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 7.35(b) 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)

7.6.1 Human capital and social capital of scientists

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 7.35(a) 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 7.35(b) 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. Hence, our research does not support the hypotheses 6C and 1C respectively.

Moreover, the estimation results do not support the hypothesis 8C which indicates that a nano-scientists with peers who have stronger industry links (PEER) have greater propensity to engage in RESEARCH-related KTT activity. In other words, the strenght of a scientist's peers' industry links has no impact on her/his propensity to engage in RESEARCH-related KTT activity. Hence, no peer effect or social learning effect is detected.

7.6.2 Organizational resources / capabilities

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. Therefore, the estimation results (Table 7.35(a)) provide strong support for the hypothesis 9C which indicates that a nano-scientist employed at the university with nano-equipments (research centers, labs, working groups) is more likely to engage in RESEARCH-related KTT activity.

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 7.35(a) 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. Hence, we can reject the hypothesis 11C which indicates that the higher the number of international links per a university's NST publication is, the greater is the likelihood of a nano-scientist employed at this university to engage in RESEARCH-related KTT activity. 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.

7.6.3 Control variables

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.

In summary, the estimation results provide evidence to support hypotheses 3C (NPATENT), 7C (NTWK) and 9C (NSTINST); and considerably weaker support for the hypothesis 10C (TOTCIT). However, our results do not support for the rest of the hypotheses. Thus, these results suggest that our model is considerably successful in explaining some individual and organizational-level factors which influence the formation of RESEARCH-related KTT activity between university nano-scientists and firms.

7.7 Conclusions and implications of the research

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. Among those channels INFORMAL interactions are the most common one. Nearly 87 percent of nano-scientists mention that they interact, to some degree, with firms through informal-interpersonal links. On the other hand, almost 40 percent of respondents engage in KTT activity frequently or very frequently through the INFORMAL channels. The second most common form of interaction among university nano-scientists to engage in KTT activity is RESEARCH-related activities. Almost 65 percent of respondents mention that they work with firms, even rarely, in collaborative or contract-based research projects or for special nanotechnology-related tests and analyses. However, only 12 percent of respondents use RESEARCH-related KTT activities intensively in their relations to industry. Moreover the share of nano-scientists who frequently or very frequently interact with firms as paid consultants (CONS) is around 9 percent. Nearly 7 percent of nano-scientists explain that their relation with industry is based on direct commercialization of research results (COMM), i.e. joint patenting with private companies; licensing and starting up a new firm.

On the other hand, the nature and quantity of knowledge flowing through each channel might vary. For instance, the quality and quantity of knowledge passing through INFORMAL channels or RESEARCH-related channels would not be similar. RESEARCH-related channels of interactions are useful in the mobilization of tacit knowledge embodied in university-scientists; however, INFORMAL channels ensure continuous information flow, and therefore, decrease information asymmetry between universities and firms but cannot be very useful in mobilizing tacit knowledge embodied in individuals. Since each channel of interaction provides different advantages, for a holistic improvement in university-industry relations STI policies should support the use of different forms of channels by university-scientists, and ensure the diversity in KTT channels.

The results obtained about the diversity of university-industry relations have some STI policy implications. First of all, in Turkey, discussion on university-industry interactions is centred upon technoparks or technology development zones; and other formal channels of technology transfer. Although they are important in the improvement of university-industry interactions, our research indicates that knowledge mostly flows through informal and interpersonal relations between universities and firms. University-scientists use indeed various channels for knowledge transfer. The role of formal, contract-based relations is very limited; for instance, the share of nano-scientists who engage in direct transfer of technology (i.e. joint patents, licensing and start-ups) to the industry is only 7 percent. Hence, STI policies designed to improve university-industry relations in the field of nanotechnology should consider that knowledge flows between universities and firms through various channels.

On the other hand, from a STI policy perspective knowing who, at universities, interacts with industry has some important conclusions. Our data suggests that there are both individual and organizational level factors influencing the proclivity of nano-scientists at Turkish 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) with higher number of patents /patent applications 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.

Our research provides a profile of boundary spanners[8] who are connecting universities and firms through various channels. These boundary spanners, even though not all of them actively collaborate with firms in their innovative R&D projects, are important to mitigate the information asymmetry between academia and industry; and moreover to acquaint the firms about the new technologies and research outcomes produced at universities. Hence, increasing the number of boundary spanning university nano-scientists will enhance the flow of knowledge between universities and firms; and in turn increase the innovative collaborations between academia and industry; and technology transfer from universities to firms.

Herein, this research has some further STI policy implications. First, the conclusions of this research suggest that policies and strategies aiming to increase the number of boundary spanners should be designed from a holistic perspective including both individual and organizational level factors. For example, our data demonstrates that not "star scientists" of nanotechnology with very high number of scientific publications but "inventor-authors" with higher number of patents / patent applications are the ones who engage in university-industry KTT activity.

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[8] Boundary spanners are key individuals in organizations who are well connected externally and internally. These individuals are also familiar with the language and concepts used outside their organizations, and hence play a critical role in knowledge transfer from and to their organizations.

Therefore, STI policies should design initiatives to encourage individual nano-scientist to patent more; and also to start some organizational arrangements within the universities to support university-scientists in legal problems occurring during the patent application process; to decrease paper work; to advertise university patents to firms; and, hence, enhance the communication between nano-scientists and firms.

Nothwithstanding, there are government strategies to improve patenting activities. For this aim, providing financial support for individual patent applications is used as a policy tool by by TUBITAK. However, this program is not specific to university-scientists but provided to all firms and individuals. It seems not encouraging, at least for now, to increase the number of patenting university-scientists in Turkey. On the other hand, in recent years, a few universities have attempted to establish special organizations to increase the number of university patents. For example, Gazi University has established an office for supporting university scientists in their patent applications; in Middle East Technical University and in Hacettepe University TTO-fashion offices have been established by the managing firms of university technoparks. On the other hand, Sabanci University founded Inovent which was the first technology commercialization office to be established in Turkey. Inovent is specialized "in development, commercialization and management of intellectual properties developed by universities, research institutions, technology companies and entrepreneurs"[9]. Moreover, the firm also functions as venture capital; Inovent Seed Fund was established in 2009 to make direct investments in technology start ups in Turkey. However, since these organizations are very recent, its impact is very limited at least for today.

Herein, strategies and science policy tools to support the formations of innovative organizational arrangements might be useful to increase the number of inventor-authors in nanotechnology field. For example; TTO-fashion organizations might be helpful to university-scientists to deal with the paper-work and legal

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[9] Information is accessed via www.inovent.com

problems occur in the patenting process; or to encourage university-scientists to disclose their inventions for patenting. However, much more than the mere existence of TTO-fashion organizations is required for this job; for instance, enhancing research capacities at universities and convincing university-scientists to disclose their discoveries for patenting rather than publishing are among some of the changes needed. Hence, such changes may be helpful to increase the number of university-scientists who patent and publish and, hence, KTT links between university-scientists and private sfirms.

Second, this research confirms that university support provided to nano-scientists during the formation of relations with firms and in cases where some problems in university-firm relations occur, plays a significant and positive role in university-industry relations in nanotechnology. In other words, universities providing administrative support to their nano-scientists encourage the formation of KTT linkages. From a STI policy perspective, this result indicates a need for intermediaries or interfaces on the university side. Due to cultural and organizational differences between academia and industry, the formation of linkages and finding solutions to the problems that might occur during this process are expected to be time-consuming for university-scientists and, therefore, demotivate them from pursue relations. Although administrative support plays an important role in university-industry interactions, only in a few universities this kind of intermediaries or interfaces exists. Hence, design of such interfaces on the university side might facilitate as catalyzer to improve relations between university nano-scientists and firms. These interfaces should not be necessarily formal organizational arranagements like TTOs, technology managers or research managers working on the half of universities might also intermediate firms and university-scientists. Such managers who are experienced in working with firms and university-scientists and knowledgeable in technologies as subjects of KTT activity might be able to support university-scientists and improve KTT between universities and firms.

Third, an important point from a STI policy perspective is that the quality of university research in nanotechnology negatively correlates with the propensity of individual nano-scientists to engage in KTT activity. As we discussed before, this might be a consequence of academic reward system and the prevailing academic culture in which scientific publications are overvalued while efforts spent for KTT activity are appraised as hampering academic performance. Some modifications in the academic reward system in order to encourage university-scientists to engage in KTT might play a key role in changing of this culture. For example, contract-based KTT activities, joint-patenting or licensing efforts of university-scientists might be rewarded with more weight for academic promotion to improve their relations to industry.

In summary, this research provides meaningful findings concerning the factors affecting nano-scientists affiliated to Turkish universities to engage in KTT activity; and moreover these findings have some STI policy implications we have discussed above. However, one last point is needed to be emphasized: universities and firms are different organizations with different cultures, reward systems, different objectives and responsibilities; and they should be kept as different entities; expecting universities to imitate firms hampers diversity in society; and it has some social and economic consequences. Therefore, university scientists in nanotechnology should be supported for conducting exploratory research for the sake of diversity, especially in the emerging field of nanotechnology; but new organizational arrangements and policy initiatives should be designed to increase the number of boundary spanning nano-scientists. A substantial increase in boundary spanners will mitigate the information asymmetry between academia and industry; enhance continuous flow of knowledge; improve relations and, hence, encourage collaborative research and technology transfer. However, KTT activity is not an issue limited to university nano-scientists; firm resources, culture and innovative capacities play a key role in university-industry relations. The following chapters will discuss the factors influencing firms' proclivity to engage in KTT activity with universities.

CHAPTER 8

FACTORS INFLUENCING NANO-TECHNOLOGY FIRMS IN THEIR RELATIONS WITH UNIVERSITIES: A QUALITATIVE INVESTIGATION

In this chapter, information collected through in-depth interviews is used to understand various individual and organizational level factors which influence those firms develop or use nanotechnology in their product and processes to engage in KTT with universities. Qualitative research methods used in this research provide flexibility to deal with the different features of firms and to analyze the collected data at different levels; i.e. individual and organizal levels. From a general perspective, interviews and observations made during the interviews indicate that there are various factors influencing a firm’s decision to interact with universities and the continuity of these relations. However for the sake of the research we consider the factors which influence 21 firms we interviewed in their relations with universities.

Section 8.1 provides a general perspective on interviewed firms. First, we focus on Group A firms from various sectors with more than 50 employees; then some descriptive information about start-up firms (Group B) is presented. In Section 8.2, the factors influencing firms to engage in KTT with universities are discussed. Among these factors the influences of the social connectedness and human capital of firm researchers on KTT activity are explored in subsections, 8.2.1 and 8.2.2. The influence of organizational capabilities of firms is examined in subsection 8.2.3. This is followed by the discussions on how start-ups function as intermediaries between universities and large-established firms. Subsection 8.2.5 examines why firms interact with universities and 8.2.6 examines the most commonly mentioned obstacles to university-industry interactions by firm managers. Section 8.3 concludes the chapter and provides some STI policy implications of the research.

8.1 Profiles of nanotechnology firms in Turkey

Nanotechnology firms interviewed in this research includes both large-established firms from various sectors and start-ups. All start-up firms deal with nanoscale R&D; on the other hand, most of the large-established firms collaborate with universities or other firms (mostly start-ups) to improve their products by using nanotechnologies. However, three of these large-established firms transferred an on-the-shelf nanotechnology from an international company and, therefore, their nanoscale R&D activity is limited in comparison to others. These three firms have commercialized nanotechnology products on the market.

As in the methodology chapter (Chapter 6.2), firms under investigation are separated into two groups: Group A and Group B. Large-established firms with more than 50 employees are included in Group A. Although some of these firms carry out some nanotechnology-related R&D, their core competence is not nanotechnology but they have other sector-specific competences such as chemicals, ceramics, electronics or textile-related technologies. However, half of these eight large incumbent firms hire researchers who are educated or experienced in nanotechnology research; and these researchers spend a considerable amount of their time for nanotechnology R&D and collaborative research activities. Among these firms, only two have necessary equipments and devices for nanotechnology-related R&D; others use mostly university labs for test, analyses or other research-related needs. All Group A firms have at least one new product improved by nanotechnology but two of them have not launched these products into the market yet due to the uncompleted R&D efforts. Table 8.1 provides a general overview of interviewed Group A firms.

Table 8.1 Overview of interviewed Group A firms

Firm Code	***Industry***	***Share in total sales of the sector's Fortune 500 firms***	***Nano-enhanced product in the market***	***Sources of nanotechnology knowledge***	***The strenght of relations with universities***
A1	Textile	-	Yes	Internal firm resources & collaboration with universities	Firm interacts with universities in various ways, i.e. research collaborations, informal relations / contacts, consultancy; moreover utilizes knowledge spillover from universities through following academic publications/research
A2	Textile	30.2 %	Yes	Internal firm resources & collaboration with universities	Firm interacts with universities in various ways, i.e. research collaborations, informal relations / contacts, consultancy, providing financial support for university students, internship programs for university student; moreover utilizes knowledge spillover from universities through following academic publications/research
A3	Textile	-	Yes	External resources; technology is transferred from a foreign company	Firm interacts with universities only through informal relations / contacts; meetings; conferences.
A4	Ceramics	-	Yes	External resources; technology is transferred from a foreign company	Firm has considerably strong relations with universities in the field of core competence but not in the field of nanotechnology. In this field relations are limited with informal relations/contacts; conferences; meetings etc.

Table 8.1 (cont'd) Overview of interviewed Group A firms

Firm Code	*Industry*	*Share in total sales of the sector's Fortune 500 firms*	*Nano-enhanced product in the market*	*Sources of nanotechnology knowledge*	*The strenght of relations with universities*
A5	Electrical equipments	4.07 %	Yes	External resources; technology is transferred from a foreign company	Firm has very strong relations with universities in the field of core competence but not in nanotechnology. In this field relations are limited with informal relations / contacts; reviewing academic publications; sponsorship for research and events.
A6	Food	11.52 %	R&D	External resources; mainly universities in Turkey	Firm interacts with universities in various ways, i.e. research collaboration, informal relations / contacts, consultancy; moreover utilizes knowledge spillover from universities through following academic publications /research
A7	Chemicals	23.43 %	R&D	Internal firm resources	Firm interacts with universities in various ways; i.e. informal relations / contacts, co-publications, allowing university researchers to use firm's equipments and lab; moreover utilizes knowledge spillover from universities through following academic publications /research
A8	Electronics	46.07 %	Yes	Internal firm resources & collaboration with universities, and other firms located either in Turkey or abroad	Firm interacts with universities in various ways; i.e research collaboration, informal relations / contacts, consultancy, supporting master students in their thesis projects; moreover utilizes knowledge spillover from universities through following academic publications /research

The relations of Group A firms with universities and characteristics of these relations differ from one firm to another. The variety in university relations will be discussed in the following section but, in general, it can be mentioned that all firms more or less have a certain level of relations with universities. The most common form of relations with universities and academics are informal relations or interpersonal contacts. Firm researchers and university scientists generally meet with each other and exchange knowledge in conferences, meetings and seminars; and firms use these informal linkages for having access to external knowledge produced at universities. Educational backgrounds of firm managers are another underlying factor influencing the presence and the extent of informal / interpersonal contacts. Firm researchers / managers use their links with their professors or classmates who are now hired at universities. Research-related collaborations are also common among Group A firms. Half of the firms collaborate with universities in the nanotechnology-related products developments; test and analyses.

On the other hand, Group B firms are start-up firms or small R&D firms. The size of these firms varies from 2 to 30 employees. These firms are simply R&D firms conducting nanotechnology-related research and new product development. Group B firms are further split into two small groups - Group B1 and Group B2 - firms on the basis of the founders' direct linkages to the academia.

Group B1 includes 7 firms which were founded or partnered by an academic-entrepreneur. An interesting point about these firms is that although, at first, they were founded to commercialize the knowledge of the nano-scientists or a technology developed by the nano-scientist most of these firms have become, in time, R&D firms. Hence, R&D activities of these firms are now considerably different from the academic research of their founders or partners. Five of these seven firms have their own R&D researchers and engineers focusing on the specific R&D activities of the firm. Nonetheless, academic founders or partners of these firms ensure organic and strong relations of these firms to the universities. Due to the law regulating the formation of firms in Technology Development Zones, the academics are only allowed to start a firm in these zones which are very close to the universities. Although academicians can start a firm in any of these zones, they generally prefer to be in the zone very close to the university they are affiliated with. Among B1 firms, only two firms have academic partners who are affiliated to the universities out of the firms' region. Therefore, the position and the relations of the academic-entrepreneur with other university-scientists become considerably important in the relations with the university and also other firms. Because of these special features, firms founded by academic-entrepreneurs are separately classified.

In Group B2, there are start-up firms which focus primarily on nanotechnology R&D and are founded by techno-entrepreneurs who do not have any current affiliation to the universities. In this group there are 6 firms. Although the founders or partners of these firms are not university-scientists most of them have very strong ties to the universities. One reason might be that five of these firms are located in technology development zones nearby universities; and most of their founders / managers have strong academic backgrounds.

Almost half of Group B firms (6 firms) develop nanomaterials, or in other words, nano-coating technologies which make the layers they are applied to hydro-phobic (water resistant); oleo-phobic (oil-resistant); easy to clean; fire-resistant, UV resistant; anti-fungal/bacterial, etc. Among the other interviewed firms two have a nano-biotechnology focus; and five work on the development of nanotechnology instruments /equipments /devices. Hence, most of these firms produce intermediary products (nanomaterials or nanoinstruments) for large scale manufacturing firms from various sectors. Since Group B firms do not have physical or financial resources required for the high volume manufacturing of nano-enabled products, these firms need to sell the knowledge and technology they develop to large manufacturing firms. Table 8.2 and Table 8.3 provide some information about Group B1 and Group B2 firms.

Another point, which should be emphasized about Group A and Group B firms, is about their access to the public funds. Interviewees from three Group A firms mention that public funds are intensively utilized for nanotechnology innovation projects. Moreover they emphasize that public funds are very important to convince the top management of firms to start a nanotechnology related projects. Due to the uncertainty in nanotechnology R&D projects, public funds enable firms to overcome some uncertainty about the results of the projects and encourage them to spend time and effort for nanotechnology-related innovations. Interviews suggest that 4 of 8 Group A firms and 7 of 13 Group B firms use public funds intensively in their nanotechnology-related R&D projects.

Table 8.2 Overview of interviewed Group B1 firms

Firm Code	***Nano-focus***	***Level of dev.***	***Nanotechnology R&D activity***	***The strenght of relation with universities***
B1-1	Material	R&D process	Developing functional nano-coatings and application to various layers	Not only the founder of the firm but also other R&D workers in firm have PhD degrees and strong organic relations with the university. In some projects for industrial firms the firm hires other university-scientists as paid consultants. Firm also use university laboratories and equipments.
B1-2	Instrument	On market	Developing instruments for nanoscale research and applications	Although the founder of the firm is a nano-scientist, the firm does not have very strong relations with universities. The firm's connection with universities is mostly limited with laboratory use, test and analysis. On the other hand, universities are among the firm's customers because these instruments are also used in university nanotechnology labs.
B1-3	Instrument	On market	Developing instruments for nanoscale research and applications	Except informal relations of the founders and two R&D workers the connections to the universities is very limited. The firm collaborates with only one university-scientist in R&D projects. However universities are among the firm's customers because these instruments are also used in university nanotechnology labs.

Table 8.2 (cont'd) Overview of interviewed Group B1 firms

Firm Code	*Nano-focus*	*Level of dev.*	*Nano R&D activity*	*The strenght of relation with universities*
B1-4	Nanobio	On market	Gene transfer and biosensors	Not only the founder of the firm but also R&D manager and workers in firm have strong organic and informal relations with the university. In some projects for industrial firms the firm hires other university-scientists as paid consultants. Firm also use university laboratories and equipments.
B1-5	Material	On market	Developing functional nano-coatings and application to various layers	Firm is founded by a number of entrepreneurs and investors including nano-scientists. The nanotechnology used by the firm was mainly developed at a university laboratory. The firm still has very strong connections with the university in which it emerged, but relations with other universities are very limited.
B1-6	Material	R&D process	Developing functional nano-coatings and application to various layers	Firm is founded by two nano-scientists who have strong organic and informal relations with universities. In some projects for industrial firms the firm hires other university-scientists as paid consultants. Firm also use university laboratories and equipments.
B1-7	Material	On market	Developing functional nano-coatings and application to various layers	Firm is founded by industry and university scientists. The founders have strong organic and informal relations with universities. In most of the projects for industrial firms the firm uses its own resources only and apply to universities only in cases they need further research or consultancy. Since firm has its own laboratories and equipments, university laboratories and equipments are only accessed in rare cases.

Table 8.3 Overview of interviewed Group B2 firms

Firm Code	***Nano-focus***	***Level of development***	***Nano R&D activity***	***The strenght of relation with universities***
B2-1	Instrument	R&D process	Developing an instrument for medical usage	The firm is founded by two techno-entrepreneurs who are at the same time PhD students. They have informal relations with universities in which they study; and they also use universities to access laboratories and nanotechnology equipments.
B2-2	Instrument	R&D process	Developing instruments for nanoscale research and applications	The firm is founded by three techno-entrepreneurs. The nanotechnology which is used by the firm was originally created by the entrepreneurs at the university laboratory during their graduate education. The firm has informal, personal relations with nano-scientists and use laboratories and other nano-equipments of the university in which they are located.
B2-3	Nanobio	R&D process	Biosensors	The firm is founded by two techno-entrepreneurs who are at the same time PhD students. They have strong informal relations with the university they study.
B2-4	Materials	R&D process	Developing functional nano-coatings and application	It is an R&D firm founded by a group of techno-entrepreneurs. The firm's relations with universities are limited with firm researchers' informal and personal links to the academia.
B2-5	Instrument	R&D process	Developing instruments for nanoscale research and applications	It is an R&D firm founded by a group of entrepreneurs to develop instruments for nanotechnology-related research. The firm's managers and R&D workers have informal and personal relations with universities; but consultancy and using laboratories and equipments at universities are the other channels of interacting with universities.
B2-6	Materials	On market	Developing functional nano-coatings and application to various layers	The firm provides nanotechnology solutions to the manufacturing firms from various sectors. The firm works on the application of university-patented technology to various products in collaboration with academic-inventors.

8.2 Linking firms to the academia: Results and discussion

Empirical studies reviewed in Chapter 4 suggest that formation of university-industry KTT linkages is a very complex process influenced by a wide range of factors; some are individual, some are organizational; and some are related to external environment, i.e. national / regional policies, strategies or simply local economic and social conditions. Due to this complexity, in this research, a holistic and multi-level approach is employed to understand all these factors influencing the process in which university-industry relations occur. This section utilizes a knowledge-based view of the firm (which is an expansion of RBV as explained in Chapter 4) and its adjacent literature on organizational learning (i.e. Cohen and Levithal, 1989; 1990; Nonaka 1991; Nonaka and Takeuchi, 1995; Leonard-Barton, 1995; March, 1991) in order to understand why and how firms are linked to the academia.

Consistent with previous studies (i.e. Cohen et al., 1998;2002; Santoro and Chakrabarti, 2002; Santoro and Bierly, 2006) the interviews done for this research suggest a wide spectrum of university-industry interactions and indicate that university-industry links are established under various conditions and are affected by a range of factors. In the following pages we describe the factors influencing firms' relations with universities.

8.2.1 Connectedness and social capital of firm scientists

In the first place, individuals are the key in the formation of university-industry linkages. Our data suggests that connectedness of firm scientists / reseachers to the academia play an extremely important role in university-industry relations in nanotechnology. Interviews indicate that firm scientists /founders have strong informal relations with nanotechnology academics, they meet university nano-scientists in conferences, meetings or events; or they are classmates. Interviews conducted indicate that firm scientists spend time and effort in order to be connected to the academia and to access external knowledge available at universities. Of course firm routines and capabilities play a considerable role but in nanoscale research the key to the university-industry interactions is the individual firm researchers.

However, it is a broad discussion whether a firm’s social capital is different from the aggregate social capital of its employees. Some studies on inter-firm collaborations and networks take the firm as the unit of analysis (i.e. Gulati, 1995; Powell et al., 1996) but some others focus on individual researchers in firms (Kale et al., 2000; Bouty, 2000; Liebeskind et al., 1996; Von Hippel, 1987; Tushman and Scanlan 1980a; 1980b). Although firm researchers at large and established firms are not independent from the overall firm strategy and policies as much as those in small start-up companies either owned by academics or non-academics, impressions coming from the interviews suggest that inviduals have the control of their own links to the academia as well as to other firms.

Theoretical and empirical studies focusing on organizational knowledge and learning posit that knowledge, especially tacit knowledge (Polanyi, 1962), and skills are embodied in individuals (Kogut and Zanger, 1992; Nelson and Winter, 1982; Leonard-Barton, 1992; Nonaka et al., 2000) and cannot be easily mobilized by other individuals or organizations. Collaborations and networks are the ways of mobilizing such kind of knowledge embodied in scientists or some key individuals, e.g. patent holders (Almedia and Kogut, 1999).

Although there are a number of studies focusing on the connectedness of individual university researchers, it is not very common in university-industry KTT literature to focus on resources, skills and capabilities of individual researchers employed at private firms. However, Santoro and Chakrabarti (2002) and Santoro and Bierly (2006) emphasize the role of boundary spanning individuals (or as they called ‘champions’) in the formation of KTT links between firms and universities. Champions are defined as individuals that exploit their position in the organization and personal characteristics to influence the dynamics of organizations (Chakrabarti, 1974); moreover they are able to promote and influence an idea, project or relationship (Santoro and Bierly, 2002; Chakrabarti, 1974; Howell and Higgins 1990). On the other hand, Liebeskind et al. (1996) explore the role of connectedness between firm-scientists and external academic scientists. Using data regarding the co-authoring paterns in publications of the scientists employed in two biotechnology firms, authors demonstrate that these two firms use firm scientists' social networks to source scientific knowledge for innovations from a large number of institutions.

Von Hippel (1987) and Schrader (1991) emphasize the importance of informal communication networks between engineers working in rival firms. According to authors, such an 'informal information trading' between firms is a new form of R&D collaboration. Pyka (1997) also investigates the role of informal networks of individual firm employees on the external knowledge sourcing of firms. Bouty (2000), on the other hand, provides a deeper insight to informal knowledge exchanges among firm scientists across organizational boundaries. She suggests a three-step decision making process to understand how individual firm scientists decide to share their knowledge with their colleagues who are employeed in other firms. Bouty (2000) demonstrates that informal acquisition of external knowledge by scientists is essential to firms and, hence, social capital play a major role in these particular organizational learning processes.

Almost all of the interviewees have mentioned that they have more or less strong informal-interpersonal relations with nanoscientists at Turkish universities. Conferences, meetings or events are considerably important to bring people from academia and industry together and ensure familiarity among firm and university scientists. Besides, some firm scientists mention that once they collaborated with university scientists in a previous research project they have an established link; and a formal relationship have turned into an informal relation or connection. However, in the other way around, an informal relation later mostly turns into formal research collaboration; because the interviewed firm researchers are strongly inclined to keep their links with the academia. The interviewees explain how they have established links to university nano-scientists: For example, R&D manager of firm A1 explains that she/he worked in nanotechnology research projects during her/his graduate education in the university X and, therefore, has strong interpersonal relations with the some of the nanoscientists in that university. Moreover she/he mentions that referees assigned by TUBITAK for the supervision of research projects are valuable resources for the company. Because the informal links are established during the projects, after the project is completed she/he can easily contact these referees to ask about their opinion regarding the problems her/his firm confronts.

A firm scientist managing nanotechnology related research in firm A6 explains that she/he and the firm R&D manager visited food-related departments of all universities in the city during the last year; they have met academics and learnt about their research. During these visits they also met a few nano-scientists working on a project of which outcomes could be used by the firm. After a few meetings, they decided to provide financial support for this nano-technology project. Morever she/he mentions that using the connections established with the university-scientists during these visits, at present, they can easily access the external information residing at the universities. She/he also stresses on the importance of classmates as the informal connections to the universities. For example, she/he mentions that both her/his classmates; and firm R&D manager's classmates who are currently academics at certain universities in the city are the main sources of obtained external information on technological developments in food research.

Tha managing partner and founder of the firm B2-2 provides that conferences are very important to meet nano-scientists at Turkish universities. She/he mentions that these informal relations are important for receiving their opinions about the technology which the firm develops. Moreover she/he mentions that these informal and interpersonal relations are also important to access laboratories at universities in which nano-devices are located. She/he explains that in the university the firm is located, formal mechanisms to reach these devices require a lot of time and effort. Therefore, they use informal interpersonal connections to use these physical resources of the university. Herein she / he emphasizes that being a graduate of this university in which the firm is located has a positive influence on the formation of these informal interpersonal linkages.

The interviewee from the firm B1-1 explains that firm scientists including the academic founder of the firm frequently attend conferences on micro and nanotechnology, they present the outcomes of the research carried out within the firm. She/he explains that “these events are very influential in the sense that during these conferences we advertise our research outcomes; and thus firms come and meet us”. Moreover, in this firm the academic owner of the firm, R&D project coordinator and firm researchers are all graduated from the same university and have very close academic connections with certain departments of the university. Therefore, the firm uses these academic relations to carry out more interdisciplinary nanoscale research. The interviewee explains that in some industry projects they mobilize all their academic links and ensure the participation of other academics to the projects.

The interviewed R&D responsible of the firm B2-4 explains that the owner of the firm is a nano-scientist at university X and she/he is also graduated from the same university. They have strong organic relations with other university scientists in the field. Hence, she/he mentions that whenever they need information they can easily access these academics because, in her/his words, “we are all members of the academic world”. She/he also adds that their academic relations are not limited with the university X; they meet other academics and also contact with firms in conferences.

Our data suggest that although there are various ways of interactions between universities and firms informal and interpersonal relations are the key for university-industry relations. University and firm scientists meet in conferences, or they are classmates, or they previously worked together; or sometimes firm researchers / or university researchers make a phone call or visit to meet each other and build up informal connections. Hence, we propose that

Proposition 1: The social connectedness of firm researchers to the academia positively correlates the probability of a firm to access knowledge produced at universities.

Informal and interpersonal relations ensure trust between agents and, therefore, facilitate the exchange of knowledge and the formation of innovative research collaborations among agents. In the organizational studies there is a bundle of studies focusing on the importance of trust in inter-organizational relations and alliance (Gulati, 1995; Das and Teng, 1998; Zaheer et al., 1998; Ring and Van de Ven, 1992). Among those Gulati (1995) suggests that partnerships between organizations and the choice of partner depend on the trust that emerges between organizations over time through repeated ties. In other words, organizations which worked together in the past trust each other and, hence, trust influence the formation of partnerships. On the other hand, Bouty (2000) emphasizes the role of trust in the decision process of individual firm researchers to exchange knowledge with the others from different firms. In the university-industry interactions trust is not an issue which is broadly discussed by the scholars; however Santoro and Bierly (2006) suggest that for organizational learning from external university resources trusting is important and conclude that especially in the acquision of tacit knowledge from university research centers trust play a critical role. Santoro and Gopalakrishnan (2000), on the other hand, provide support not only for the importance of trust in knowledge transfer activities between universities and firms but also demonstrate that trust is a key variable that facilitates the institutionalization of knowledge transfer activities between universities and firm. With institutionalization of knowledge transfer activities authors mean the routinization of knowledge acquisition activities; or in other words mechanisms allowing continuous acquisition of knowledge over time.

Herein, informal and interpersonal relations are not only the most common form of interactions between universities and firms but also the key for the formation of trust between universities and firms. Trust ensures a continuous interaction and knowledge exchange among universities and firms. Why trust is important is explained by the managing partner of the firm B2-6. She / he emphasizes the problems related to lack of trust between academia and industry; and mentions that as a firm when they ask other academics they have met before to collaborate for some research projects, there is no such a problem. The interviewee from the firm B2-4 emphasizes that in Turkey the formal ways of university-industry interactions are not well developed like in the USA and explains that "in the USA when you ask an academic for an information she/he is not very reluctant to share that information or she/he explains why the information you need cannot be openly accessed; due to for example privacy agreements or commercial value of the information. So, either you can receive information; or you are informed about how much information you can access. However, in Turkey, university-scientists do not want to share information". She/he explains the possible reasons of this attitude of academics in Turkey as lack of interest, the tendency for keeping information in a closed community or that they are not very sure about the confidentiality of the information and, therefore, how much information they can disclose. Thus, in such an environment, the interviewee argues that organic relations with the academics are the key to reach valuable information; as she/he emphasizes that "in such a case where professional relations have not been established yet having access to information strictly depends on these organic relations".

Additionally, most of interviewees mention that sometimes they need prompt information during the R&D process and it is very important for them to reach this information in a very short course. In these cases, their informal relations play an important role; and they emphasize that many times a phone call is enough to reach the necessary information. Hence, interviews suggest that repeated interactions between firm and university-scientists in informal and interpersonal relations increases the trust between them and ensures a continuous flow of information between universities and firms. Herein we propose that

Proposition 2: Informal and interpersonal relations increase trust among university and firm scientists; and trust ensures a continuous flow of information between universities and firms. Therefore, trust established between firm and university scientists as a consequence of repeated interactions and familiarity positively correlates with the probability of a firm to access to the external information resided at universities.

8.2.2 Human capital of boundary spanning firm researchers

Tushman and Scanlan (1981a; 1981b) suggest that external learning is achieved by boundary spanners and posit that “communicating across organizational boundaries requires learning the local coding schemes and languages as well as the specialized conceptual frameworks” (1981a). In other words, boundary spanning individuals must be familiar with the language and concepts used by the individuals they communicate outside their organizations; therefore, they must have the background, experience, and training to deal with the communications impedance separating her organization from external ones.

The interviews indicate that boundary spanners have a range of social capital required to access external knowledge / information resources; however social capital is usually not sufficient by itself to ensure the flow of external knowledge to the firm. Our data suggests that boundary spanners of firms need human capital in the form of formal and informal education, experience or know-how to understand value and acquire external knowledge. As the social capital literature provides human and social capital are interconnected. While human capital of individuals enhances their social connectedness, social capital contributes to human capital (Burt 1997; Coleman 1988). Burt (1992) posits that through social capital individuals receive opportunities to use their human capital and exchange human capital (Coleman, 1988); however, without the social capital of opportunities human capital is useless (Burt, 1997).

Nonetheless, there is a limited number of empirical studies providing evidence for the importance of human capital endowments of boundary spanning firm researchers. Cockburn and Henderson (1998) focus on absorptive capacity and state that benefiting from publicly funded research requires hiring good scientists and allowing them to do fundamental research in the firm. Rothaermel and Hess (2007) argue that a firm’s star scientists function as technological boundary-spanners and gatekeepers; and facilitate a firm's ability to acquire new knowledge from external resources in two-step process: (i) they have capability to access and understand external knowledge; (ii) they are able to translate and disseminate external knowledge into terms that are meaningful and useful to other firm members. Authors' empirical research demonstrates that such individuals are very effective in the innovation and adaptation process of a firm. Santoro and Bierly (2006) also emphasize on this two-stage process of knowledge acquisition; and the role of boundary spanners in this process. They suggest that boundary spanners must have strong technical skills to understand valuable external knowledge as well as professional social contacts outside the firm to reach new knowledge.

Almost all our interviewees have strong educational background in engineering or natural sciences fields. In 10 of the interviewed firms there is at least one researcher with a PhD degree. In five among the other 11 firms, there are researchers who are still working on their PhD research. Some of these firms' researchers have become involved in nanotechnology during their graduate education and worked in nanotechnology projects with their professors. Hence, they are experienced in academic research projects. However some have improved her/his knowledge on nanotechnology just due to her/his personal interests. For example the interviewed firm researchers explained:

> The reason behind the nanotechnology research in the firm is mainly due to my interest and that of my colleagues. The firm top management does not motivate us to be directed to the nano-technology or develop special plans and strategies for nanotechnology research. I and some of my colleagues who are interested in this emerging field have accessed research papers, industry magazines and new product development reports, some news about nanotechnology innovations in the industry abroad and other materials; joined nano-technology conferences and events. We have been motivated in nanoscale research by finding innovative solutions to our current needs and to some problems that occurred in the R&D process. Hence, first we had a learning period; in this period a few people in the firm's R&D department spent a lot of time to learn nanotechnology by reading and discussing the research papers, reports and news on innovations in the international industry publications; and applying them in the laboratories. (Firm A7)

> As a graduate student I was working in a research project for the firm, I am now working for, a nanomaterial was developed. After the project was completed I took an offer from the company to work for them. Now I am here (Firm A1)
>
> There is no specific nanotechnology strategy of the firm. I am the only one in the firm who is interested in nanotechnology. Because I came from academia, I have great interest in this issue. Sometimes, my academic interests precede the interests of the firm. At these times, I feel like I need to restrain myself (Firm A6)

All the quotations above are from Group A firms; however in Group B firms the academic background and interest of researchers/founders of the firms play a considerable role. They are all experienced in academic nanotechnology research. Among the B2 firms which are founded by non-academic entrepreneurs, three have founders who started the firm in order to further develop and commercialize the research they carried out in the university labs during their PhD education. Another B2 firm has a general manager who has a PhD degree from a US university on nanotechnology.

Our data suggests that individuals who are interested in nanotechnology, who follows new developments in the field, who can understand the nanotechnology related knowledge generated at universities or other organizations; who are able to communicate with the academic world; who are familiar with the language of the academic research and literature are important resources for firms to communicate with universities. In other words, these individuals have certain level of absorptive capacities (Cohen and Levinthal, 1990) which ensure their ability to evaluate and utilize outside knowledge. According to Cohen and Levinthal (1990), the ability of individuals to acquire and exploit external knowledge is a function of the level of prior knowledge which includes basic skills, a shared language or knowledge of the most recent scientific or technological developments in a certain field. Hence, boundary spanners with their absorptive capacities function as interfaces between firms and universities for the acquisiton of external knowledge. Therefore, we propose that

Proposition 3: Firm researchers, who are able to gather and understand external knowledge, function as boundary spanners between universities and firms. The presence of researchers /founders /managers who are knowledgeable in nanotechnology and capable of understanding external nanotechnology knowledge in firms positively correlates with the probability of a firm to interact with the academia.

8.2.3 Organizational capacities/capabilities

Internalization and exploitation of external knowledge by a firm certainly depend on the firm's absorptive capacity. Cohen and Levinthal (1990) emphasizes that "a firm's absorptive capacity is not simply the sum of absorptive capacities of its employees". According to authors, an organization's absorptive capacity is not limited with its ability to acquire external knowledge but linked also to its exploitation. Therefore, absorptive capacity of a firm is not limited to absorptive capacities of the individuals who function as organization's direct interfaces to the external world but also related to the internal communication between subunits of the organization and the distribution of expertise within the organization. Cohen and Levinthal (1990) emphasize that the level of organizational absorptive capacity does not depend solely on the gatekeepers or boundary spanners' capabilities but is also a function of the expertise of the individuals to whom gatekeepers/boundary spanners transfer the information or knowledge. Hence, for authors relying on a small set of boundary spanners/gatekeepers may not be sufficient for a successful innovation process.

Moreover, Cohen and Levinthal (1989) emphasize the role of internal R&D in the advancement of organizational absorptive capacity. Authors suggest that R&D does not only generate innovations but also "develops a firm's ability to identify, assimilate and exploit knowledge from the environment" (ibid). Lane and Lubatkin (1998) suggest that absorptive capacity of each collaborating firm is not equal or similar. Thus, in an interorganizational learning process there is one teaching firm and one student firm; and learning from a teaching firm depends on student firm's absorptive capacity. Mowery et al. (1996; 1998) also provide that when an alliance is used by one partner to internalize new technology-based capabilities from the other partner ‘the student’ (learning partner) must have a considerable in-house technical expertise that complements the learning process.

All Group B firms we interviewed do R&D and exploit internal or external knowledge or both to develop new nanotechnologies. On the other hand, only one firm among Group A firms does internal R&D for the development of a nanotechnology without any research collaboration. R&D efforts of four Group A firms focus on the application of a nanotechnology developed in collaboration with universities or other start-up firms to their main product line. Last three Group A firms completely use external resources for their nanotechnology products; they have bought an on-the-shelf technology from an international firm.These three firms (A3, A4, A5) have relatively weak links to the universities in the field of nanotechnology. Although A5 has very strong relations with universities in their core technology field which is electrical equipments; for now they are not well connected to the universities in the field of nanotechnology. Not doing nanotechnology R&D might. be the main reason of this low level of university engagement

Among Group A firms, A1, A2, A6 and A7 conduct nanotechnology R&D in collaboration with universities or start-up firms. However, their main contribution to the R&D partnership is the application of a specific nanotechnology to their own products; and producing nano-enabled new product innovations. Among those firms, especially A2 and A7 have a very wide range of R&D collaborations with universities; and these firms have high in-house nanotechnology expertise at least in the fields they are concerned. Their high level technical expertise increases their ability to learn from external knowledge resources; and moreover increases the probability to collaborate with universities and other firms. For example, firm A7 not only have strong relations with Turkish universities but also have collaborated with high calibrated research institutes, especially in European countries, and participated to EU FP7 projects and EUROKA projects in the field of nanotechnology.

All Group B2 firms founded by non-academic entrepreneurs have a certain level of expertise in the field of nanotechnology and they do internal R&D; but they mostly use universities to access nanotechnology instruments and laboratories. However, their relations with universities are mostly limited to informal-interpersonal interactions or using university laboratories. Among B2 firms we did not observe any research collaboration with universities; nor did we observe that they were looking for collaborators from universities. Four of these firms looks for partners or sponsors from large-established firms to commercialize their products.

Among Group B1 firms, interviewees from B1-1, B1-4 and B1-6 mention that when they need an expertise which is absent in the firm they collaborate with other academics they have acquiantance. The need for external expertise mainly occurs due to the demands coming from other firms, i.e. demand for consultancy or research collaboration from large-established firms in manufacturing industry. Nonetheless, the interviewee from the firm B1-2 explains that they never engage worked with universities for any other reason than using laboratories because the firm has a high level of technical expertise and a large R&D team in the nanotechnology field it is specialized in. The founder of the firm B1-3, on the other hand, mentions that they have collaborated only with one academician in this field; and she/he argues that there is only a few number of academics who have a high level expertise and knowledge in their NST field. Firm B1-5 on the other hand is strictly connected to the university the founders and partners are affiliated with; but no relations with others due to the the fact that the firm does not need further expertise which does exist outside this university.

Our interview data indicates that most of Group A and Group B firms which carry out R&D by either themselves or in collaboration with universities or other firms interact with universities. However, the nature of the nanoscale R&D conducted in firms and in-house technical expertise influence the extent and type of interaction. For example, if a firm is specialized on a NST field, and the firm's expertise in nanotechnology is considerable and it easily exploits this technology for new product innovations this firm usually prefers having access to external knowledge resources through informal - interpersonal contacts, or use universities for only accessing nanotechnology instruments and laboratories. Such firms make research collaboration only in the cases where they do not have an easy access to tacit knowledge residing outside the firm. On the other hand, some firms which are not dedicated nanotechnology firms but large-established manufacturing firms prefer formal research collaborations access external knowledge even though they carry out nanotechnology-related R&D themselves. Because such firms are not and do not want to become nanotechnology firms but solely use nanotechnology to improve their own products; they collaborate with nanotechnology start-ups or nano-scientists at universities for developing innovative ways of nanotechnology applications. Therefore, we propose that

Proposition 4: A high level absortive capacity of a firm increases the likelihood of internal or collaborative R&D activities; this, in turn, increases the possibility of a firm to interact with the universities. However, presence of strong in-house technical expertise influences the form and intensity of university-industry interactions. While start-up firms having strong R&D skills and knowledge mostly prefer informal-interpersonal forms of interactions in their relations with universities; large-established firms having an advanced absorptive capacity in the application of nanotechnology in their product line prefer formal research collaborations to access knowledge produced at universities.

In the second place, the organizational culture and R&D strategy of a firm play a considerable role in the formation of university-industry relations among Group A firms. We observe that firms in which there is an innovation culture and the top management supports R&D managers or researchers to access external knowledge, to acquire it or to transfer it are more open to collaborate with universities and other firms. Laursen and Salter (2004), Veugelers and Cassiman (2005) and Bercovitz and Feldman (2007) show that firms’ research strategies for external knowledge sources and innovation strategy influence the proclivity of firms to engage in KTT from universities. An intervewee explains that:

This is a family firm but the managing owners of the firm are strongly willing in supporting R&D. The firm allocates a considerable amount for R&D expenses. The managing owners are very open minded and well educated; they closely monitor R&D activities. Moreover, the first nanotechnology-enabled product idea came from the top management. They made a lot of research on the issue and created it in collaboration with the university X (Firm A1).

Firm A8 has a very large R&D team with a central R&D department and also distributed R&D departments at various production plants. Central R&D department functions as a research center and develop technologies which are previously designed by the firm's management team. This firm has a special department for managing external relations and collaborations, called "collaborations and projects department". Moreover the firm has developed a routine to increase university-industry interactions and to acquire talented students after graduation. The firm signs protocols with many universities: "first we develop a project with professors in the universities. If it is possible for master students to write their own thesis as a part of these projects; master students are involved in the projects. The number of master students to be part of the collaboration is selected by the professors. These students work in the central R&D department nearly two years until they complete their master program. During this period, the selected master students work with firm researchers and complete their theses. If they want, these students are hired by the firm as R&D researchers".

Firm A6 has a similar R&D structure with distributed R&D departments in various production plants and a newly established central R&D team. The interviewee from the firm explains that "the firm management strongly supports university-industry relations. R&D manager joins the meetings with the academics".

The founder of B1-7 worked for a large-established chemical company before starting her/his firm and mentions that "in Turkey firms are not very much concerned about the future; they do not invest in the future". She/he emphasizes that the support of the firm top management is very important for the success of nanotechnology projects.

Interviews, not only with Group A firms, but also with Group B firms provide that firms' innovation culture is crucial for their nanotechnology R&D efforts and, hence, for their absorptive capacity and their relations with the universities in this emerging field. Firms which have innovative strategies and vision; and an innovative organizational culture conduct R&D and enter into research alliances, develop absorptive capacity to access external knowledge, acquire and exploit it; improve human capital endowments and support their members to improve their social capital and social connectedness. Such firms develop intense relations with universities.

On the other hand, some interviewees from Group B firms which intensively interact with large-established firms in various projects argue that the most important obstacle in Turkey to the formation of university-industry relations is the low innovative capacity of Turkish firms, their reluctantance about new technologies, and their lack of an innovation culture. For example, they explain that

> Most firms in Turkey do not have clear visions for the future. Firm managers generally think that they sell what they produce using conventional technologies; indeed they sell their products for today. But they are not interested in what the future brings (Firm B1-7).

> We do not work with Turkish firms because they do not know anything about nanomaterials and, hence, they do not demand these materials. Most firms in Turkey produce using conventional technologies and they earn money; they are manufacturers not R&D intensive firms. The owners and managers of these firms are not mostly interested in R&D; they have no such a broad vision; they do not have good educational backgrounds; they do not follow the current technological developments; therefore, they do not attempt to invest money in new technologies (Firm B1-1).

Thus, individuals play a key role in the formation of informal and interpersonal relations and building of channels to access external knowledge, however firm routines, resources and capabilities are central to the innovation process. Innovative organizations are at the same time learning organizations; and organizational learning is both a function of access to new knowledge and the capabilities existing in the organization for utilizing and building on this knowledge (Powell et al., 1996). Thus we propose that

Proposition 5: Firms which have an innovation culture, clear innovation strategies, and provide clear support to firm researchers to develop innovative solutions, to improve their social capital and social connectedness are strongly inclined to collaborate with universities.

8.2.4 Start-ups as boundary spanning organizations

Interviews indicate that some start-up firms (B1-1, B1-4, B1-5, B1-6, B1-7) actively function as boundary-spanning organizations among universities and firms. Among these firms while B1-1, B1-4 and B1-5 have been founded by university-nano-scientists, in B1-6 and B1-7 university-nanoscientists are partnered with non-academic entrepreneurs. Therefore, these five firms have very strong relations with the academia. Their special positions in between universities and large-established firms in various sectors provide valuable policy implications.

Stuart et al. (2007) focus on young biotechnology firms as intermediaries between universities and more established pharmaceutical and biotechnology companies and suggest that the diversity and quality of the connections of these start-up firms' founders and advisors with the academia influence the chances of these young firms to successfully acquire the licenses of scientific discoveries developed at universities and transfer them to the large pharmaceutical firms. According to authors, such young firms often function as value-added intermediaries in the transfer of technology to the partners in the pharmaceuticals industry; moreover they emphasize that these arguments would be relevant for other science-driven high-technology industries including nanotechnology.

Our interview data supports the arguments provided by Stuart et al. (2007) in some ways. Interviews indicate that these start-ups which have organic relations with universities and have a considerably strong absorptive capacity function as a bridge between universities and large-established companies. In Turkey, where universities do not usually have TTOs or where existing TTO-fashion organizations are very young and, therefore, currently lack abilities to effectively coordinate the relations between universities and firms it seems that start-up firms which have strong organic relations with universities function as intermediaries. This issue is disclosed by some interviewees:

> When working with the industry you have to be faster and you have to consider various parameters. A university scientist cannot understand these parameters unless she/he closely works with the industry. Therefore, R&D firms, like ours, which are close to the industry and other types of interfaces are needed... When a large-established firm, a university and small R&D firm collaborate in research projects, everything works faster (Firm B1-7).
>
> Being successful in new technologies such as nano-biotechnology depends on the intersection of people working in different fields in academia and industry; and building up strong relations between these people. However in Turkey, there is no technology officers who bring these people specialized in different fields together and establish the links among them in R&D projects. Indeed, this is what we are trying to do as a firm. We are trying to bring together different people or knowledge residing in different locations. There is a strong need for such mechanisms (Firm B1-4).

On the other hand, interviewees from the aforementioned five start-ups indicate that large-established firms come to these young R&D firms to collaborate on R&D project. Joint research projects, contract-based research or consulting R&D projects are the most common forms of interaction between these start-ups and large-established firms. For these projects, it is needed start-up firms mobilize not only their human capital but also their social capital; hence, large-established firms benefit from the academic networks of the start-up firms. As emphasized by the interviewee from firm B1-4, start-up firms successfully manage the R&D projects because they know where the necessary knowledge resides and can access it. Moreover, these start-up firms know where the physical resources are located. In nanotechnology, the ability of firms to easily access university laboratories or other necessary nano-devices and instruments is very important. Hence, such firms also provide solutions to large –established firms to reach these physical resources.

However, among Group A firms, interviewees from A1, A5 and A6 emphasize that they prefer to work start-up firms owned by nano-scientists due to the bureaucratic or cultural difficulties hampering research collaborations with universities. For example, firms A5 and A1 sometimes prefer collaborating with university-scientists via their own firm due to the problems generated by university revolving fund regulations. Firm A6 prefers firm-owner university scientists because of the belief that they understand firm's needs and expectations more than the others. The interviewee from firm A6 emphasizes that universities and firms have different organizational cultures and usually university-scientists cannot understand or respond to their needs and expectations on time; and working with universities takes longer time than they expect or they can tolerate.

In sum, our interviews indicate that, in the field of nanotechnology in Turkey, young start-up firms which have organic and strong relations with universities play an important role in knowledge transfer between universities and industry. They function as intermediaries between universities and nanotechnology firms since universities do not have efficient TTO-fashion intermediary organizations to manage the relations with firms. Therefore, we propose that

Proposition 6: Start-up firms with strong ties to universities function as intermediaries for knowledge transfer between universities and firms. Hence, large-established firms collaborating with such start-ups are more inclined to benefit from nanotechnology-related knowledge generated at universities.

8.2.5 Why firms interact with the academia

Interviews indicate that, in the field of nanotechnology, firms commonly interact with universities in order to use the laboratories and nano equipments located at universities. These nano-equipments are generally used for testing and analyses of newly developed nanotechnology, nanomaterial or nano-enabled products. Moreover, firms interact with universities for external learning and access knowledge-based competences residing at universities. Hence, almost all interviewees mention that they interact with universities for nanotechnology capabilities either in the form of physcial resources or in the form of tacit or explicit knowledge which resides at universities.

Our data indicates that firms engage with universities not to find new product ideas but to learn how to make an innovation in their mind happen; or solve problems occurring in the innovation process. Interviews indicate that a new product idea generally occurs inside firms. Interviewees mention that they strictly follow innovations in their sectors, especially on the international market. They read about these innovations in industry magazines or are informed in industry-related conferences, events, expositions. Therefore, they have the idea of innovations in their mind; they discuss these ideas in firm R&D teams and with the top management. Interviewees explain that they generally interact with nano-scientists or universities to learn more about how and if they can realize these nanotechnology-enabled product innovations and to collaborate with them in the innovation process. For example an interviewee explained that:

> The new product idea mostly generates in-the-firm research; but the ultimate decision to implement the innovation idea is made by the top management. After the decision is made within the firm, as an R&D responsible, I do some research on internet, find people at Turkish universities who might be interested in the issues related to the new product idea, have first contact on the phone and collect some further information about the technology. So, we interact with universities not to access new product innovation ideas but to solve a problem we encounter during in-house research or to collaborate for the realization of a product idea (Firm A1).

The founder and managing partner of firm B1-6 explains that large-established firms from various sectors come to ask for collaboration to make a new product idea happen: "firms have their own ideas of new product; but they do not now how they can make these ideas happen. Therefore, they look for specialized people and come to us". She/he also emphasizes that these firms generally contact them before starting an R&D process. The interviewees from the firms B1-4 and B1-7 also confirm that large-established firms from different sectors apply to them to solve a problem occurring in their R&D process or to make a product idea in their mind happen in collaboration. However, the managing partner of the firm B1-7 emphasizes that

> “Firms come to us mostly with certain problems in their mind, but during the meetings new ideas emerge and sometimes a completely different product innovation flashes in their minds. Hence, during the meetings and collaborations, everything might change.”

Our data suggests that firms interact with universities or university nanoscientists mostly in order to make an innovation idea happen, to solve a problem which occurs in the innovation process, to monitor the new developments, or technologies that can be applied in their production lines. Hence, we can argue that, at least in the field of nanotechnology, having relations with universities is strictly connected to a firm’s exploration strategy.

March (1991) develops exploration and exploitation approaches to the external learning. Author argues that both exploration and exploitation is essential for organizations. Levinthal and March (1993) define exploration as “the pursuit of knowledge, of things that might come to be known” and exploitation as “the use and development of things already known”. Rothaermel and Deeds (2004) suggest that a firm’s decision to enter into alliances and its choice of the type of alliance to enter are influenced by the firm’s motivations to explore new opportunities or exploit existing capabilities. Bercovitz and Feldman (2007) use exploration-exploitation framework to understand firms’ collaborations with universities; and demonstrate that a firm’s strategy for exploration and exploitation is influential over the firm’s relations with the university. Authors provide that firms which allocate much of the R&D expenditure to in-the-firm exploratory research projects tend to spend more for exploratory research which is carried out in collaboration with universities.

In conclusion, a firm interacts or collaborates with universities in the field of nanotechnology in order to have an access to resources and competences which do not exist in the firm. As proposed by KBV of the firm, the most critical resource of the firm is new knowledge which can be either generated in the firm or obtained from external resources. Thus we propose that

Proposition 7: In the emerging field of nanotechnology, firms explore new ideas, new opportunities; and seek for variation and innovations. Firms which are motivated by exploring new opportunities and ideas instead of exploiting existing capabilities are more inclined to collaborating with universities.

8.2.6 Obstacles to university-industry interactions in nanotechnology

The most commonly mentioned obstacle by interviewees is about university scientists' not having enough time to deal with the needs of firms. Firm interviewees mostly mention that they cannot obtain quick response to their demand and inquiries. Some interviewees mention that university-scientists have too much burden at universities and, therefore, they cannot respond on time; however some others believe that universities and firms are completely different organizations in terms of the way in which works and time are organized; and therefore university-scientists cannot understand the urgency of matters on the firm side. For example,

> I worked as a research assistant at a university; therefore I know how things work on both sides. I know there are differences between two sides in terms of using time. However, in order to work together both sides need to understand each other's needs; and should respond on time (Firm A6).
>
> The most important problem in relations with universities is about time. University-scientists are so busy with their academic duties and therefore they cannot allocate enough time for the problem we interface. As a firm, we have very good relations with universities but we cannot obtain quick responses; moreover there are differences among universities in terms of providing quick responses; for example university Y is much quicker than others. Even tests and analyses at universities take very long time. However when we use laboratories outside Turkey, we obtain the results of tests and analyses in a very short time period (Firm A2).
>
> There are cultural differences between universities and firms; especially in terms of time usage. Firm management expect to get research outcomes in a very short course but in academic research it is not possible (Firm A8).

The second one is about the information asymmetry between universities and firms. Some interviewees mention that they do not know in which university who works on what, especially in the nanotechnology field. For example they explain that

> For us, one of the most important problems is to identify in which universities who carries out research on the technologies which can be used in our firm. We are not informed about the research topics that universities work on (Firm A6).
>
> Universities need to hire marketing people. With these people, universities might both build relations with industry and also advertise research projects carried out in universities. Hence, they might inform firms about the outcomes of these projects (Firm A2).

Third, some interviewees mention the problem related to the applicability of the outcomes of academic research. They explain that university research projects are guided mostly by academic concerns and therefore their outcomes are not easily applicable to the industry; moreover university-scientists are not very much informed and experienced about the problems which may occur during the transfer of university technology to industry. Interviewees explain this problem:

> Firms are not organizations doing basic science; this kind of research should be carried out in universities. We need special projects and research which can solve our problems (Firm A7).
>
> Research institutes at universities should be independent from universities and should work on research projects which have industrial applicability (Firm A2).
>
> In university research only a few parameters are considered; however in the industry you have to consider various parameters including cost and efficiency. Only the university-scientists who closely work with the industry are able to understand fully these parameters (Firm B1-7).

Among Group B firms, three interviewees mention that most of the university-scientists do not have some qualification and knowledge to engage in KTT activity with firms. They argue that among university-scientists in Turkey, the number of scientists producing new knowledge and technology or doing pathbreaking research projects is very limited; and most of the academics allocate their time for educational activities. Therefore, according to these interviewees, there are a very small number of university-scientists who are able to or willing to engage in university-industry KTT activity. For example, one interviewee explains that

> The number of good scientists at universities is very low in Turkey. In order to improve university-industry relations, first the number of good scientists should be increased. In Turkey, most of university-scientists go on working in the academia without doing any research (Firm B1-1).

Some interviewees mention that although they try to build connections with university-scientists and collaborate with them, these scientists are not very much interested in working with their firm. For example, interviewees from two Group A firms (A6, A7) explain that they made a number of visits and meetings with some university-scientists for various projects but these scientists are not very much interested in working together. Two interviewees from Group B firms also complain about the disinterest of university-scientists in collaborating with firms. They argue that “most of university-scientists are not extroverted, they are very reluctant to interact with firms”. Hence, since they cannot find academics who are enthusiastic about collaborating with firms they finally gave up looking for opportunities to collaborate with the academia. According to some interviewees, university-scientists are reluctant to collaborate with firms due to their academia-related burdens. Besides these obstacles, some interviewees explain that problems related to regulations for university revolving capital, and the high prices charged by universities to firms for laboratory use are important factors that impede firms to interact with universities.

8.3 Conclusions and implications of the research

The impact of individual and organizational factors on firms’ decision to interact with universities has extensively been discussed in this chapter. Our data is collected through in-depth interviews with top level R&D managers /founders /partners of firms which either develop nanotechnologies or use any form of nanotechnology in the products and processes. Figure 8.1 presents a visual representation of the model with the factors influencing the formation of KTT linkages with universities and its consequences. As represented by the model, individual firm researchers’ human and social capital endowments as well as organizational capabilities / routines for learning from external knowledge resources play key roles in the formation of links between universities and firms.

Interviews indicate that individual firm researcher / managers /founders are the key in the formation of KTT linkages with universities. Such firm researchers function as boundary spanners and, hence, have the capability to access external knowledge resources; to acquire and transfer knowledge into the firm. In the second place, our interviews demonstrate that firms' absorptive capacity and organizational arrangements that facilitate individual researchers' access to external knowledge and its transfer also important in university-industry relations.

On the other hand, interviews also suggest that firms usually interact with universities to explore new opportunities, new knowledge and competences that do not currently exist within the firms. The main motivation of firms to interact with universities is to have access to new knowledge residing at university-scientists' mind, and learn how to improve their products using nanotechnology. However, this might be either a natural consequence of the pecularities emerging nanotechnologies or due to the characteristics of collaborations with universities because these are the organizations where state-of-the-art knowledge is generated. Although in some Group B firms (especially those producing nanoinstruments) we notice that interacting with universities is motivated by the exploitation of existing firm knowledge and capabilities, this is not very common. Therefore "exploitative research" is represented by a grayed text box in Figure 8.1.

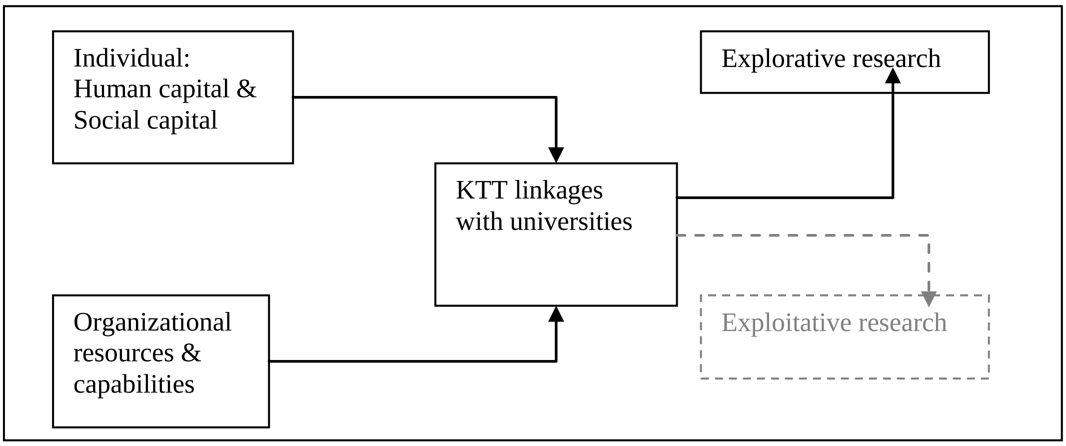

Figure 8.1 Visual representations of factors influencing firms' KTT activities

However, there are many obstacles to university-industry relations in nanotechnology. The most commonly spoken obstacles can be explained by organizational and cultural differences between universities and firms; and by lack of the information channels which enhance the continuous flow of knowledge.

Nonetheless, a number of managerial and STI policy implications can be derived from the analysis of in-depth interviews with firms' top managers who are responsible for nanotechnology-related research in the organization. The first managerial implication of this research is that firms which aim to collaborate with universities need boundary spanners who have capabilities to access external knowledge resources; and are able to transfer the knowledge obtained from these resources into the firm. Therefore, firms which hire qualified researchers, who are experienced in academic research, can easily communicate with university nano-scientists, understand not only the codes and language of the scientific research but also the academic culture, expectations and needs would be more capable to establish linkages with universities and access the new knowledge generated at universities.

However, hiring good researchers is not sufficient to ensure a continuous flow of knowledge from universities to firms. Our interviews and observations indicate that firms need to develop necessary organizational arrangements that support the boundary spanners to increase their absorptive capacities and to benefit from their social connectedness to the academia. Moreover, internal R&D or collaborative R&D activities of firms are also decisive in the improvement of firms' absorptive capacity, thus, collaboration with universities. Scholars (Cohen and Levinthal, 1989; 1990) indicate that a firm's absorptive capacity is not equal to the sum of boundary spanners' absorptive capacities; and the acquisition and exploitation of the external knowledge depends on the firm's internal technical capabilities and the organization of internal R&D activities. Hence, our data confirms the literature and suggests that firms which have a high absorptive capacity; and competences and capabilities to access, to understand and to acquire knowledge tend to interact and collaborate with universities more than other firms.

There are also some STI policy implications of this research. First of all, qualitative data demonstrates that the low level of university-industry interactions is strictly bound to the low innovative capacities of firms. Our interviews indicate that innovative firms which have developed necessary technical capabilities and routines / skills for generating new knowledge within the firm or for external learning, tend to interact with universities and learn from universities. Any discussion on STI policies aiming to motivate firms for innovation is out of the scope of this research; however, we need to mention that enhancing university-industry interaction is an important policy tool for innovation and development. Our data indicates that especially in the field of nanotechnology collaborating with universities significantly increases the innovation capacity of the firms. Hence, STI policies and strategies to be followed in order to improve KTT between universities and firms will eventually generate positive impact over the firms across various industries. In the following paragraphs, we discuss the policies and strategies which might motivate firms to collaborate with universities, and reduce the obstacles to the formation of university-industry relations.

First and foremost, collaborative research especially in the field of nanotechnology needs to be supported and promoted by policies and strategies. Our interviews indicate that almost all of the firms we interviewed use extensively government funds for nanotechnology-related R&D activities. However, most of the firms using government funds for innovation do not prefer to collaborate with universities. Collaborative research funds which motivate firms to find partners from universities would lead to increase university-industry relations.

Second, this research indicates that more and effective intermediary organizations are needed to reduce the information asymmetry between universities and firms; to manage the relations; to handle the paper work; to answer firms when they need information; and finally to gather different expertise in interdisciplinary projects. In Chapter 3, we discussed how TTOs play an important role to decrease information asymetry between universities and firms. Where they exist TTOs advertise the research projects and their outcomes; provide information to firms on these projects and function as intermediaries between universities and firms for the formation of linkages. Some interviewees mentioned how intermediary organizations are necessary to cope with obstacles such as not receiving quick responses from university-scientists; not having been informed about the research projects carried out by university-scientists; to tackle with a lot of paper work occurred during collaborative research funded by government, etc.

TTO-fashion intermediary organizations and chief technology officers hired by universities are widely used solutions both in developed and developing countries to improve university-industry relations. For example, in Taiwan chief technology officers at universities who are experienced in technology transfer and educated in IPR-related issues play a considerably important role in the formation of university-industry relations (Chang et al., 2005).

Interviews indicate that, in Turkey, project offices and technology officers employed in such offices might decrease the organizational boundaries between universities and firms and, hence, improve university-industry relations. Such offices would also work to find research funds from industry; and thus increase the share of private funding in university research budgets.

Third, interviews indicate that nano-equipments and nanotechnology-related physical resources located at universities function as platforms to gather people from universities and firms together. Reorganization of nanotechnology research institutes or laboratories as fully functioning technology platforms on the regional basis would improve university-industry interactions; increase the dissemination of nanotechnology innovations and develop innovation capabilities of firms in the region. Agglomeration of nano-instruments and infrastructure for advanced research is important for the formation of technology platforms. Moreover, the agglomeration of such physical resources indicates that human capital and skills are also accumulated around these physical resources. Moreover such platforms also play an important role in the formation of innovative networks.

In the recent period, well-equipped nanotechnology centers have been established in certain universities in Turkey. The use of nanotechnology research centers is mainly left to the universities; and unfortunately firms cannot fully benefit from these equipments. Moreover, these research institutes do not work as research platforms but like ordinary laboratories doing tests and analyses for firms. However, the re-organization of these research centers as technology platforms which are able to gather different agents in the field of nanotechnology and to enhance the formation of networks would increase the relations between universities and firms and also increase the innovative capabilities of nanotechnology firms. Some interviewees emphasized the importance of these research centers and made some recommendations; for example “such university research institutes might be independent from universities and much focused on applied research” (Firm A2); or “research institutes which function as interfaces between universities and firms are needed” (Firm B1-7).

We have discussed some managerial and STI policy implications of our research. Of course, some further policy and strategy recommendations might be provided. However, this research demonstrates that the formation of university-industry interactions needs to be analyzed from a multi-level approach. There are individual-level, organizational-level and policy-level factors that influence the formation of KTT linkages at the industry side. However, what should be done to improve university-industry relations are not limited with the policies and strategies dealing with the formation of KTT links, but should also include those aiming to improve innovative capabilities of firms; research capabilities at universities; human capital and social capital of individuals both in the industry and academia.

CHAPTER 9

CONCLUSION

The purpose of this thesis is to provide an extensive insight to the factors influencing the formation of linkages between nano-scientists and nanotechnology firms, and discuss the STI policy implications of this research. Our main motivation to focus on these two issues of great importance in today's knowledge economy, which are nanotechnology development and KTT between universities and firms, is to make a valuable contribution to STI policy research and policy design in Turkey.

The factors impacting significantly on the formation of university-industry KTT links have received an increasing attention not only from scholars of STI studies but also from policy makers for the last three decades. Programs and strategies to improve university-industry relations are used as effective policy tools for the formation of regional and / or national innovation systems, economic and technological development especially in developed countries. However, the requirements of the global knowledge economy create new challenges for late-coming countries to improve university-industry KTT across various technology fields including the emerging ones, such as ICT, biotechnology and nanotechnology.

Among those, nanotechnology deserves a special attention since its peculiarities are not limited to the nature of technology itself but also related to STI policy attitudes toward nanotechnology. As discussed in Chapter 2, nanotechnology is welcomed and supported extensively by policy makers as the 'next industrial revolution'. The NST field has tremendously grown in terms of the number of scientific publications and patents since the beginning of the 2000s. Moreover, with the convergence of different technology fields on the nanoscale, public and private R&D fundings for NST have recently gain impetus.

In Turkey, some efforts have been made for nanotechnology development. An important policy document, called Vision 2023 (TUBITAK, 2004) includes nanotechnology as one of the technology fields with strategic importance for scientific and technological development of the country. Nanotechnology is also included in the last Five-Year Development Program for the period 2007-2013 as being among the priority technology fields. However, at present, nanotechnology R&D efforts in Turkey are mostly concentrated in and limited with the academia. The number of NST publications generated in Turkish universities has increased by eight fold in the period 2000-2009 and, new NST research centers, master and PhD programs have been launched. However, the potential economic value of the outcomes of NST-related R&D projects conducted at Turkish universities cannot be utilized effectively by private firms mainly due to the weak connections that facilitate KTT between universities and firms.

This thesis aims at investigating the individual and organizational level factors that influence nano-scientists at Turkish universities and nanotechnology firms to interact with each other. To this end, this thesis carries out three empirical studies which all contribute to the science and technology policy research in Turkey. The first one covers the empirical investigation of NST-related research. Using scientific publications and findings of a social network analysis, it provides valuable findings about the main characteristics of NST research in Turkey. Second, using data collected from 181 nano-scientists, who are currently affiliated with Turkish universities, through a questionnaire survey, we examine the individual and organizational level factors which influence nano-scientists to engage in KTT activity. Finally, based on the interviews conducted with the top level managers of 21 firms conducting nanotechnology R&D or using nanotechnology in their product and production processes we explore which firm characteristics play a critical role in the interactions with the academia.

Section 9.1 presents overall findings of these empirical studies. In Section 9.2 we discuss the STI policy implications of the overall research and discuss or advance some policy tools in order to improve university-industry KTT in the field of nanotechnology. Section 9.3 presents some limitations of the research; and finally Section 9.4 discusses some directions for further research.

9.1 Overall findings

Nanotechnology, at the simplest form, can be defined as the understanding, measuring, modeling and manipulating matter at dimensions between 1 and 100 nanometers. The delineation of nanotechnology field is primarily based on the length scale and this makes the notion of nanotechnology as something fuzzy and its boundaries are obscured. Such a broad definition of the technology leads to some discussion about the nature of the technology itself; some argues that nano has become a scientific marketing term (Loeve, 2010).

An important conclusion we arrived at from the extensive literature survey on the history, politics and economics of nanotechnology is that nanotechnology itself provides a fertile gound for analyzing issues related to STI policy tool for boosting innovations, supporting scientific and technological development and, increasing both public and private R&D investments. The various definitions of nanotechnology have one common aspect which is the strong emphasis on its capability to enable “novel applications” or “technological innovations in various fields”. In the last decade, nanotechnology has been widely promoted by both developed and developing countries to encourage scientific and technological development; in this time period the number of NST publications and patents has tremendously increased. Among developing countries, in China, India and Brazil nanotechnology was turned into a policy tool for catching up with the advanced countries. China launched a national nanotechnology initiative at the same year with that of the USA in 2000. At present, China has catched up with the USA at least in terms of the number of nanotechnology publications.

In Turkey, however, nanotechnology has mostly been left to the realm of the academia. The main actors of nanotechnology in Turkey are universities and university-scientists. Scientific publication data retrieved from ISI WoS-SCI shows that in a ten-year period from 2000 to the end of 2009 almost an eight fold increase has occurred in the number of scientific articles authored byTurkish researchers. The number of agents (i.e. universities, public research institutes and firms) has increased form 37 in 2000 to 107 in 2009. Our research indicates that universities are the most important contributors to the NST research in Turkey. University nano-scientists are industry scientists to nanotechnology literature is limited to 1.1 percent. On the other hand, a regional agglomeration in academic NST research can be observed: the most productive three universities in the NST-field are located in Ankara. These are METU, Hacettepe and Bilkent University.

Despite the growing academic interest to this emerging field of technology, our research suggests that the NST research in Turkey has some drawbacks. First of all, there is a high concentration of nanoscale research at certain universities. The most prolific 10 universities in Turkey generated more than half of the NST related research articles in 2009. Second, the research collaboration among Turkish universities is very low. Only a very small number of universities collaborate intensively with other universities in Turkey. Moreover, international collaboration of Turkish NST academia is very limited. A small number of universities and nano-scientists in Turkey are linked to the international knowledge networks. This hampers that the most recent knowledge produced in international networks accrues to the Turkish academia. Fourth, NST research in Turkey has a weak interdisciplinary nature in the sense that most of the articles are produced by collaborating academicians from the same disciplines. Last but not least, the number of NST patents granted by TPO is very low.

Publication data retrieved from WoS-SCI is further analyzed to identify nano-scientists who are currently affiliated with Turkish universities. 703 university-scientists, who are currently hiring a position at Turkish universities and have at least three NST-related scientific publications, are identified from the data.

This group of nano-scientists is explored further for their relations with the industry. Among 703 nano-scientists 181 are selected for the questionnaire survey.

Our empirical research which examines individual and organizational level factors influencing the formation of KTT linkages at both sides of the relations (i.e. academia and industry) uses a large array of literature questioning the factors which impact over KTT between universities and firms. One group of literature examined in Chapter 3 focuses merely on the institutional change and emphasize the impact of changes in knowledge production system or capitalization of knowledge on the role of universities in the society and economy and, on the relations between academia and industry. Mode 2 (Gibbons et al., 1994) and Triple Helix Model (Etzkowitz and Leydesdorff, 1997; 2000) are the theoretical approaches which are frequently referred to the literature. These perspectives investigate KTT between universities and firms at the institutional level and provide a meta-analysis regarding the changing nature of university-industry relations. However, these approaches receive criticism due to their limitations. Among those limitations two are important for our research: (i) their macro perspective addressing the changes at the aggregate level while ignoring changes at individual and organizational level and, (ii) their being context-independent and, therefore, not very useful in explaining the factors influencing university-industry relations in a developing country context.

The second strand of literature includes resource-based view (RBV) and scientific and technological human capital (STHC) approaches to KTT. Although they are originated from different streams both are utilized intensively in the empirical literature which explores the individual and organizational level factors influencing the KTT activity. The number of empirical studies using at least one of these two perspectives has recently increased in the literature. Thus, these two approaches and the empirical literature utilizing them contributed significantly to our research from the research design stage to the analyses of the data. Based on a careful review of theoretical and empirical literature we hypothesize that, at the individual level, human capital and social capital endowments of nano-scientists and, at the organizational level, physical resources (in the form of nano-equipments, laboratories, etc.), research quality and organizational capabilities of universities have a positive impact on the proclivity of a nano-scientist to engage in KTT activity.

The data we collected through questionnaire survey indicates that nearly 46 percent of nano-scientists frequently interact with private firms. However, nano-scientists interact with firms through various channels of KTT including informal and interpersonal relations, conferences, contract research, test and analysis, firms' accession to university laboratories, joint publications with firm researchers, consultancy, joint-patenting, licensing agreements or starting up a firm. Among those channels, nano-scientists use frequently informal-interpersonal channels; almost 40 percent of interviewed nano-scientists mention that they frequently use informal channels to interact with firms. The second most common form of interactions between universities and firms is research-based activities, such as joint research projects, ad hoc research for firms, laboratory tests and analyses. However, consultancy or commercial forms of interactions (i.e. joint patenting, licensing and start-up firm formation) are not very common among nano-scientists; for instance, only 9 percent of nano-scientists interact frequently with private firms as a paid consultant, and only 7 percent has engaged in direct commercialization of knowledge and technology developed at universities.

The models estimated in the binary probit analysis indicate that there are both individual and organizational level factors which significantly influence the propensity of a nano-scientist to engage in KTT activity. The analysis of these factors provides the profile of university nanoscientists who interact with firms on a frequent basis. The findings show that nano-scientists who engage in KTT are not the star scientists of the NST field with a high number of SCI publications but rather those who (i) both publish and patent; (ii) do more applied research; (iii) have access to public funds (iv) are well connected to Turkish NST academia; (v) are working in universities which are not the most active ones in the NST field; but have nano-equipped laboratories; and support nano-scientists in their relations with industry; and finally (vi) are motivated by commercialization of their research outcomes.

Number of patents, not surprisingly, is associated positively with the propensity of a nano-scientist to engage in university-industry KTT activity. Applied research is another factor with positive impact in the formation of KTT linkages between universities and firms. These two findings indicate that nano-scientists who carry out more industrially applicable research have a greater probability to interact with private firms. On the other hand, the extent to which a nano-scientist conducts publicy funded research positively and significantly associates with her/his procilivity to engage in KTT activity. Our data also provides that a nano-scientist who is well networked among other nano-scientists in Turkish academia tends to interact with private firms than others with weaker ties.

As we hypothesized, the presence of nanotechnology equipments and laboratories at universities has a significant and positive impact in the formation of KTT linkages between nano-scientists and private firms. Most importantly, our results confirm that university support to academics in their relations with private firms is very critical for the improvement of university-industry relations in the field of nanotechnology.

The most interesting results derived from our data are related to the impacts of publications both at the individual and organizational level. Findings reveal that both the number of NST-related scientific publications of a nano-scientist and the quality of a university's NST research, which is measured by the number of international collaborations per NST publications, negatively correlates with her/his proclivity to interact with firms; and their impacts are statistically significant. These results might imply a trade-off between academic success and being engaged in KTT activity. Nano-scientists who have greater motivation to conduct scientific research might consider the interactions with industry as distracting their scientific pursuits.

On the industry side, 21 firms we interviewed display a great variety in terms of their size, products, industry, nanotechnology R&D efforts and their relations with universities. Most of these firms prefer informal-interpersonal relations in order to access and use knowledge embodied in university nano-scientists. Among those firms, only a few large established firms conduct collaborative research (i.e. joint research projects or contract based research) with universities. Our findings confirm the literature on organizational learning and suggest that boundary spanners of firms, who are mostly R&D researchers, managers, partners or founders of the firms, play the key role in external learning from universities. Social connectedness of boundary spanners and their human capital in the form of research experience, scientific and academic knowledge, being familiar with academic culture, language and codes of academic world ensure access to external knowledge resources and, acquisition and transfer of knowledge to firms.

In addition to the presence of boundary spanners, the firm's organizational absorptive capacity (Cohen and Levinthal, 1990) plays an important role for the transfer of external knowledge into the organization and its exploitation in the innovation process. Therefore firms' own R&D efforts and the organization of R&D within the firm both have considerable influence over KTT between universities and firms. Innovation culture prevailing within the firm and the attitudes of the firm's top management vis-à-vis external learning and its support for university-industry interactions are among the other organizational level factors affecting KTT on the firm side.

The interviews we conducted also suggest that young start-up firms with strong relations to universities function as boundary spanning organizations or intermediaries between universities and firms; and enhance technology transfer from universities to firms. On the other hand, the main motivation of firms to engage in KTT activity is to explore new knowledge. Hence, firms which engage in explorative R&D have higher propensity to interact with universities. The most commonly expressed obstacles to KTT between universities and firms are the differences in organizational cultures and the information symmetry. Two sets of data we collected from nano-scientists and high level managers of firms suggest two general conclusions: (i) between universities and firms knowledge flows through a large spectrum of channels; and informal-interpersonal relations are the most common forms of university-industry interactions observed; (ii) individual and organizational level factors are equally important in KTT between universities and firms.

9.2 Research implications and policy tool research

In this section, we review the main STI policy implications of the research and discuss some possible policy tools which can be l designed and implemented to encourage not only the formation of university-industry relations but also to improve NST-related research conducted inTurkish universities and firms. Some major implications derived from findings of the present research can be summarized as follows:

(i) Despite the growing number of scientific publications, the share of Turkey in total NST publications is still very low. Therefore new policies and strategies should be developed to encourage NST-related research in Turkey.

(ii) Low level of research collaboration among university nano-scientists (see Chapter 5) should be addressed by science and technology policies and strategies.

(iii) The number of nanotechnology patents is very low. Universities and university nano-scientists should be encouraged for more patent applications. The number of patents a nano-scientist possesses positively associates with her/his proclivity to interact with firms. Hence, policies which encourage nanotechnology patents not only contribute to the knowledge stock of the country but also influence university-industry relations positively.

(iv) Between universities and firms knowledge flows through a large spectrum of channels. Thus, a holistic perspective which takes into account the variety in the forms of KTT activity should be adopted in designing STI policies for the improvement of university-industry relations.

(v) The formation of intermediary organizations which function as interfaces between universities and private firms should be supported by STI policies and strategies. The need for intermediaries is commonly mentioned by firm managers due to the fact that university-scientists cannot be reached easily due to their time constraints. However, since the presence of such intermediaries eliminate some of the burdens of KTT activity on university-scientists and, hence, may positively influence nano-scientists in their decisions to interact with firms.

(vi) Nanotechnology research centers and laboratories play the role of technological platforms which bring university and firm scientists together. Therefore, new research centers and laboratories should be established and more importantly new strategies should be developed for the organization of these research centers as technological platforms.

In order to address these STI policy implications of the research a number of policy tools should be conceived and implemented. First and foremost, the most important policy tool which should be urgently launched is a specific nanotechnology programme or initiative aiming at increasing NST-related R&D. Indeed, while most of the developed and developing countries have launched special programs and strategies to support NST research, and allocated high amount of budgets to nanotechnology R&D held in universities and firms; in Turkey, no similar initiative or science-technology programmes addressing specifically nanotechnology development has been launched yet. It should be remembered that after Clinton’s announcement of the creation of National Nanotechnology Initiative (NNI) in the USA and an increase in the budget for nanotechnology expenditures in 2000 nanotechnology research has boomed in the USA. Similar trends observed in other countries as well; China, India and Brazil are among the countries which have launched special nanotechnology programs and subsequently have achieved a great success as seen in Table 5.3. At present, these countries are among those with a high stock of nanotechnology knowledge. The launch of such a specific program or initiative is an effective policy tool not only to improve nanoscale research in universities and firms but also to encourage collaborations among different agents of the NST field and to achieve a planned scientific and technological development. The directorate of such a programme would launch nanotechnology roadmaps and develop strategies to increase national and international collaborations among university scientists and between universities and firms. Hence, with such a programme or initiative for nanotechnology it would be possible to address the specific drawbacks of the nanotechnology field identified in our thesis and to develop state-of-the art strategies to eliminate them.

Triple Helix organization of technological platforms on the regional basis would be an effective policy tool to encourage the formation of strong linkages between universities and firms, among universities and among firms. For the formation of Triple helix technological platforms, a special funding scheme and programme can be launched by TUBITAK. In order to benefit from such a programme, a certain number of universities, public research institutes and firms would be requested to sign a protocol for collaboration and prepare a program including the short, mid and long term objectives of the technological platforms and, the strategies to achieve these objectives. After the acceptance of the project including the establishment of a technological platform, an executive committee for the administration of this new form of organization should be selected and, representatives not only from the member institutes of the technological platform but also from TUBITAK and Ministry of Science, Industry and Technology should be included in the committee. Such technology platforms can also be given privilege in infrastructural investments made by State Planning Organization (SPO), i.e. nanotechnology laboratories, research infrastructures or research centers. In this way, it would be ensured that laboratories and other equipments are utilized by all the members of technological platforms. Triple Helix technological platforms would work well to bring together nano-scientists from universities, firms or public research institutes in the same region; they would share the same laboratories, collaborate on research projects, and learn to understand and trust each other, exchange valuable knowledge. Throughout such Triple Helix technological platforms the formation of regional nanotechnology knowledge networks can be achieved.

The establishment of technoparks and technology developments zones and, KTT mechanisms related to commercialization of research outputs (i.e. patenting, licensing and start-up formation) are generally articulated as the most popular policy tools in the improvement of university-industry relations. However, the empirical studies we reviewed in this thesis (Chapter 4) and our empirical research indicate that there is a strong need for a policy tool to improve all the possible forms of KTT activity. To this end, on the part of universities, using PhD training as a way of improving university-industry relations might be considered. For this aim, collaborative PhD programmes in which the research of PhD students are supported and financed by industry firms would be launched. In many countries (i.e. Norway, Denmark, Sweden, France, UK) collaborative doctoral research programs between universities and private firms, such as industry PhD programs or collaborative research projects including PhD students be used an effective policy tool in the formation of university-industry links (Thune, 2010). With such a collaborative PhD program continuity in university-industry relations can be achieved and doctoral students are used as bridge builders (Thune, 2010) between universities and firms. Moreover, students learn to collaborate with firms during their PhD training. Such collaborative doctoral programs would also provide PhD students some financial support. Data collected in our thesis from nano-scientists indicate that for most of these academics to find financial support for their PhD students is an important motivation to collaborate with private firms. Thus, such collaborative doctoral programs aiming to PhD students would also motivate senior nano-scientists to collaborate with private firms.

However, in Turkey, an “industry PhD program” exists, which is funded by SPO, however, it is not widely used by the universities. In Anadolu University an industry PhD program for ceramic industry and, another one in Ege University for textile industry have already been implemented. By these programs PhD students are financially supported by private and public funds, and after graduation they are expected to work for the company by which they were earlier supported. However, this program is mainly designed for human capital improvement in the industry not specifically to improve collaborative research. Second, this program does not fit well to the interdisciplinary nature of nanotechnology. Hence, an industry PhD program which is based on interdisciplinary and collaborative research rather than training would be a very effective policy tool for a holistic improvement of university-industry relations.

Formation of intermediary organizations between universities and firms has been proposed as the most popular policy tool both in developed and developing countries. Such organizations might play a critical role in mitigating the information asymmetry between universities and firms, in technology transfer (i.e. patenting, licensing) activities and, the formation of contract-based research agreements between university-scientists and firms. One important point about such organizations is that industry professionals who are knowledgeable about certain industries and have strong links to the industry should be hired in these organizations. A policy initiative or program to support formation of such interfaces with experienced industry professionals would play an important role in the development of university-industry relations. In a later stage, the networks between these intermediary organizations would be formed. For instance, in the USA, TTO managers of universities are coordinated and collaborated under the Association of University Technology Managers (AUTM) (see Chapter 3).

As aforementioned, the collaboration among Turkish nano-scientists who are from different disciplines as well as from different universities is weak. Additionally, except some nano-scientists who are affiliated with some universities with a high quality of NST-related research (METU, Bilkent, Hacettepe, etc.) others have very limited access to international research networks. To address the problem of the low level of collaborative research, collaborative research funding would be used an effective policy tool. Collaborative research programs are used extensively in many countries to increase research collaborations not only among university-scientists but also between universities and firms. Using such research programs, firms which apply for public R&D funds might be encouraged to find partners from more than one university or more than one academic discipline; or research consortiums including more than one firm (i.e. high-tech start-ups and incumbent firms), universities, governmental or non-governmental organizations- and might be privileged in their applications for R&D funding.

Last but not least, a web-based tool which is designed to provide access to all the information about nanotechnology projects and their outcomes, NST-related publications, conference papers, conference announcements etc. would be very efficent way to increase the extant of collaboration between between Turkish universities. The low level of collaboration might be mainly due to the information asymmetry among nano-scientists; and knowing who at which university work on what might encourage nano-scientists to contact with others working on similar subjects. TUBITAK may open a call for the design and implementation of such a web-based tool. Moreover, over such a web based system nano-scientists can be allowed to make some announcements to find partners / collaborators from other universities for their research projects. Such a web tool might also be very useful in mitigating the information asymmetry existing between universities and firms and, hence, might encourage the formation of links between universities and firms.

9.3 Limitations of the research

This study has a numner of limitations resulting from the research design. First of all, in the quantitiave investigation of nano-scientists holding a position at Turkish universities, the target population is selected on the basis of the number of publications listed in SCI. Let us remind that at first 4408 SCI articles published at least by one scholar affiliated to Turkish universities were collected; then 5806 different scientists who contributed to these articles were listed. Among these scientists those who had less than 3 articles were excluded and the remaining 1134 scientists were selected as the target population of the research. However for only

703 nano-scientists among 1134, contact addresses, e-mails and phone numbers could be collected through an internet research. Therefore the sampling frame of the quantitative research was limited to these 703 nano-scientists.

In other words, quantitative research concerning nano-scientists affiliated with Turkish universities is limited to these scholars with at least three NST-related SCI articles. However, scientists who are affiliated with Turkish universities and doing NST related research but have not published at least three articles are excluded from the investigation due to research design. On the other hand, the research design also excludes some Turkish nano-scientists who have authored more than three NST-related articles but are not currently affiliated with Turkish universities. Therefore, those nano-scientists who have retired, or quitted university positions or are visiting fellows abroad are not included in the sampling frame. Indeed, some changes might occur in our findings if the range of target population were extended so as to include nano-scientists who have not published yet. However, there was no practical way of identifying the whole set of nano-scientists with no NST-related publications or finding contact addresses of scientists who have retired, or quitted university positions or are visiting fellows abroad. Practical reasons forced us to apply such limitations to the study; nonetheless we can argue that population of nano-scientists we analyzed in this research represents the majority of scientists who are strongly involved in nanoscale research.

Second, qualitative research on firms has also limitations due to research design. As aforementioned, we could not find a list of firms conducting nanotechnology R&D or using any form of nanotechnology in their product and processes; therefore the list was prepared by us using different sources, such as internet research, publications, industry magazines, individuals, etc. Hence, the list of firms is limited with those which advertised their nanotechnology R&D or product or processes. Firms which conduct nanotechnology R&D but have not disclosed these efforts to the public yet cannot be included in the research. However, since the number of interviewed firms is high we can argue that, in spite of the limitations, the firm population we have reached is representative.

9.4 Direction for further research

The objective of this thesis was to explore the forms of KTT activity between universities and firms and to investigate individual and organizational level factors which influence the formation of university-industry interactions at both sides of the relations, i.e. academia and industry. This research is limited to the emerging field of nanotechnology in Turkey. Therefore, many questions have remained out of the scope of this research.

Some of these questions are: (i) to which extent the findings of this thesis are appropriate for other technology fields in Turkey; (ii) whether in the emerging field of nanotechnology university-industry relations are different from those in force in other technology fields; or (iii) whether the nature of nanotechnology has impacted the individual and organizational level factors which facilitate university-industry interactions questioned. Therefore, a check of findings across different technology fields, such as ICT, biotechnology or more conventional technologies, may be interesting research topic for further research.

Second, due to its limitations this research did not address performance-related issues of university-industry relations. In other words, in this thesis, we did not investigate how the interactions, flow of knowledge or research collaborations have affected the performance of nano-scientists at universities or firms doing nanotechnology R&D or usiny any form of nanotechnology in products and processes. Further research on the performance impact of university-industry relations would provide another important contribution to science and technology policy studies in Turkey.

Third, due to the small number of nanotechnology firms and the differences among firms in size and industry we could not carry out a quantitative analysis at the firm level. A questionnaire survey and a quantitative study to confirm our findings about the factors influencing firms in their decision to interact with universities are left for for further research.

In conclusion, this thesis has investigated the individual and organizational level factors at the sides of academia and industry which influence the formation of KTT linkages between these two spheres in the emerging field of nanotechnology inTurkey. It is the first study in Turkey which explores the university-industry relations in such a comprehensive manner in both universities and firms. Therefore, we believe that this thesis has made an important contribution to science and technology policy research in Turkey and also opened up some new perspectives of research on university-industry relations.

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APPENDICES

APPENDIX A

NANOTECHNOLOGY PATENT RESEARCH IN TPO DATABASE

Keywords for patent database research

Keywords
Selfassembl*
Self assembl*
Atomic force microscop*
Atomic-force-microscop*
Scanning tunneling microscop*
Scanning-tunneling-microscop*
Atomistic simulation
Biomotor
Molecular device
Molecular electronics
Molecular modeling
Molecular motor
Molecular sensor
Molecular simulation
Quantum computing
Quantum dot*
Quantum effect*
Nano*

Source: Huang et al., 2003

Table A.1 List of nanotechnology patents assigned to Turkish institutes or people resident in Turkey

Title	Assignee	IPC Codes
Fulleren, fullaren türleri türleri, karbon nanotup veya lipit nanotüp ile hazırlanmış/stabilize edilmiş lipozomlar	İSMAİL TUNCER DEĞİM	A61K 47/44 A61K 33/44 A61K 9/127
Aşırı sert karbon nano yapılar katarak alüminyum karışımlarının fiziko mekanik göstergelerini (parametre değerlerini) artırma metodu.	YÜKSEK TEKNOLOJİ MALZEMELERi ARAŞTIRMA VE GELİŞTİRME A.Ş.	C22C 1/02 B82B 1/00
lsıtıcılarda yenilik.	KUMTEL DAYANIKLI TÜKETİM MALLARI PLASTİK SANAYİ VE TİCARET A.Ş.	H05B 3/50
TiO2-ZnO nanokompozit film.	(DYO) DURMUŞ YAŞAR VE OĞULLARI BOYA, VERNİK VE REÇİNE FABRİKALARI	B01J 21/06 B01J 23/06
Biyoaktif uçucu yağ ve bileşenlerinin polimerleri ve elde ediliş yöntemi	TÜBİTAK-TÜRKİYE BİLİMSEL VE TEKNOLOJİK ARAŞTIRMA KURUMU	C08G 65/00 C12P 1/00 C12P 7/22
Karbonlu nano yapılar katarak kauçuk ve plastik ürünlerin fiziki ve mekanik göstergelerini artırma metodu.	YÜKSEK TEKNOLOJİ MALZEMELERİ ARAŞTIRMA VE GELİŞTİRME A.Ş.	C09C 1/48 C01B 31/06 C08K 3/04 B82B 3/00
Katalitik dönüştürücü	FORD OTOMOTİV SANAYİ ANONİM ŞİRKETİ	F02B 51/02
Katalitik malzeme nano-parçacıkları içeren karbon nanofiberler.	SABANCI ÜNİVERSİTESİ; TÜBİTAK	D01D 5/00 D01F 9/12
Anti mikrobiyal metal kaplı implantlar ve implantlara adapte edilebilen AC/DC sabit akım kaynağı	DR.KUTSAL DEVRİM SEÇİNTİ	A61F 2/02 A61B 17/00
Bir nano-parçacık yığınlaştırma yöntemi	YEDİTEPE ÜNİVERSİTESİ	B01J 13/00
Radyoiyot, radyoiyot işaretli urasil ve urasil glukuronit konjuge manyetik nanoparçacıklar	PERİHAN ÜNAK, EMİN İLKER MEDİNE (Ege Üniversitesi); SERHAN SAKARYA (Adnan Menderes Üniversitesi)	A61K 41/00
Süper-hidrofobik yüzey bileşimlerini hazırlama yöntemi, bu yöntem ile elde edilen yüzeyler ve onların kullanımı.	SABANCI ÜNİVERSİTESİ	D01D 5/00 C09D 127/12
Bir nano-takviyeli polimer çelik üretim yöntemi	İDRİS KAYNAK	B82B 3/00
İlaç taşıyıcısı olarak I-131 işaretli manyetik nanoparçacıklar	PERİHAN ÜNAK (Ege Üniversitesi); RECEP BEKİŞ (Dokuz Eylül Üniversitesi); KAĞAN DAĞDEVİREN (Dokuz Eylül Üniversitesi)	A61K 41/00 A61K 49/06
Antibakteriyel nano gümüş kaplı seramik hava ve/veya su filtresi	MEB METAL VE BİRLEŞİK SANAYİ VE TİCARET LİMİTED ŞİRKETİ	B01D 39/20
Katmanlı, yüzeyi desenli biyomalzemeler ve doku mühendisliği iskeleleri	VASIF NEJAT HASIRCI ODTÜ	C08J 5/18
Yüzeyde zenginleştirilmiş raman saçılmasına dayalı bir tanı yöntemi.	YEDİTEPE ÜNİVERSİTESİ	C12Q 1/00 C12Q 1/04
Fe-katkılı alumina seramiklerin üretimi ve bu seramiklerin karbon nanotüp büyütülmesinde kullanılması.	ENDER SUVACI, YASEMİN BOZKAYA (Anadolu Üniversitesi)	C04B 35/111 B82B 3/00
Nano boyutta gümüş içeren kompozisyonun cilt hastalıklarının tedavisinde ve/veya önlenmesinde kullanımı.	MEB METAL VE BİRLEŞİK SANAYİ VE TİCARET LİMİTED ŞİRKETİ	A61K 9/00
Özel örgülü kumaş yapısına sahip, bonel yay sistemli yatak	DOĞTAŞ DOĞANLAR MOBİLYA İMALAT SANAYİ TİCARET ANONİM ŞİRKETİ	D04B 1/00

Title	Assignee	IPC Codes
PVA/PAA polimer malzemelerden elektro-eğirme yöntemiyle antimikrobiyal etkili ve tedavi edici özellikli nanoelyaf yara materyalleri üretimi ve yöntemi	İBRAHİM USLU (Selçuk Üniversitesi); MEHMET LEVENT AKSU (Gazi Üniversitesi); ALİ GÜL (Gazi Üniversitesi); TUTKU CEREN KARABULUT; NESRİN ŞİR (Hacettepe Üniversitesi)	B82B 3/00
Görünür dalgaboyu aralığında optik modülasyon ve darbe üretimi sağlayan nano malzeme ve bunu içeren kuvantum modülatörü	HİLMİ VOLKAN DEMİR (Bilkent Üniversitesi)	H01S 5/026 H01S 5/34
Bölümleri bay ve bayan vücuduna göre farklılaştırılarak uygulanabilen yatak.	DOĞTAŞ DOĞANLAR MOBİLYA İMALAT SANAYİ TİCARET ANONİM ŞİRKETİ	A47C 23/00
Ezetimib nanokristallerinin hazırlanması için yöntem ve farmasötik formülasyonları.	LEVENT ÖNER (Hacettepe Üniversitesi); REYHAN NESLİHAN GÜRSOY (Hacettepe Üniversitesi); TUĞBA GÜLSÜN (Hacettepe Üniversitesi)	A61K 31/00 A61K 9/00
Non-iyonize radyasyonun etkisini azaltan, elektromanyetik dalga ekranlama özelliğine haiz kumaş	BOYTEKS TEKSTİL SANAYİ VE TİCARET A.Ş.	D06M 11/83
Fukoidan Multipartiküler İlaç Taşıyıcı Sistemleri.	ECZ. ALİ DEMİR SEZER	A61K 9/00
İleri Teknoloji Uygulamaları için Küçük Dielektrik Sabitli Kriptokristaller Ve Nanoyapılar	TÜBİTAK	B82B 3/00
Metal bir yüzey üzerine seçici absorplayıcı film kaplama yöntemi.	FİGEN KADIRGAN	C25D 5/14 F24J 2/48 F24J 2/46
Yüksek basınçlı homojenizatör ile nano-çinkoborat üretimi	MEHMET ÖZGÜR SEYDİBEYOĞLU	C01G 9/00 C01B 35/12 C09C 3/04 B01J 3/00
Hibridize olmamış probe'un PCR ortamından uzaklaştırılması	METİS BİYOTEKNOLOJi VE DIŞ TİCARET LİMİTED ŞİRKETİ; OĞUZ BALCI	C12Q 1/68
Görüntüleme ajanı olarak 99mTc işaretli magnetite nanoparçacıklar	PERİHAN ÜNAK, EMİN İLKER MEDİNE (Ege Üniversitesi); RECEP BEKİŞ (Dokuz Eylül Üniversitesi)	A61K 49/06 B82B 1/00 A61B 6/03 G01T 1/164
Tek çip üzerinde morötesi dalga boyu aralığında kuvantum modülatörü, dedektörü ve ışık kaynağı olarak çalışabilen aygıt.	HİLMİ VOLKAN DEMİR (Bilkent Üniversitesi); TUNCAY ÖZEL (Bilkent Üniversitesi); EMRE SARI (Bilkent Üniversitesi)	H01L 31/0203
Metal kaplı nano fiberler.	SABANCI ÜNİVERSİTESİ	D01F 6/38 D01F 6/42 D06M 11/83 D01D 5/00
Nanotek saksı.	BEY-OM-SİN ÖZEL SAĞLIK HİZMETLERİ ELEKTRİK ELEKTRONİK İLETİŞİM NANO TEKNOLOJİ SANAYİ VE TİCARET LİMİTED ŞİRKETİ	A01G 9/02
Bir boya ve üretim yöntemi.	DURMUŞ YAŞAR VE OĞULLARI BOYA VERNİK VE REÇİNE FABRİKALARI ANONİM ŞİRKETİ	C09C 1/00 C09D 1/00
Güneş gözlük camlarının Pb2O3 kaplanması	FİKRET GÜLER	G02B 1/10 G02C 7/10
Yakıt tankları, depoları, tüpleri ve patlamayan gaz.	PESTGO ELEKTRONİK VE KİMYA TEKNOLOJİSİ ARAŞTIRMA GELİŞTİRME DANIŞMANLIK SAN. VE TİC. LTD.ŞTİ.	F17C 1/00
Fotoluminesant nanomalzeme ile güneş pillerinin verimliliğinin artırılması	HİLMİ VOLKAN DEMİR (Bilkent Üniversitesi); İBRAHİM MURAT SOĞANCI (Bilkent Üniversitesi); EVREN MUTLUGÜN (Bilkent Üniversitesi)	H01L 31/055
Motor yağı katkısı.	FORD OTOMOTİV SANAYİ ANONİM ŞİRKETİ	C10M 125/00

APPENDIX B

SET OF KEYWORDS USED TO RETRIEVE NST PUBLICATION DATA IN SCI

1	CU=Turkey AND TS= (NANOPARTICLE* OR NANOTUB* OR NANOSTRUCTURE* OR NANOCOMPOSITE* OR NANO-COMPOSITE* OR NANOWIRE* OR NANOCRYSTAL* OR NANOFIBER* OR NANOFIBRE* OR NANOSPHERE* OR NANOROD* OR NANOTECHNOLOG* OR NANOCLUSTER* OR NANOCAPSULE* OR NANOMATERIAL* OR NANOFABRICAT* OR NANOPOR* OR NANOPARTICULATE* OR NANOPHASE OR NANOPOWDER* OR NANOLITHOGRAPHY OR NANO-PARTICLE* OR NANODEVICE* OR NANODOT* OR NANOINDENT* OR NANO-INDENT* OR NANOLAYER* OR NANOSCIENCE OR NANOSIZE* OR NANO-SIZE* OR NANOSCALE* OR NANO-SCALE* OR NANOROBOT*) Databases=SCI-EXPANDED Timespan=All Years
2	CU=Turkey AND TS= (((NM OR NANOMETER* OR NANOMETRE*) SAME (SURFACE* OR FILM* OR GRAIN* OR POWDER* OR SILICON OR DEPOSITION OR LAYER* OR DEVICE* OR CLUSTER* OR CRYSTAL* OR MATERIAL* OR SUBSTRATE* OR STRUCTURE* OR ROUGHNESS OR MONOLAYER* OR RESOLUTION OR PARTICLE* OR ATOMIC FORCE MICROSCOP* OR TRANSMISSION ELECTRON MICROSCOP* OR SCANNING TUNNELING MICROSCOP*))) Databases=SCI-EXPANDED Timespan=All Years
3	CU=Turkey AND TS= ((AFM OR ATOMIC FORCE MICROSCOP* OR SCANNING ELECTRON MICROSCOP* OR SEM OR SCANNING TUNNELING MICROSCOP* OR STM OR SELF-ASSEMBL* OR SELF-ORGANIZ* OR TRANSMISSION ELECTRON MICROSCOP* OR TEM) SAME (SURFACE* OR FILM* OR LAYER* OR SUBSTRATE* OR ROUGHNESS OR MONOLAYER* OR MOLECUL* OR STRUCTURE* OR RESOLUTION OR ETCH* OR GROW* OR SILICON OR SI OR DEPOSIT* OR PARTICLE* OR FORMATION OR TIP OR ATOM* OR GOLD OR AU OR POLYMER* OR COPOLYMER* OR GAAS OR INAS OR SUPERLATTICE* OR ADSORPTION OR ADSORB* OR ISLAND* OR SIZE OR POWDER* OR RESOLUTION OR QUANTUM OR MULTILAYER* OR ARRAY* OR NANO*)) Databases=SCI-EXPANDED Timespan=All Years
4	CU=Turkey AND TS= ((NSOM OR CHEMICAL VAPOR DEPOSITION OR CVD OR CHEMICAL VAPOUR DEPOSITION OR X-RAY PHOTOELECTRON SPECTROSCOPY OR DIFFERENTIAL SCANNING CALORIMETRY OR X-RAY DIFFRACTION OR XRD OR SURFACE PLASMON RESONANCE OR "NEAR" FIELD SCANNING OPTICAL MICROSCOP*) SAME (SURFACE* OR FILM* OR LAYER* OR SUBSTRATE* OR ROUGHNESS OR MONOLAYER* OR MOLECUL* OR STRUCTURE* OR RESOLUTION OR ETCH* OR GROW* OR SILICON OR SI OR DEPOSIT* OR PARTICLE* OR FORMATION OR TIP OR ATOM* OR GOLD OR AU OR POLYMER* OR COPOLYMER* OR GAAS OR INAS OR SUPERLATTICE* OR ADSORPTION OR ADSORB* OR ISLAND* OR SIZE OR POWDER OR RESOLUTION OR QUANTUM OR MULTILAYER* OR ARRAY* OR NANO*)) Databases=SCI-EXPANDED Timespan=All Years

5	CU=Turkey AND TS= (NANOMECHANICAL OR NANOELECTRONIC* OR NANOHARDNESS OR NANORIBBON* OR NANOBELT* OR NANOGRAIN* OR NANOCABLE* OR NANOCHANNEL* OR NANOSHEET* OR NANODIAMOND* OR NANOMAGNET* OR NANODISK* OR NANOSHELL* OR NANOCONTACT* OR NANOREACTOR* OR NANOIMPRINT* OR NANOHOLE* OR NANOWHISKER* OR NANOCHEMISTRY OR NANOGRAPHITE OR NANOELECTRODE* OR NANOGRANULAR OR NANOFOAM* OR NANOMETER-SIZE* OR NANOCOLLOID* OR NANORING* OR NANOPHOTONIC* OR NANOSENSOR* OR NANOELECTROSPRAY* OR NANOBRIDGE* OR NANOMETER-SCALE* OR NANOBIO* OR BIONANO* OR HIPCO) Databases=SCI-EXPANDED Timespan=All Years
6	CU=Turkey AND TS= (MOLECUL* MOTOR* OR MOLECUL* RULER* OR MOLECUL* DEVICE* OR MOLECULAR ENGINEERING OR MOLECULAR ELECTRONIC* OR COULOMB STAIRCASE* OR QUANTUM DOT* OR QUANTUM WELL* OR QUANTUM WIRE* OR COULOMB BLOCKADE* OR MOLECULAR WIRE*) Databases=SCI-EXPANDED Timespan=All Years
7	CU=Turkey AND SO= (BULK "AND" GRADED NANOMETALS OR CURRENT NANOSCIENCE OR FROM NANOPOWDERS TO FUNCTIONAL MATERIALS OR FULLERENES NANOTUBES "AND" CARBON NANOSTRUCTURES OR FULLERENES NANOTUBES "AND" CARBON NANOSTRUCTURES OR FUNCTIONAL MOLECULAR NANOSTRUCTURES OR IEEE TRANSACTIONS ON NANOBIOSCIENCE OR IEEE TRANSACTIONS ON NANOTECHNOLOGY OR INORGANIC POLYMERIC NANOCOMPOSITES "AND" MEMBRANES OR JOURNAL OF COMPUTATIONAL "AND" THEORETICAL NANOSCIENCE OR JOURNAL OF NANOPARTICLE RESEARCH OR JOURNAL OF NANOSCIENCE "AND" NANOTECHNOLOGY OR MICROSYSTEM TECHNOLOGIES MICRO "AND" NANOSYSTEMS INFORMATION STORAGE "AND" PROCESSING SYSTEMS OR NANO LETTERS OR NANOPOROUS MATERIALS IV OR NANOTECHNOLOGY OR ON THE CONVERGENCE OF BIO INFORMATION ENVIRONMENTAL ENERGY SPACE "AND" NANO TECHNOLOGIES PTS 1 "AND" 2 OR PHYSICA E LOW DIMENSIONAL SYSTEMS NANOSTRUCTURES OR PRECISION ENGINEERING JOURNAL OF THE INTERNATIONAL SOCIETIES FOR PRECISION ENGINEERING "AND" NANOTECHNOLOGY OR SYNTHESIS "AND" REACTIVITY IN INORGANIC METAL ORGANIC "AND" NANO METAL CHEMISTRY) Databases=SCI-EXPANDED Timespan=All Years
8	CU=Turkey AND AD= (NANO* NOT NANOPHOTON*) Databases=SCI-EXPANDED Timespan=All Years
9	#1 or #2 or #3 or #4 or #5 or #6 or #7 or #8 Databases=SCI-EXPANDED Timespan=All Years
10	#9 AND PY=2000-2009 Databases=SCI-EXPANDED Timespan=All Years

APPENDIX C

NUTS LEVEL 2 REGIONS IN TURKEY

REGION	***CITIES IN THE REGION***
TR1	İSTANBUL
TR2	TEKİRDAĞ, EDİRNE, KIRKLARELİ, BALIKESİR, ÇANAKKALE
TR3	İZMİR, AYDIN, DENİZLİ, MUĞLA, MANİSA, AFYON, KÜTAHYA, UŞAK
TR4	BURSA, ESKİŞEHİR, BİLECİK, KOCAELİ, SAKARYA, DÜZCE, BOLU, YALOVA
TR5	ANKARA, KONYA, KARAMAN
TR6	ANTALYA, ISPARTA, BURDUR, ADANA, MERSİN, HATAY, KAHRAMANMARAŞ, OSMANİYE
TR7	(KIRIKKALE, AKSARAY, NİĞDE, NEVŞEHİR, KIRŞEHİR, KAYSERİ, SİVAS, YOZGAT
TR8	ZONGULDAK, KARABÜK, BARTIN, KASTAMONU, ÇANKIRI, SİNOP, SAMSUN, TOKAT, ÇORUM, AMASYA
TR9	DOĞU KARADENİZ (TRABZON, ORDU, GİRESUN, RİZE, ARTVİN, GÜMÜŞHANE)
TRA	ERZURUM, ERZİNCAN,BAYBURT, AĞRI, KARS, IĞDIR, ARDAHAN
TRB	MALATYA, ELAZIĞ, BİNGÖL, TUNCELİ, VAN, MUŞ, BİTLİS, HAKKARİ
TRC	GAZİANTEP, ADIYAMAN, KİLİS, ŞANLIURFA, DİYARBAKIR, MARDİN, BATMAN, ŞIRNAK, SİİRT

APPENDIX D

SURVEY QUESTIONNAIRE

S.0 KİŞİSEL BİLGİLER

[X-3] Üniversite: _______________________________

[X-4] Fakülte / Bölüm: _______________________________

[X-5] Doktora derecesini aldığınız yıl: __________________________

[X-6_7] Doktora derecesini aldığınız üniversite / bölüm: __________________________ /

Lisans derecesini aldığınız bölüm: __________________________

[X-9] Akademik unvanınız: __________________________

[X-10] Cinsiyet: 1( ) Kadın 2( ) Erkek

S1. Aşağıdaki tabloda üniversiteden sanayiye bilgi ve teknoloji aktarımını sağlayan başlıca kanal ve aktiviteler sıralanmıştır. NANOTEKNOLOJİ alanında yaptığınız çalışmaları göz önünde bulundurarak, son 5 yıl içinde aşağıda listelenen aktiviteleri ne sıklıkta gerçekleştirdiğinizi verilen ölçeğe göre işaretleyiniz.

		Hiç	**Nadiren**	**Arada sırada**	**Sık**	**Çok sık**
[X-12]	1.1 Firmalardan gelen talep doğrultusunda yapılan, firmaya özel araştırmalar	1( )	2( )	3( )	4( )	5( )
[X-13]	1.2 Firmalar için yapılan testler	1( )	2( )	3( )	4( )	5( )
[X-14]	1.3 Sanayi ile ortak araştırma projeleri yapılması	1( )	2( )	3( )	4( )	5( )
[X-15]	1.4 Firmaların üniversitelerdeki nanoteknoloji laboratuvar, ekipman ve alt yapısından yararlanmaları	1( )	2( )	3( )	4( )	5( )
[X-16]	1.5 Firmalardan katılımcıların da olduğu seminer, konferans, kongre ve toplantılara katılım	1( )	2( )	3( )	4( )	5( )
[X-17]	1.6 SAN-TEZ (Sanayi tezleri) projeleri yürütülmesi	1( )	2( )	3( )	4( )	5( )
[X-18]	1.7 Aynı zamanda firmalarda çalışan yüksek lisans ve doktora öğrencilerine tez danışmanlığı yapılması	1( )	2( )	3( )	4( )	5( )
[X-19]	1.8 Sanayideki araştırmacılar ile ortak bilimsel makaleler yazılması	1( )	2( )	3( )	4( )	5( )
[X-21]	1.9 Sanayideki araştırmacılar ile ortaklaşa yüksek lisans veya doktora tez danışmanlığı yapılması	1( )	2( )	3( )	4( )	5( )
[X-22]	1.10 Sanayide çalışan mezun öğrencileriniz ile kişisel ilişkiler yoluyla bilgi paylaşılması	1( )	2( )	3( )	4( )	5( )
[X-23]	1.11 Sanayide çalışan (öğrencileriniz dışında) uzmanlarla kişisel ilişkiler yoluyla bilgi paylaşılması	1( )	2( )	3( )	4( )	5( )
[X-24]	1.12 Diğer (lütfen kısaca açıklayınız)	1( )	2( )	3( )	4( )	5( )

S2. <u>NANOTEKNOLOJİ</u> alanında <u>son 5 yıl içinde</u> yaptığınız çalışmaları göz önünde bulundurarak, aşağıdaki soruları yanıtlayınız.

S2.1. Herhangi bir patent ya da patent başvurusunda buluş sahibi olarak yer aldınız mı? [X-25]

1( ) Evet **-----→ EVET ise, kaç tane?** [X-26] ....

2( ) Hayır ----→ **<u>LÜTFEN SORU 2.4'E GEÇİNİZ</u>**

S2.2. Türkiye'den herhangi bir firma ile ortak patentiniz ya da patent başvurunuz var mı? [X-27]

1( ) Evet **-----→ EVET ise, kaç tane?** [X-28] ....
2( ) Hayır

S2.3. <u>Eğer patent alınmışsa</u>, patent ya da patentlere ilişkin Türkiye'de herhangi bir firma ile lisans anlaşması yapıldı mı? [X-29]

1( ) Evet 2( ) Hayır 3( ) Patent başvuru yapıldı, ancak henüz alınmadı

<u>S.2.4. NANOTEKNOLOJİ</u> alanındaki çalışmalarınız doğrultusunda, aşağıda verilen proje tiplerine göre, <u>son beş yıl içinde</u>, firmalara ne sıklıkta danışmanlık yaptığınızı verilen ölçeğe göre belirtiniz.

		Hiç	**Nadiren**	**Arada sırada**	**Sık**	**Çok sık**
[X-30]	2.4.1 Firmaların kamu fonları (TÜBİTAK, DPT, Sanayi Bakanlığı gibi kurumlarca sağlanan) ile yürüttükleri projelerde	1( )	2( )	3( )	4( )	5( )
[X-31]	2.4.2 Firmaların Avrupa Birliği çerçeve programlarından aldıkları fonlarla yürüttükleri projelerde	1( )	2( )	3( )	4( )	5( )
[X-32]	2.4.3 Firmaların diğer uluslararası kuruluşlardan sağladıkları fonlarla yürüttükleri projelerde	1( )	2( )	3( )	4( )	5( )
[X-33]	2.4.4 Firmaların tamamen kendi fonları ile yürüttükleri projelerde	1( )	2( )	3( )	4( )	5( )

S.3.1. <u>Bugüne kadar</u> araştırma sonuçlarınızı ticarileştirmek amacıyla firma kurdunuz mu ya da bir firmaya ortak oldunuz mu? [X-35]

1( ) Evet-------→ **<u>LÜTFEN SORU 4'E GEÇİNİZ</u>**
2( ) Hayır
S.3.2. Araştırma sonuçlarınızı ticarileştirmek amacıyla bir firma kurmayı ne derece düşünürsünüz? [X-36]

1( ) Kesinlikle düşünmem 2( ) Düşünmem 3( ) Kararsızım

4( ) Düşünürüm 5 ( ) Kesinlikle düşünürüm

<u>S3.3. (S3.2'DE "DÜŞÜNÜRÜM" VEYA "KESİNLİKLE DÜŞÜNÜRÜM" CEVABI VERİLMİŞ İSE) Ne kadar yakın bir gelecekte firma kurmayı düşünürsünüz? [X-37]</u>

1( ) 2 yıl içinde 2( ) 5 yıl içinde 3( ) Henüz planlamadım

S3.4. <u>(S.3.2'DE "KARASIZIM", "DÜŞÜNMEM" VEYA "KESİNLİKLE DÜŞÜNMEM" CEVABI VERİLMİŞ İSE)</u> Araştırma sonuçlarınızın bir ya da bir kaçının ticari başarı kazanma olasılığının yüksek olduğunu fark ettiğiniz durumda, bu fırsatı değerlendirmek amacıyla firma kurmayı ne derece düşünürsünüz? [X-38]

1( ) Kesinlikle düşünmem
2( ) Düşünmem
3( ) Kararsızım
4( ) Düşünürüm
5( ) Kesinlikle düşünürüm

S4. NANOTEKNOLOJİ alanını göz önünde bulundurduğunuzda aşağıda listelenen faktörlerin, <u>SİZİ</u> sanayi ile işbirliği yapmaya yönlendirmek ve teşvik etmek konusunda <u>ne derece etkili</u> olduğunu lütfen belirtiniz.

		Hiç etkili değil	**Etkili değil**	**Ne etkili ne değil**	**Etkili**	**Çok etkili**	En etkili olduğunu düşündüğünüz 3 seçeneği 1,2,3 şeklinde sıralayınız **[X-55/57]**
[X-40]	4.1 Sanayinin üniversitelere yeni ürün fikirleri ile gelmesi, araştırmalar için yeni fikirler sağlaması	1( )	2( )	3( )	4( )	5( )	( )
[X-41]	4.2 Sanayinin, üniversitedeki araştırmalar sonucunda elde edilen bulgu/ ürün veya teknolojiye farklı bir bakış açısı getirmesi	1( )	2( )	3( )	4( )	5( )	( )
[X-42]	4.3 Üniversitedeki araştırma sonuçlarının uygulanabilirliğinin test edilmesi	1( )	2( )	3( )	4( )	5( )	( )
[X-43]	4.4 Üniversitedeki araştırma sonuçları için patent alınması, patentlenebilir araştırmalara ağırlık verilmesi	1( )	2( )	3( )	4( )	5( )	( )
[X-44]	4.5 Alınan patentler için firmalarla lisans anlaşması yapılması	1( )	2( )	3( )	4( )	5( )	( )
[X-45]	4.6 Üniversitedeki araştırma sonuçlarının ticarileştirilmesine yönelik iş fırsatları yaratması	1( )	2( )	3( )	4( )	5( )	( )
[X-47]	4.7 Üniversitedeki araştırmalar için yeni fonlar, kaynaklar sağlanması	1( )	2( )	3( )	4( )	5( )	( )
[X-48]	4.8 Yüksek lisans ve doktora öğrencilerinin tez çalışmalarının burs ve araştırma fonları yoluyla sanayi tarafından desteklenmesinin sağlanması	1( )	2( )	3( )	4( )	5( )	( )
[X-49]	4.9 Firmalarda çalışan araştırmacılar ile deneyimlerin ve bilgilerin paylaşımı	1( )	2( )	3( )	4( )	5( )	( )
[X-50]	4.10 Mezunlar için iş ve çalışma olanaklarının artırılması	1( )	2( )	3( )	4( )	5( )	( )
[X-51]	4.11 Üniversitelerde mevcut laboratuvar ve teknik donanımın yenilenmesi, geliştirilmesi, alt yapı ihtiyaçlarının giderilmesi	1( )	2( )	3( )	4( )	5( )	( )
[X-52]	4.12 Firmaların sahip olduğu teknik donanımlardan ve olanaklardan yararlanılması; firmaların özel donanım ve teknolojilerine ulaşılması	1( )	2( )	3( )	4( )	5( )	( )
[X-53] [X-54]	4.13 Diğer (lütfen kısaca açıklayınız)	1( )	2( )	3( )	4( )	5( )	( )

S5. NANOTEKNOLOJİ alanında sanayi ile kurduğunuz ilişkileri göz önünde bulundurduğunuzda, sanayi ile ilişkilerin üniversitede yaptığınız çalışmalarınıza aşağıda sıralanan katkıları ne ölçüde sağladığını belirtiniz.

		Hiç katkı sağlamadı	**Pek katkı sağlamadı**	**Ne katkı sağladı ne sağlamadı**	**Katkı sağladı**	**Çok katkı sağladı**
[X-59]	5.1 Sanayinin üniversitelere yeni ürün fikirleri ile gelmesi, araştırmalar için yeni fikirler sağlaması	1( )	2( )	3( )	4( )	5( )
[X-60]	5.2 Sanayinin, üniversitedeki araştırmalar sonucunda elde edilen bulgu/ ürün veya teknolojiye farklı bir bakış açısı getirmesi	1( )	2( )	3( )	4( )	5( )
[X-61]	5.3 Üniversitedeki araştırma sonuçlarının uygulanabilirliğinin test edilmesi	1( )	2( )	3( )	4( )	5( )
[X-62]	5.4 Üniversitedeki araştırma sonuçları için patent alınması, patentlenebilir araştırmalara ağırlık verilmesi	1( )	2( )	3( )	4( )	5( )
[X-63]	5.5 Alınan patentler için firmalarla lisans anlaşması yapılması	1( )	2( )	3( )	4( )	5( )
[X-64]	5.6 Üniversitedeki araştırma sonuçlarının ticarileştirilmesine yönelik iş fırsatları yaratması	1( )	2( )	3( )	4( )	5( )
[X-66]	5.7 Üniversitedeki araştırmalar için yeni fonlar, kaynaklar sağlanması	1( )	2( )	3( )	4( )	5( )
[X-67]	5.8 Yüksek lisans ve doktora öğrencilerinin tez çalışmalarının burs ve araştırma fonları yoluyla sanayi tarafından desteklenmesinin sağlanması	1( )	2( )	3( )	4( )	5( )
[X-68]	5.9 Firmalarda çalışan araştırmacılar ile deneyimlerin ve bilgilerin paylaşımı	1( )	2( )	3( )	4( )	5( )
[X-69]	5.10 Mezunlar için iş ve çalışma olanaklarının artırılması	1( )	2( )	3( )	4( )	5( )
[X-70]	5.11 Üniversitelerde mevcut laboratuvar ve teknik donanımın yenilenmesi, geliştirilmesi, alt yapı ihtiyaçlarının giderilmesi	1( )	2( )	3( )	4( )	5( )
[X-71]	5.12 Firmaların sahip olduğu teknik donanımlardan ve olanaklardan yararlanılması; firmaların özel donanım ve teknolojilerine ulaşılması	1( )	2( )	3( )	4( )	5( )
[X-72] [X-73]	5.13 Diğer (lütfen kısaca açıklayınız)	1( )	2( )	3( )	4( )	5( )

S6. Üniversite-sanayi ilişkilerini olumsuz etkileyen hatta engelleyen pek çok faktör aşağıdaki listede sıralanmıştır. NANOTEKNOLOJİ alanındaki çalışmalarınızı göz önünde bulundurarak bu faktörlerin SİZİ sanayi ile işbirliği yapmak konusunda olumsuz yönde etkilediğine veya engellediğine ne ölçüde katıldığınızı belirtiniz.

		Kesinlikle KATILMIYORUM	**Katılmıyorum**	**Ne katılıyorum ne katılmıyorum**	**Katılıyorum**	**Kesinlikle KATILIYORUM**
[X-75]	6.1 Üniversitelerdeki araştırmaların uygulamaya yönelik olmaması	1( )	2( )	3( )	4( )	5( )
[X-76]	6.2 Üniversitelerdeki araştırmaların ticarileştirilebilmesinin birçok akademik disiplinin işbirliğini gerektirmesi	1( )	2( )	3( )	4( )	5( )
[X-77]	6.3 Üniversitelerde sanayi ile ilişkileri kuracak ve devamlılığını sağlayacak örgütsel yapıların (teknoloji transfer ofisleri gibi) yeterli olmaması	1( )	2( )	3( )	4( )	5( )
[X-78]	6.4 Üniversitelerdeki araştırmaların sonuçlarının ticarileştirilebilmesine ilişkin belirsizlikler	1( )	2( )	3( )	4( )	5( )
[X-79]	6.5 Sanayi ile ilişkilere ayrılan zaman nedeniyle akademik faaliyetlerin aksayacak olması	1( )	2( )	3( )	4( )	5( )
[X-80]	6.6 Üniversite-sanayi işbirliğini teşvik edici kamu fonlarının yeterli olmaması	1( )	2( )	3( )	4( )	5( )
[X-81]	6.7 Firmaların üniversitelerdeki araştırmaları hayata geçirmek için yeterli kaynaklara (teknoloji, eğitimli personel gibi) sahip olmamaları	1( )	2( )	3( )	4( )	5( )
[X-82]	6.8 Firmaların üniversitelerdeki nanoteknoloji araştırmaları hakkında bilgi sahibi olmamaları	1( )	2( )	3( )	4( )	5( )
[X-84]	6.9 Firmaların henüz geleneksel üretim yöntemleri ve ürünleri terk ederek bu alana yatırım yapmayı tercih etmemeleri	1( )	2( )	3( )	4( )	5( )
[X-85]	6.10 Fikri mülkiyet hakları konusunda firmalarla yaşanabilecek problemler	1( )	2( )	3( )	4( )	5( )
[X-86]	6.11 Firmaların ihtiyaç duyduğu alandaki araştırmaların, akademik araştırmalar için yeteri kadar cazip olmaması	1( )	2( )	3( )	4( )	5( )
[X-87]	6.12 Firmalar için yapılan araştırmalarda firmanın gizlilik talebi ve akademik yayına izin vermeyişi	1( )	2( )	3( )	4( )	5( )

[X-88]	6.13 Firma ve üniversitelerin farklı çalışma ortamı, örgütsel yapı dolayısıyla farklı kurumsal ve kültürel geleneklere sahip olmaları	1( )	2( )	3( )	4( )	5( )
[X-89]	6.14 Sanayinin üniversiteyi bilimsel bilgi kaynağı olarak değil bir iş ortağı gibi düşünmesi; beklentilerinin üniversitenin verebileceğinden farklı olması	1( )	2( )	3( )	4( )	5( )
[X-90]	6.15 Üniversiteler ve sanayi arasında iletişimi sağlayacak kanalların yeterli olmaması	1( )	2( )	3( )	4( )	5( )
[X-91]	6.16 Firma yöneticileri ve akademisyenlerin araştırma projelerine ilişkin maliyet, verimlilik, proje takvimi gibi konularda farklı bakış açıları ve önceliklere sahip olmaları	1( )	2( )	3( )	4( )	5( )
[X-92] [X-93]	6.17 Diğer (lütfen kısaca açıklayınız)	1( )	2( )	3( )	4( )	5( )

S7. Bu bölüm akademik çalışmalarınızın tümüne ilişkin soruları içermektedir.

7.1. Science Citation Index (SCI)'e giren makalelerinizin sayısı (son beş yıl) [X-95]:

....

7.2. Sanayi çalışanları ile ortak yazdığınız makalelerinizin (eğer varsa) sayısı [X-96]**:**

....

7.3. Son 5 yıl içinde yürütücüsü olduğunuz ya da görev aldığınız tüm ulusal (BAP projeleri hariç) ve uluslararası araştırma projelerinizin sayısı

Ulusal [X-97]: ....   Uluslararası [X-98]:...................................

7.4. Son 5 yıl içindeki araştırmalarınızı göz önünde bulundurduğunuzda, aşağıdaki fon tiplerinin araştırma bütçelerinizdeki payını lütfen belirtiniz.

[X-99]	7.4.1 Türkiye'deki firmalardan sağlanan araştırma fonları	%...........
[X-100]	7.4.2 Kamu kurum ve kuruluşları (TÜBİTAK, DPT, Sanayi Bakanlığı gibi) tarafından sağlanan araştırma fonları	%...........
[X-101]	7.4.3 Çalıştığınız üniversite tarafından sağlanan araştırma fonları	%...........
[X-102]	7.4.4 Avrupa Birliği tarafından sağlanan araştırma fonları	%...........
[X-103]	7.4.5 Yurtdışındaki üniversiteler, araştırma enstitüleri, firmalar ya da diğer kurumlardan ortak araştırmalar için sağlanan fonlar	%...........
[X-104]	7.4.6 Diğer fon kaynakları	%...........
[X-105]	**TOPLAM**	**%100**

7.5. Aşağıda listelenen akademik faaliyetlere, son dönemde, haftalık çalışma sürenizin yaklaşık yüzde kaçını ayırdığınızı lütfen belirtiniz.

[X-106]	Araştırma	%...........
[X-107]	Dersler	%...........
[X-108]	Tez yönetimi	%...........
[X-109]	Diğer görevler	%...........
[X-110]	**TOPLAM**	**%100**

7.6 Akademik araştırma projelerinizi amaçları açısından gruplandırdığınızda, aşağıda verilen gruplardan size uygun olanları en çok zaman ayırdığınız araştırmalardan en aza doğru lütfen sıralayınız. (ZAMAN AYIRMADIĞINIZ GRUPLAR VAR İSE ONLARI LÜTFEN BOŞ BIRAKINIZ)

		Sıra no
[X-111]	A- Yeni teori ve bilimsel bilgi geliştirme	( )
[X-112]	B- Mevcut teorilerin geliştirilmesi	( )
[X-113]	C- Uygulamaya yönelik bilgi geliştirilmesi	( )
[X-114]	D- Mevcut bilgiden yararlanarak yeni malzeme, ürün veya cihaz üretmek	( )
[X-115]	E- Mevcut bilgiden yararlanarak var olan malzeme, ürün ve cihazları geliştirmek	( )

S8. Bu bölüm sadece NANOTEKNOLOJİ alanındaki akademik çalışmalarınıza ilişkin soruları içermektedir.

8.1. Nanoteknoloji alanındaki çalışmalarınızın tüm akademik çalışmalarınızın içindeki payı ne kadardır? [X-116]

1( ) Çok fazla değil 2( ) Fazla değil 3( ) Ne fazla ne değil 4( ) Fazla

5( ) Çok fazla

8.2. Nanoteknoloji ile ilk olarak kaç yıl önce ilgilenmeye başladığınızı lütfen belirtiniz [X-117] **.** ....

8.3. Nanoteknoloji alanında son 5 yıl içinde danışmanlığını yaptığınız *(halen devam edenler de dahil)* yüksek lisans ve doktora tezlerinin sayısını lütfen belirtiniz [X-118] **.** ....

8.4. Nanoteknoloji alanında yaptığınız çalışmaları göz önünde bulundurduğunuzda, bu araştırmalarınızın ne ölçüde sanayinin ihtiyaçlarına ve beklentilerine uygun olduğunu düşünüyorsunuz? [X-119]

1( ) Çok uygun değil 2( ) Uygun değil 3( ) Ne uygun ne değil 4( ) Uygun

5( )Çok uygun 6( ) Fikri yok

8.5. (S8.4'DE "NE UYGUN NE DEĞİL", "UYGUN" VEYA "ÇOK UYGUN" CEVABI VERİLMİŞ İSE) Nanoteknoloji alanındaki araştırmalarınızın sonuçlarının hangi sektör ya da sektörlerde ağırlıklı olarak kullanılabileceğini düşünüyorsunuz? [X-120]

.... / .... /
....

8.6. Nanoteknoloji alanında yürüttüğünüz son 3 araştırma projesini göz önünde bulundurduğunuzda, araştırma sonuçlarının Türkiye'deki firmalar tarafından kullanılabilmesi için aşağıdakilerden hangisine ihtiyaç olduğunu düşünüyorsunuz? (Birden fazla seçenek işaretlenebilir) [X-121]

1( ) Ticarileştirilme aşamasında, finansman sağlanması halinde üretim sürecine başlanabilir
2( ) Ticarileştirilebilir fakat yeni bir üretim tekniği /süreci gerektiriyor.
3( ) Ticarileştirilebilir fakat yeni bir hammaddenin kullanımını gerektiriyor
4( ) Ticarileştirilebilir fakat bazı testlerden geçmesi gerekiyor
5( ) Henüz ticarileştirilebilecek bir düzeyde değil, araştırmalar devam ediyor
6( ) Ticarileştirilme olanağı yok.
( ) Diğer (lütfen kısaca belirtiniz) ....

S9. Bu bölüm görev yaptığınız üniversite ile ilgili soruları içermektedir.

9.1. Görev yaptığınız üniversitede nanoteknoloji araştırma merkezi, çalışma grubu ya da laboratuvarı var mı?
[X-123]
1( ) Evet 2( ) Hayır

9.2. Görev yaptığınız üniversitenin nanoteknoloji alanında yüksek lisans ve / veya doktora programları var mı? [X-124]
1( ) Evet 2( ) Hayır

(9.1 ve 9.2 SORULARININ HER İKİSİNE DE "HAYIR" YANITI VERİLMİŞSE 9.4'E GEÇİNİZ)

9.3 Üniversitenizdeki nanoteknoloji araştırma merkezi, çalışma grubu ya da yüksek lisans/doktora programlarında şu anda görevli misiniz ya da hiç görev aldınız mı? [X-125]

1( ) Evet ----------→ **9.3.1. EVET ise kaç ay?** [X-126] ....

2( ) Hayır

9.4. Üniversite-sanayi ilişkilerinin çalıştığınız üniversite tarafından (özellikle firma ile ilişkilerin kurulması ve devamlılığı, ilişkiler sırasında çıkabilecek problemlerin çözümü konusunda) ne ölçüde desteklendiğini lütfen belirtiniz. [X-127]
1( ) Hiç desteklenmiyor
2( ) Pek desteklenmiyor
3( ) Ne destekleniyor ne desteklenmiyor
4( ) Destekleniyor
5( ) Çok destekleniyor
6( ) Fikri yok

S10. Bu bölüm nanoteknoloji alanında çalışan diğer akademisyen ve uzmanlarla olan ilişkilerinize ilişkin sorular içermektedir.

10.1 Nanoteknoloji alanında kendi üniversiteniz ya da Türkiye'deki başka üniversitelerde çalışan, bildiğiniz tanıdığınız akademisyenleri göz önünde bulundurduğunuzda bu meslektaşlarınızın sanayi ile ilişkilerinin genel olarak ne düzeyde olduğunu belirtir misiniz? [X-128]

1( ) Çok güçlü değil2( ) Güçlü değil 3( ) Ne güçlü ne değil 4( ) Güçlü 5( )Çok güçlü

6( ) Fikri yok

10.2 Nanoteknoloji alanında kendi üniversiteniz ya da Türkiye'deki başka üniversitelerde çalışan, bildiğiniz tanıdığınız akademisyenler arasında araştırma sonuçlarını ticarileştirmek amacıyla firma kurma ya da bir firmaya ortak olma girişiminde bulunanlar var mı? [X-129]

1( ) Evet 2( ) Hayır

10.3 Aşağıda belirtilen organizasyonlarda görevli nanoteknoloji alanında çalışan araştırmacılar ile ne sıklıkta kişisel olarak görüştüğünüzü *(yüz yüze, e-mail, e-mail grubu ya da telefon ile yapılan görüşmeleri de dahil ederek)* lütfen belirtiniz.

		Hiç	**Nadiren**	**Arada sırada**	**Sık**	**Çok sık**
[X-131]	10.3.1 Türkiye'deki diğer üniversitelerde görevli akademisyenler	1( )	2( )	3( )	4( )	5( )
[X-132]	10.3.2 Yurtdışındaki üniversite ve araştırma enstitülerindeki akademisyen ve araştırmacılar	1( )	2( )	3( )	4( )	5( )
[X-133]	10.3.3 Türkiye'deki kamu kurumlarında (TÜBİTAK, DPT, Sanayi Bakanlığı ya da diğer bakanlıklar gibi) görevli uzmanlar	1( )	2( )	3( )	4( )	5( )
[X-134]	10.3.4 Türkiye'de faaliyet gösteren firmalarda çalışan araştırmacı ve uzmanlar	1( )	2( )	3( )	4( )	5( )
[X-135]	10.3.5 Sanayi ve meslek odaları, dernekler gibi sivil toplum örgütlerindeki uzmanlar	1( )	2( )	3( )	4( )	5( )

10.4 Firmalarla kurduğunuz ilişkilerin tümünü göz önünde bulundurduğunuzda, bu bağlantıların ilk olarak kim tarafından kurulduğunu lütfen belirtiniz. [X-136]

1( ) Benim tarafımdan
2( ) Firma tarafından
3( ) Üniversitemizdeki diğer akademisyenler tarafından
4( ) Başka üniversitelerde görevli tanıdığım akademisyenler tarafından
( ) Diğer (lütfen kısaca açıklayınız)____________________________________
6( ) Firma bağlantım yok

APPENDIX E

SEMI-STRUCTURED INTERVIEW GUIDE

1) Firmanızdaki nanoteknoloji AR-GE çalışmaları ile ilgili bilgi verebilir misiniz? AR-GE çalışmaları kaç yıldır devam ediyor? AR-GE çalışmaları ticarileştirme aşamasına geldi mi? AR-GE çalışmalarının ne kadarı firma içinde yürütülüyor? Dışardan AR-GE desteği alınıyorsa ne amaçla alınıyor?
2) Üniversitelerde ve araştırma merkezlerinde görevli akademisyenler ile ilişkiler hangi kanallardan iletişim kuruluyor? Bu ilişkiler ne kadar güçlü?
3) Hangi amaçla ya da hangi nedenlerle üniversitelerle ilişki kuruluyor ya da kurulması hedefleniyor?
4) Üniversitelerle ilişki kurmanın firmanın nanoteknoloji AR-GE çalışmalarına katkıları nelerdir?
5) Ülkemizde, üniversite sanayi ilişkilerinin kurulması ve geliştirilmesi konusunda en önemli engeller nelerdir?
6) Üniversitedeki araştırmacılar ya da üniversitelerin hangi yetkinlik ve kurumsal yeterliliklere sahip olması nanoteknoloji alanında üniversite-sanayi ilişkilerini güçlendirir ve bilgi-teknoloji transferini hızlandırır?
7) Üniversiteler dışında nanoteknoloji alanında başka hangi kişi ve kurumlarla iş birliği yapılıyor? Bu işbirliklerinin nanoteknoloji AR-GE ve ürün geliştirme çalışmalarına katkısı üniversitelerle karşılaştırıldığında nasıl?

8) Firma tarafından geliştirilen ürünlerin ticari bir ürüne dönüştürülmesinin önündeki temel problemler nelerdir? Firma tarafından ticareştirilen ya da başka firmalara transfer edilen teknoloji ve ürünler var mı?
9) Firmada kaç AR-GE personeli çalışmaktadır? Firma ortakları ve çalışanlar arasında şu an ya da daha önce akademide görev almış kişi / kişiler var mı? AR-GE çalışanları arasında kaç kişi nanoteknoloji alanında tam zamanlı olarak çalışıyor?
10) Firma nanoteknoloji alanındaki AR-GE projelerinin finansmanı için kamu fonlarından (TÜBİTAK TEYDEB, Sanayi Bakanlığı, gibi) ya da uluslararası fonlardan (AB projeleri gibi) yararlanıyor mu?
11) Firmanın nanoteknoloji alanında önümüzdeki beş yıla ilişkin planları, stratejileri var mı? Varsa neler yapılması planlanıyor?

APPENDIX F

PRINCIPAL COMPONENT FACTOR ANALYSIS

Principal component analysis (PCA) is a statistical technique that linearly transforms a set of variables into a substantially smaller set of uncorrelated variables which are called as principal components that represent most of the information in the original data set (Duntelman, 1989). The aim of the PCA is to reduce the dimensionality in a data set containing large number of interrelated variables while keeping the variation in the data set as much as possible (Joliffe, 2002). In other words, PCA transforms a set of correlated variables $(x_1, x_2, ..., x_p)$ to a set of principal components $(y_1, y_2, ..., y_p)$ in which y_1 explains the maximum possible of the total variance, y_2 explains the maximum possible of the remaining variance, and so on. Hence, while first few principal components account for a large part of the total variance, the full set of principal components explain the total variance. The proportion of variance explained by each principal component depends on the degree of correlation between xs (Bartholomew et al., 2008).

$$\sum_{j=1}^{p} \mathrm{var}(y_j) = \sum_{i=1}^{p} \mathrm{var}(x_i) \qquad \text{(Eq. E.1)}$$

Principal components are linear combinations of xs and can be written as follow:

$$y_1 = a_{11}x_1 + a_{21}x_2 + ... + a_{p1}x_p = \sum_{i=1}^{p} a_{1i}x_i \qquad \text{(Eq. E.2)}$$

$$y_2 = a_{12}x_1 + a_{22}x_2 + ... + a_{p2}x_p = \sum_{i=1}^{p} a_{2i}x_i \qquad \text{(Eq. E.3)}$$

.

$$y_p = a_{1p}x_1 + a_{2p}x_2 + ... + a_{pp}x_p = \sum_{i=1}^{p} a_{pi}x_i \qquad \text{(Eq. E.4)}$$

where $a_{ij}s$ are the weights or coefficients, and each component is a weighted sum of x s. To maximize the variance of y_1 requires the satisfaction of a constraint that the sum of the squared weights / coefficients is equal to one, i.e.

$$\sum_{i=1}^{p} a_{1i}^2 = 1 \qquad \text{(Eq. E.5)}$$

When the variance of y_1 is maximized the sum of the squared correlations between y_1 and x variables are also maximized, i.e. $\sum_{i=1}^{p} r_{y,x_i}^2$.

The second principal component y_2 is maximized subject to the constraint

$$\sum_{i=1}^{p} a_{2i}^2 = 1 \qquad \text{(Eq. E.6)}$$

However y_2 is required to be orthogonal to (uncorrelated with) y_1.

$$\sum_{i=1}^{p} a_{1i}a_{2i} = 0 \qquad \text{(Eq. E.7)}$$

Here the problem is to calculate a_{ij} and, thus the variances of principal components. The problem is easily solved because these weights / coefficients are exactly the elements of the (normalized) eigenvectors of a matrix which, in this case, is either the covariance or the correlation matrix. The calculated eigenvalues denoted by $(\lambda_1, \lambda_2, ..., \lambda_p)$ also indicate the variances of principal components (Duntelman, 1989; Bartholomew et al., 2008; Raykov and Marcoulides, 2008).

The eigenvalue calculated for each component equals to the proportion of total variance of original variables explained by this principal component. Therefore, determination of the number of principal components is simply based on eigenvalues. However there are various ways of determining the maximum number of principal components to extract. For example, the widely applied Kaiser criterion (Kaiser, 1960) recommends retaining principal components with eigenvalues greater than one. However, Joliffe (2002) argues that Kaiser criterion tends to throw too much information and therefore suggests a cutoff of 0.7 for eigenvalues. Cattell (1966), on the other hand, proposes using a scree graph of the eigenvalues to decide on the number of principal components to be retained. After plotting the eigenvalues against the number of components on the graph; starting with the first one the plot slopes steeply downward and then slowly becomes an approximately horizontal line. The point, k, where the line begins to straighten out, in other words, where the line is steep to the left of the point m, but not steep to the right of that point provides the maximum number of principal components to be retained. Another criteria is based on achieving a certain level of cumulative percentage of total variance. In this criteria, retaining m number of principal components which, in total, contribute 70-90 percent of total variance is the principal (Duntelman, 1989; Joliffe, 2002; Hair et al., 2006).

For the interpretation of retained principal components, sometimes the rotation of the components is preferred due to the simplicity it provides. Rotation of the principal components redistributes the variance explained by the retained components based on the argument that it is more important to interpret m-dimensional space defined by retained m number of principal components (Hair et al., 2006; Joliffe, 2002). Rotation does not change the relative positions of principal components loadings which are the correlation between original variables (xs) and the principal components but alters the loading themselves. Therefore interpretation of new principal components differ (Bartholomew et al., 2008). There are two procedures of rotation, i.e. orthogonal and oblique factor rotation. In orthogonal rotation, the new axes, like principal component axes, are perpendicular to one another (Duntelman, 1989). While in orthogonal rotation it is assumed that rotated principal components are mathematically independent, in oblique rotation the axes need not to be orthogonal, and thus principal components are not assumed to be uncorrelated with each other (Hair et al., 2006). Varimax rotation is the most popular orthogonal rotation procedure. Varimax procedure redistributes the explained variance in a way based on finding a very few number of principal components with high loadings and many with near-zero loadings. Hence, Varimax procedure gives a clearer separation of the principal components and provides a simple structure.

APPENDIX G

BINARY PROBIT ESTIMATIONS FOR GROUP 1 AND GROUP 2 NANOSCIENTISTS

Table F.1 Marginal effects: KTT activity for Group 1 and Group 2 nanoscientists

	Group 1≥8 articles			*Group 2<8 articles*		
	(1)	(2)	(3)	(1)	(2)	(3)
EXP	0.020	0.016	0.015	-0.012	-0.012	-0.017
	(1.38)	(1.00)	(0.99)	(1.38)	(1.14)	(1.60)
NSTPUB	-0.103	-0.132	-0.130	-0.058	-0.056	-0.046
	(3.84)***	(3.43)***	(3.99)***	(0.97)	(0.93)	(0.75)
NPATENT	0.088	0.008	0.016	0.181	0.172	0.191
	(1.93)*	(0.45)	(0.71)	(1.93)*	(2.15)**	(2.06)**
NPUBGRANT	-0.110		-0.129	0.462		0.389
	(0.48)		(0.53)	(3.10)***		(2.64)***
INDFUND		0.075	0.072		0.016	0.012
		(3.04)***	(2.98)***		(0.76)	(0.58)
APPL	0.643	0.819	0.805	0.099	0.048	0.070
	(2.81)***	(2.16)**	(2.45)**	(1.54)	(0.71)	(1.04)
NTWK	0.172	0.233	0.243	0.221	0.244	0.227
	(1.61)	(1.90)*	(1.86)*	(2.22)**	(2.39)**	(2.20)**
PEER	0.226	0.206	0.194	-0.047	0.007	-0.030
	(2.20)**	(1.87)*	(1.83)*	(0.59)	(0.09)	(0.37)
TOTCIT	0.000	0.000	0.000	-0.000	0.000	0.000
	(0.79)	(0.97)	(1.01)	(0.12)	(1.01)	(0.55)
INTCOLLAB	-0.963	-1.370	-1.403	-0.321	-0.367	-0.443
	(2.38)**	(2.42)**	(2.57)**	(1.22)	(1.36)	(1.63)
NSTINST	0.934	0.991	0.993	0.092	0.183	0.146
	(2.96)***	(2.86)***	(3.17)***	(0.62)	(1.20)	(0.95)
UNIVSUPP	0.140	0.180	0.182	0.101	0.098	0.116
	(1.38)	(1.27)	(1.42)	(1.55)	(1.52)	(1.63)
ENGINEERING	-0.074	0.188	0.158	0.425	0.210	0.361
	(0.24)	(1.17)	(0.91)	(2.38)**	(1.24)	(1.99)**
MOTIVECOMM	0.377	0.528	0.537	0.325	0.291	0.374
	(3.58)***	(2.67)***	(2.86)***	(3.57)***	(3.31)***	(3.89)***
Observations	61	61	61	74	70	70

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

Table F.2 Marginal effects: INFORMAL KTT activity for Group 1 and Group 2 nanoscientists

	Group 1≥8 articles			*Group 2<8 articles*		
	(1)	(2)	(3)	(1)	(2)	(3)
EXP	0.019	0.021	0.018	-0.008	-0.012	-0.013
	(1.80)*	(2.40)**	(1.92)*	(0.93)	(1.19)	(1.37)
NSTPUB	-0.063	-0.060	-0.065	-0.007	0.009	0.023
	(2.77)***	(4.01)***	(3.33)***	(0.14)	(0.16)	(0.41)
NPATENT	0.122	0.013	0.059	0.023	0.049	0.030
	(3.10)***	(0.58)	(1.82)*	(0.24)	(0.51)	(0.31)
NPUBGRANT	-0.560		-0.477	0.233		0.170
	(2.31)**		(2.09)**	(1.73)*		(1.36)
INDFUND		0.066	0.058		0.008	0.005
		(2.50)**	(2.00)**		(0.40)	(0.22)
APPL	0.359	0.318	0.339	0.103	0.062	0.077
	(2.29)**	(2.56)**	(2.23)**	(1.66)*	(0.91)	(1.14)
NTWK	0.092	0.054	0.101	0.175	0.197	0.173
	(1.08)	(0.62)	(1.07)	(2.02)**	(2.08)**	(1.90)*
PEER	0.158	0.154	0.138	-0.011	0.034	0.020
	(1.82)*	(1.37)	(1.36)	(0.14)	(0.46)	(0.26)
TOTCIT	0.000	0.000	0.000	0.000	0.000	0.000
	(0.67)	(0.77)	(0.92)	(0.34)	(1.22)	(1.06)
INTCOLLAB	-0.581	-0.656	-0.694	-0.300	-0.445	-0.479
	(1.42)	(1.79)*	(1.79)*	(1.18)	(1.61)	(1.76)*
NSTINST	0.611	0.610	0.636	0.215	0.298	0.296
	(2.64)***	(2.75)***	(2.64)***	(1.52)	(2.04)**	(2.01)**
UNIVSUPP	0.051	0.003	0.036	0.124	0.161	0.164
	(0.53)	(0.03)	(0.35)	(2.45)**	(2.83)***	(2.88)***
ENGINEERING	-0.432	-0.189	-0.325	0.370	0.292	0.363
	(1.75)*	(0.83)	(1.43)	(2.38)**	(1.68)*	(2.07)**
MOTIVECOMM	0.231	0.151	0.240	0.227	0.275	0.294
	(2.03)**	(1.63)	(1.89)*	(2.79)***	(3.30)***	(3.37)***
Observations	61	61	61	74	70	70

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

TURKISH SUMMARY

Bu tez, Türkiye'de nanoteknoloji alanında üniversite-sanayi ilişkilerini derinlemesine incelemeyi amaçlamaktadır. Bu amaca ulaşmak üzere üç farklı görgül çalışma yapılmıştır. İlk olarak Türkiye'de 2000-2009 yıllarını kapsayan on yıllık dönem içinde nanobilim ve nanoteknoloji alanında yapılan akademik çalışmalar bibliyometrik analiz yöntemleri kullanılarak incelenmiştir. Bu çalışmada, Türkiye'de nanobilim ve nanoteknoloji araştırmaların temel karakteristiklerinin ve belli başlı aktörlerinin belirlenmesi amaçlanmıştır. Daha sonra, üniversite-sanayi ilişkilerinin taraflarını oluşturan (i) Türkiye'deki üniversitelerde nanobilim ve nanoteknoloji alanlarında araştırma yapan akademisyenlerle ve (ii) nanoteknoloji alanında araştırma-geliştirme (AR-GE) yapan ya da nanoteknolojiyi ürün ve üretim süreçlerinde kullanan firmalar ile iki farklı görgül çalışma yürütülmüştür. Bu tez kapsamında 181 akademisyenden anket yoluyla veri toplanmıştır. Firmalar ile yapılan çalışmada ise vaka incelemesi yöntemi uygulanmıştır. Firmalar hakkında bilgi toplamak üzere farklı kaynaklar kullanılsa da bu araştırmada kullanılan bilgiler temel olarak nanoteknoloji alanında AR-GE yapan ya da nanoteknoloji ürün ve üretim süreçlerinde kullanan 21 firmanın üst düzey yöneticileri ile yapılan yarı-yapılandırılmış derinlemesine mülakatlar yoluyla elde edilmiştir.

Nanoteknoloji en genel tanımıyla 1 ila 100 nanometre arasında olan yapıların incelenmesi, kontrolü, modellenmesi ve mühendisliği olarak anlaşılabilir. Bir nanometre metrenin milyarda birine eşittir. Bu haliyle nanoteknoloji 1 ila 100 nanometre aralığındaki canlı ve cansız tüm yapıları inceleyen, kontrol eden ya da mühendisliğini içeren çok farklı teknoloji ve bilim alanlarını içermektedir. Nanoteknolojinin tek sınırı odaklandığı ölçü birimidir; bu ölçü birimini özel kılan şey bu boyutta yapıların normalde olduğundan çok farklı fiziksel, kimyasal ve biyolojik özellikler sergilemeleridir. Örneğin, 100 nanometrenin üstünde altın sarı ve katı bir metalken 100 nanometrenin altında kırmızı renkte ve sıvı olarak bulunmaktadır; ya da gümüş iyonları nanometre boyutunda anti-bakteriyel özellikler göstermektedir. Nanoteknoloji, nanoboyutta maddelerin sahip olduğu bu farklı ve normal dışı fiziksel, kimyasal ve biyolojik özelliklerden yararlanmayı amaçlamaktadır. Bu özellikler sayesinde daha hızlı bilgisayarlar, daha gelişmiş malzemeler ve akıllı ilaçlar yapmak mümkün hale gelecektir.

Nanoteknoloji fikir olarak ilk kez Nobel ödüllü fizikçi Feynman tarafından 1959 yılında dile getirilmiştir. Oysa nanoteknoloji araştırmalarının ve inovasyonlarının ivme kazanması, ancak 1980'li yılların ikinci yarısından sonra, iki mikroskobun IBM laboratuvarlarında icat edilmesinin ardından gerçekleşmiştir. Bunlar taramalı tünelleme mikroskobu ve atomik güç mikroskoplarıdır. Bu mikroskoplar sayesinde sadece 1-100 nanometre boyutundaki yapıların incelenmesi değil aynı zamanda onlara müdahale edilebilmesi, atomların yan yana getirilmesi ve bu sayede yeni yapıların oluşturulabilmesi mümkün olmuştur. Ama nanoteknolojinin asıl ivme kazanması 2000'li yıllardan itibaren bu alana yönelik bilim ve teknoloji politikaları sayesinde olmuştur. 2000 yılında ABD'de Ulusal Nanoteknoloji Inisiyatifi (NNI) oluşturulmuş ve bu çerçevede oldukça yüksek miktarlarda fon nanoteknoloji AR-GE harcamaları için ayrılmıştır. Aynı yıl Çin Halk Cumhuriyeti de nanoteknoloji ile ilgili bilim ve teknoloji programı başlatmıştır. Bu iki ülkenin ardından pek çok gelişmiş ve gelişmekte olan ülkede nanoteknolojinin geliştirilmesine yönelik özel program ve stratejiler oluşturulmuştur. Rakamlar nanoteknoloji yatırımlarının küresel boyutta hızla arttığına işaret etmektedir; örneğin 2005 yılından 2008 yılına kadar geçen üç yıllık dönemde nanoteknoloji yatırımları neredeyse iki katına çıkarak 2008 yılında 18.2 milyar ABD dolarına ulaşmıştır. Kuşkusuz ki, nanoteknoloji yatırımlarının altında nanoteknoloji ile ilgili yüksek ekonomik beklentiler yatmaktadır. ABD'nin ulusal bilim kuruluşu (NSF) tarafından 2001 yılında yayımlanan raporda, 2015 yılında nanoteknoloji ürünlerinin toplam değerinin 1 trilyon ABD dolarına ulaşacağı ve nanoteknolojinin gelişmesi ile en az iki milyon kişiye yeni iş olanağı yaratılacağı ileri sürülmüştür. 2009 yılında Lux Research tarafından yayımlanan rapor ise 2015 yılında toplam nanoteknoloji pazarının 2.5 trilyon ABD doları olacağı tahmininde

bulunmuştur. Nanoteknoloji ile ilgili küresel pazar tahminleri çeşitlilik gösterse de yapılan tüm öngörülerde nanoteknoloji ürün pazarının özellikle 2010 yılından sonra hızla artacağı tahmin edilmektedir. Ayrıca, rakamlar nanoteknoloji alanındaki bilimsel makale ve patent
sayılarının da dünya çapında hızla arttığını göstermektedir. Örneğin, 2000 yılında ABD patent ofisine (USPTO) kayıtlı nanoteknoloji patent başvurularının sayısı sadece 405 iken bu sayı 2008 yılında neredeyse dört bine yaklaşmaktadır. Nanobilim ve nanoteknoloji alanındaki toplam bilimsel makalelerin sayısı da yine 1991'den 2005 yılına kadar olan dönemde altı kat artmıştır.

Nanoteknoloji gelişmekte olan ülkeler için üzerinde durulması gereken alanlardan biridir. Bir diğeri ise üniversite-sanayi ilişkilerinin geliştirilmesidir. Özellikle 1980 sonrası dönemde, gelişmiş ülkelerde üniversite-sanayi ilişkileri yeniden önem kazanmaya başlamıştır. Bu değişimdeki en önemli faktörler arasında (i) 1970'li yıllardan itibaren ortaya çıkan iktisadi krizlere paralel olarak üniversitelere ayrılan kamu fonlarının azalması, (ii) sanayinin AR-GE harcamalarının azalması, bilginin firma içinde üretilmesine yönelik stratejilerin yerini firma-dışı kaynaklardan özellikle üniversitelerden yaranılması yolundaki inovasyon ve AR-GE stratejilerine bırakması, ve son olarak (iii) bilim temelli teknolojilerin (biyoteknoloji, nanoteknoloji, enformasyon teknolojileri gibi) ekonominin temel itici gücü haline gelmeleri sayılabilir. Bu süreç içerisinde üniversite-sanayi ilişkilerinin geliştirilmesi için bir çok ülkede yeni politika ve stratejiler geliştirilmiştir. Bunlardan en önemlisi ABD'de 1980 yılında hazırlanan ve daha sonra pek çok ülkede benzerleri kabul gören Bayh-Dole yasasıdır. Bu yasa üniversitelerde kamu fonları ile yapılan araştırmalar sonucunda elde edilen sonuçların üniversiteler tarafından patentlenebilmesine olanak sağlamaktadır. Böylelikle, bu araştırmalar sonucunda elde edilen sonuçların üniversiteler tarafından ticarileştirilmesinin önü açılmış ve aynı zamanda üniversitelerin gelirlerini bu yolla artırmalarına olanak sağlanmıştır. Bayh-Dole yasasının etkilerini ölçmek üzere yapılan görgül araştırmalar arasında yasanın etkisine dair tam bir fikir birliği bulunmamaktadır. Bazı çalışmalar Bayh-Dole yasasının üniversite patentlerinin artmasında önemli bir rolü olduğunu ortaya koyarken bazıları bu etkinin başka nedenleri de olabileceğini ileri sürmektedir etkinin başka nedenleri de olabileceğini ileri sürmektedir (özellikle, aynı dönemde, biyoteknoloji ile ilgili araştırma faaliyetlerinin artmasının patent sayısındaki artışı tetiklemiş olduğu düşünülmektedir).

1980 sonrası dönemde üniversite-sanayi ilişkilerini inceleyen görgül çalışmaların büyük çoğunluğu patent, lisans ve üniversitelerde üretilen bilginin ticarileştirilmesini amaçlayan yeni firmaların kurulması üzerine odaklansa da, son dönemlerde yapılan çalışmalarda, üniversite-sanayi arasındaki bilgi ve teknoloji transferinin sadece bu üç kanal aracılığıyla olmadığı, bir çok yoldan gerçekleştiği üzerinde durulmaktadır. Son dönemlerde üniversite-sanayi ilişkileri üzerine yapılan çalışmalarda gözlemlenen bir diğer önemli nokta ise bu çalışmaların bireyin rolü üzerine odaklanmalarıdır. Dolayısıyla, son dönemdeki görgül çalışmalar özellikle akademisyenlere yönelik olarak yapılmaktadır. Bu tez, üniversite-sanayi ilişkilerine odaklanan görgül çalışmalardan yola çıkarak bu iki nokta üzerine inşa edilmiştir. Bu amaçla, bu tezde üniversiteler ve sanayi arasındaki bilgi ve teknoloji transferinin pek çok kanal üzerinden gerçekleşebileceği göz önünde bulundurulmuş; öte yandan bu ilişkilerin kurulmasında kişisel faktörler de örgütsel faktörlerle birlikte değerlendirilmiştir.

Bu tez genel olarak üniversite-sanayi ilişkilerine odaklansa da, bu çalışmada asıl amaç üniversiteler ve sanayi arasında bilgi ve teknoloji transferini sağlayan kanalların kurulmasında etkili olan kişisel ve örgütsel düzeydeki faktörlerin belirlenmesidir. Bu sayede hangi faktörlerin bilgi ve teknoloji transferini olumlu hangilerinin olumsuz etkilediğinin belirlenmesi ve bu yolla bilim ve teknoloji politikalarının ve stratejilerinin geliştirilmesi hedeflenmektedir. Bu tezde, üniversiteler ile sanayi arasındaki bilgi ve teknoloji transferini etkileyen faktörlerin incelenmesinde iki farklı kuramsal yaklaşımdan yararlanılmıştır. Bunlar "kaynak temelli yaklaşım" ve "bilimsel ve teknik beşeri sermaye" yaklaşımlarıdır. Her iki kuramsal yaklaşım da üniversite-sanayi ilişkilerini etkileyen faktörlerin analiz edilmesinde yaygın olarak kullanılmaktadır.

Kaynak temelli yaklaşımı üniversite-sanayi ilişkilerine uygulayan çalışmaların temel savı kişilerin ve kurumların kendilerine has, taklit edilemeyen ve satın alınamayan bazı özelliklere ve kaynaklara sahip oldukları ve bu kaynakların ancak kurulan ilişkiler sayesinde üniversiteler ve sanayi arasında aktarıldığıdır. Dolayısıyla kişisel ve örgütsel düzeyde bu tür kaynakların ve özelliklerin olması üniversiteler ile sanayi arasındaki ilişkilerin artmasını sağlayacaktır. Benzer bir şekilde bilimsel ve teknik beşeri sermaye yaklaşımı da, özellikle üniversitelerdeki akademisyenlerin sahip oldukları beşeri ve sosyal sermayelerinin üniversite-sanayi ilişkilerinin gelişmesinde önemli rol oynadığını ileri sürmektedir. Her iki yaklaşımın da en önemli avantajı çok katmanlı analizlere olanak sağlamalarıdır. Diğer bir deyişle her iki yaklaşım kullanılarak hem kişisel düzeyde hem de örgütsel düzeydeki faktörlerin üniversite-sanayi ilişkilerine etkilerinin incelenmesi mümkün olmaktadır. Ayrıca kaynak temelli yaklaşım temel olarak firmaların rekabet gücünün anlaşılmasına yönelik olarak geliştirilen bir kuramsal yaklaşım olduğu için sadece akademisyenlerin sanayi ile kurdukları ilişkinin analiz edilmesinde değil aynı zamanda firmaların üniversiteler ile kurdukları ilişkilerin analiz edilmesinde de bu kuramsal yaklaşımdan yararlanılmıştır.

Daha önce de bahsedildiği gibi bu çalışmada üç farklı görgül çalışma yapılmıştır. Bunlardan ilki Türkiye’de 2000-2009 yılları arasındaki on yılı kapsayan dönemde Türkiye’de yapılan nanobilim ve nanoteknoloji araştırmalarının incelenmesi ve bu yolla nanoteknoloji alanında aktörlerin belirlenmesi, nanoteknoloji araştırmalarının temel karakteristiklerinin ortaya konmasıdır. Bu amaçla ISI Web of Science –SCI veri tabanında yer alan makaleler incelenmiş ve adres kısmında Türkiye olan nanoteknoloji makaleleri belirlenmiştir. Nanoteknoloji makalelerin belirlenmesinde Kostoff ve diğerleri (2007a) çalışması tarafından önerilen anahtar kelimeler kullanılmıştır. Böylelikle Türkiye’de herhangi bir kuruma bağlı olarak çalışan en az bir bilim insanının katılımı ile yazılan nanoteknoloji makalelerinin listesine ulaşılmıştır. Türkiye’deki bilim insanlarınca yazılan nanobilim ve nanoteknoloji makalelerinin sayısı 2000 yılında 115 iken bu sayı 2009 yılında neredeyse 8 kat artarak 928’e yükselmiştir. Ayrıca 2009 yılı verilerine göre, Türkiye SCI veritabanındaki nanobilim ve nanoteknoloji makalelerinin yüzde 1.06’sını üreterek diğer ülkeler arasında makale sayısına göre 23’üncü sıraya yükselmiştir. Türkiye’deki bilim insanlarınca üretilen nanobilim ve nanoteknoloji makalelerinin yüzde 99.2 ile neredeyse tamamı üniversitelerde görevli akademisyenlerin katkısı ile yazılmaktadır. Dolayısıyla, Türkiye'de nanoteknoloji alanında en önemli aktör üniversitelerdir. Diğer yandan, üniversitelerdeki nanoteknoloji araştırmalarının da belli başlı bir kaç üniversite yoğunlaştığı görülmektedir. 2009 yılında basılan nanobilim ve nanoteknoloji makalelerinin yarısından fazlasının (yüzde 56) Türkiye'deki 10 üniversitede görevli akademisyenler tarafından yazıldığı görülmektedir. Bu alanda en çok bilimsel makale yayını yapan üniversiteler ODTÜ, Bilkent ve Hacettepe üniversiteleridir.

Bibliyometrik analizler sonucunda Türkiye'deki nanobilim ve nanoteknoloji çalışmalarının son dönemde çok hızlı arttığı ama buna rağmen bazı zayıf noktalarının olduğu görülmektedir. Bu zayıf noktaların en önemli olanlarından biri iş birliklerinin çok zayıf olması olarak gösterilebilir. Analizler, nanobilim ve nanoteknoloji araştırmalarının sadece belli üniversitelerde odaklandığını ve özellikle ulusal çapta üniversiteler arasında iş birliklerinin ve ilişkilerin çok zayıf olduğunu göstermektedir. Diğer yandan uluslar arası bilgi ağlarına ulaşmak açısından da bazı zayıflıklar görülmektedir. Türkiye'de nanoteknoloji alanında çok iyi olan bir kaç üniversite dışında kalan üniversitelerdeki nanobilimcilerin yurt dışındaki bilgi ağlarına ulaşma şansı yakalayamadıkları görülmektedir. Hem ulusal çapta hem de uluslararası işbirliklerinin zayıflıkları göz önünde bulundurulduğunda Türkiye'de nanobilim ve nanoteknoloji alanında bilgi akışının çok iyi olmadığı görülmektedir. Bu özellikle belli başlı bir kaç üniversite dışında kalan üniversiteler için ciddi sorunlar doğurabilme potansiyeli taşımaktadır. Analizler Türkiye'de nanobilim ve nanoteknoloji alanında akademik araştırma faaliyetlerinin geliştirilmesi için işbirliklerinin artırılması gerektiğini vurgulamaktadır. Üniversiteler arası işbirliklerini artırmaya yönelik stratejiler ve ortak araştırma projelerini teşvik edecek araştırma fonları sayesinde ulusal işbirlikleri artırılabilecektir. Uluslararası bilgi ağlarına girebilen üniversitelerin ülkedeki, diğer üniversiteler ile bağlarının güçlendirilmesi yoluyla da yurt dışı ağlardan Türkiye'deki üniversitelere bilgi akışı sağlanabilir. Diğer yandan, yapılan analizler Türkiye'deki nanoteknoloji araştırmalarında disiplinler arası işbirliğinin de düşük olduğunu göstermektedir. Bu durum, Türkiye'de disiplinler arasındaki sınırların geleneksel olarak yüksek olmasından kaynaklanmaktadır. Ortak araştırma projelerinin desteklenmesi disiplinler arası bu sınırları da azaltacaktır.

Bibliyometrik çalışmadan elde edilen sonuçlar ayrıca Türkiye'de üniversitelerde görevli nanobilimcilerin belirlenmesinde de kullanılmıştır. Nanobilim ve nanoteknoloji, daha önce de bahsedildiği gibi 1 ila 100 nanometre boyutlarındaki yapıları inceleyen farklı bilim ve teknoloji alanlarını içermektedir. Bu nedenle de nanobilimciler aslında üniversitelerde farklı akademik disiplinlerde görev yapmaktadır. Dolayısıyla nanobilimcilerin belirlenmesinde yapılan araştırmaların dikkate alınması gerekmektedir. Bu tezde, Türkiye'deki nanobilimcilerin belirlenmesinde ISI WoS SCI'den alınan makaleler kullanılmıştır. İlk olarak bu makalelerin yazarlarında oluşan bir liste hazırlanmış ve bu bilim insanları arasından 2005-2009 arasındaki beş yıllık dönemde en az 3 nanobilim ve nanoteknoloji makalesi yazmış olan bilim insanlarını belirlenmiştir. Bunlar arasında halen Türkiye'deki üniversitelerden birinde akademisyen olarak görev yapan toplam 703 akademisyen Türkiye'deki nanobilim ve nanoteknoloji alanında çalışan akademisyenlerin popülasyonu olarak belirlenmiştir. Bu akademisyenlerden seçilen 181 kişilik örneklemden yüz yüze anket yöntemiyle bilgi toplanmıştır. Hazırlanan anket, akademisyenlerin sanayiye bilgi ve teknoloji transferi için kullandıkları 18 farklı kanala ilişkin soruların yanı sıra onların beşeri ve sosyal sermayesini ölçmeye yönelik soruları ve aynı zamanda çalıştıkları üniversiteye ilişkin soruları da içermektedir.

Toplanan anketlerin değerlendirilmesi sonucunda, araştırmamıza katılan 181 nanobilimcinin yaklaşık yüzde 46'sının en az bir kanal üzerinden sanayi ile iyi ilişkiler kurduğu ve bu sayede üniversiteden-sanayiye bilgi ve teknoloji transferine aktif olarak katıldığı görülmektedir. Türkiye'de üniversitelerde görev yapan nanobilimciler arasında sanayiye bilgi ve teknoloji transferi için en çok kullanılan kanallar ENFORMAL kanallardır. ENFORMAL kanallar ile kişisel ilişkiler, kişisel tanıdıklar ya da konferans, seminer ve diğer etkinlikler aracılığıyla kurulan ilişkiler kastedilmektedir. Görüşme yapılan nanobilimcilerin neredeyse yüzde 40'ı diğer kanal ARAŞTIRMA faaliyetlerine yönelik kanallardır. Bunlar arasında firmalar için

ENFORMAL kanallar üzerinden sanayi ile sıkça ilişki kurduğunu belirtmiştir. ENFORMAL kanallar kadar sık kullanılmasa da, Türkiye'deki nanobilimcilerin üniversite-sanayi arasındaki bilgi ve teknoloji transferinde en çok kullandıkları test ve analizler yapılması, firmaların üniversitelerdeki laboratuvar ve ekipmanları kullanmaları, ortak araştırma projeleri ve sözleşme yoluyla firmalar için yapılan özel araştırmalar sayılabilir. Araştırmamıza katılan nanobilimcilerin yaklaşık yüzde 12'si ARAŞTIRMA faaliyetleri ile ilgili kanallardan en az birini firmalar ile ilişkilerinde sıkça kullandığını belirtmişlerdir. Öte yandan, firmalara AR-GE faaliyetlerinde ve projelerinde sıkça DANIŞMANLIK hizmeti verdiğini belirten nanobilimcilerin oranı yaklaşık yüzde 9'dur. Ortak patent, lisans ve firma kurma gibi TİCARİ faaliyetleri içeren kanallar üzerinden sanayi ile ilişki kuran nanobilimcilerin oranı yaklaşık yüzde 7 iken, Türkiye'de üniversitelerde görevli nanobilimciler arasında AKADEMİK kanalların kullanım oranının oldukça düşük (yüzde 2.76) olduğu gözlemlenmektedir. AKADEMİK kanallar arasında SAN-TEZ, sanayideki uzmanlarla ortak yüksek lisans ve doktora tez yönetimi ve ortak bilimsel makaleler yazılması sayılabilir. Tablo 1 farklı bilgi ve teknoloji transferi kanallarının kullanım oranları hakkında bilgi vermektedir.

Tablo 1. Bilgi ve teknoloji transferi kanallarının nanobilimciler arasında kullanım oranları

	0=İlişkisi yok	*1=İlişkisi var*
ENFORMAL	60.77	39.23
ARAŞTIRMA	87.85	12.15
DANIŞMANLIK	91.16	8.84
TİCARİ	92.82	7.18
AKADEMİK	97.24	2.76
TUM KANALLAR	54.14	45.86

Anket yapılan 181 nanobilimcinin yaklaşık yüzde 67 ile büyük bir çoğunluğu üniversitelerin temel bilimler ve fen bilimleri fakültelerinde yüzde 25'i ise mühendislik fakültelerinde görev yaptıklarını belirtmişlerdir. Üniversitelerde görev yapan nanobilimciler arasında erkeklerin oranı (yüzde 72) kadınlara (yüzde 28) göre oldukça yüksektir. Yüzde 45'i professör iken yüzde 32'si doçent yüzde 18'i ise yardımcı doçent olarak görev yapmaktadır. Yüzde 75 ile nanobilimcilerin büyük çoğunluğu doktora derecelerini Türkiye'deki bir üniversiteden aldıklarını belirtmişlerdir.

Türkiye'deki üniversitelerde görev yapan nanobilimciler haftalık çalışma sürelerinin ortalama yarısını ders vermek ve tez yönetimi gibi eğitim faaliyetleri için kullanmaktadırlar. Araştırmaya ayrılan süre ortalama olarak haftalık çalışma süresinin ancak yüzde 38'lik bir bölümüne denk gelmektedir. Nanobilimcilerin araştırmaları için yararlandıkları fonların kaynakları incelendiğinde kamu araştırma fonlarının ve kendi üniversiteleri tarafından sağlanan araştırma fonlarının toplam araştırma bütçesi içindeki payının oldukça yüksek olduğu görülmektedir. Çalışmaya katılan nanobilimcilerin toplam araştırma bütçeleri içinde kamu araştırma fonlarının payı ortalama yüzde 50 iken, kendi üniversiteleri tarafından sağlanan fonların toplam içindeki payı ortalama yüzde 41'dir. Firmalar tarafından sağlanan fonların toplam bütçe içindeki ortalama payı ise ancak yüzde 1'dir. Araştırmamıza katılan nanobilimcilerin ancak yüzde 17'si araştırmaları için firmalardan fon bulabildiklerini belirtmişlerdir.

Araştırmamızın sonuçlarına göre türkiye'de üniversitelerde görev yapan nanobilimciler nanoteknoloji ile ortalama 7.15 yıldır ilgilenmektedir. Söz konusu nanobilimcilerin yüzde 42'si nanobilim ve nanoteknoloji araştırmalarının payının toplam akademik çalışmaları içindeki payının yüksek veya oldukça yüksek olduğunu belirtmişlerdir. Toplam akademik çalışmaları içinde nanobilim ve nanoteknoloji araştırmalarının görece daha önemsiz yer tuttuğunu belirtenlerin oranı ise yüzde 37'dir. Mann-Whitney U-testi sanayi ile ilişkiye girmek ve nanobilim ve nanoteknolojinin akademik çalışmalar içindeki payına ilişkin değişkenler arasında istatistiksel olarak anlamlı bir ilişki olduğunu ortaya koymuştur. Sonuçlara göre, nanobilim ve nanoteknolojiye akademik çalışmaları içinde daha fazla ağırlık veren nanobilimcilerin firmalarla bilgi ve teknoloji transferi ilişkisine daha fazla girdiklerini göstermektedir. Araştırma sonuçları, ayrıca, Türkiye'de üniversitelerde yapılan nanoteknoloji ile ilgili araştırmaların sanayinin ihtiyaçlarına uygun olduğunu göstermektedir. Örneğin, araştırmamıza katılan nanobilimcilerin yüzde 63'ü yaptıkları nanoteknoloji ile ilgili akademik çalışmaların sanayinin ihtiyaçlarını karşılayacağını belirtmişlerdir. Yaptıkları araştırmanın sanayinin ihtiyaçlarına uygun olmadığını düşünen nanobilimcilerin oranı yüzde 18'dir. Mann Whitney U-testi araştırma sonuçlarının sanayinin ihtiyaçlarına uygunluğunun derecesi ile sanayi ile ilişki kurma arasında istatistiksel olarak anlamlı bir ilişki olduğunu ortaya koymaktadır. Diğer bir deyişle, sanayinin ihtiyaçlarına uygun araştırmalar yapan nanobilimciler sanayi ile ilişki kurma eğilimi göstermektedir.

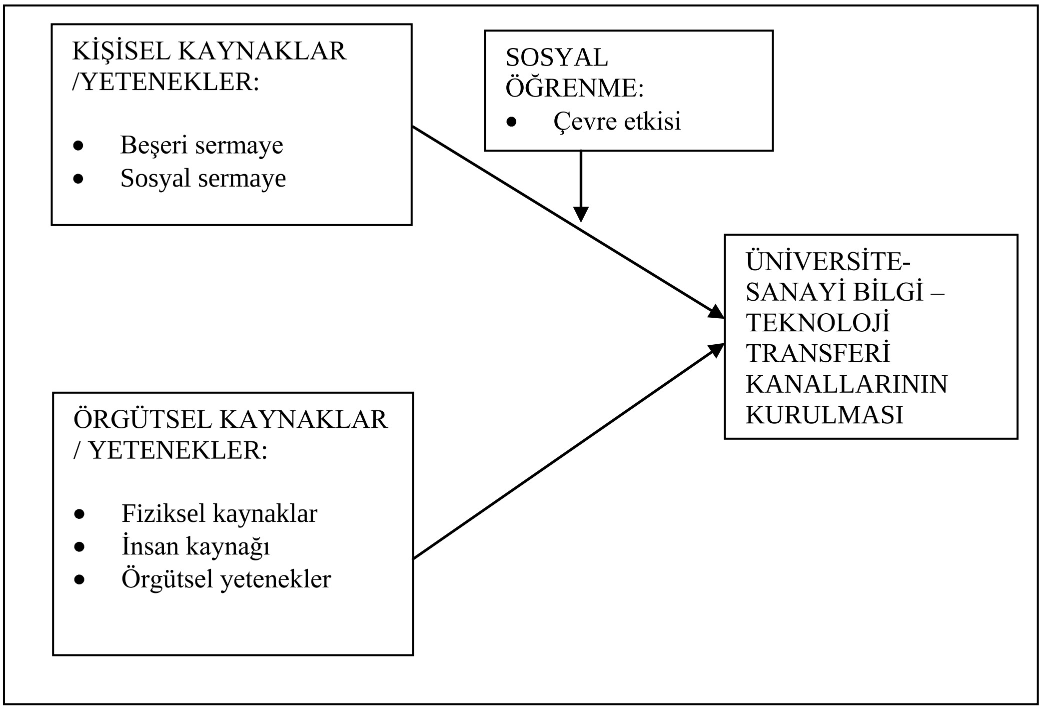
Diğer yandan Türkiye'de üniversitelerde görev yapan nanobilimcilerin Türkiye'deki diğer üniversitelerdeki nanobilimcilerle iletişimlerinin iyi olduğu gözlenmektedir. Örneğin, araştırmamıza katılan nanobilimcilerin yüzde 68'si arada sırada ya da daha sık olarak Türkiye'deki diğer üniversitelerde görevli nanobilimcilerle görüştüklerini belirtmişlerdir. Öte yandan, yurtdışındaki nanobilimcilerle ilişkilerin daha zayıf olduğu görülmektedir. Katılımcıların dörtte biri yurt dışındaki nanobilimcilerle hiç bir ilişkilerinin olmadığını belirtmişlerdir, yurtdışındaki nanobilimcilerle arada sırada ya da daha sık görüşen akademisyenlerin oranı ise ancak yüzde 50'dir.

Araştırmamıza katılan akademisyenlerin yüzde 60'ı görev yaptıkları üniversitede nanoteknoloji laboratuvarı veya araştırma merkezi veya araştırma grubu olduğunu diğer bir deyişle üniversitelerinde nanoteknoloji alanında araştırma yapmak için gerekli donanımın bulunduğunu belirtmişlerdir. Ayrıca görüşme yapılan nanobilimcilerin yüzde 43'ü görev yaptıkları üniversitenin yönetiminin kendilerini sanayi ile ilişki kurmak konusunda desteklediklerini belirtmişlerdir; yüzde 38'i ise üniversite yönetimlerinin üniversite-sanayi ilişkileri konusunda yeteri kadar destekleyici bulmamaktadır. Mann Whitney U-testi üniversite yönetimlerinin sanayi ile ilişkilerde nanobilimcilere sağladığı desteğin derecesi ile nanobilimcilerin sanayi ile ilişki kurması arasında istatistiksel olarak anlamlı bir ilişki olduğunu ortaya koymaktadır.

Nanobilimcileri sanayi ile ilişki kurmak konusunda teşvik edecek en önemli motivasyonların ise akademik çalışmalar ile ilgili olduğu görülmektedir.

olduğunu düşünmektedir. Yüzde 92'si ise akademik çalışmaları için yeni fon kaynakları bulmanın sanayi ile ilişkiye geçmek konusunda önemli veya çok önemli bir motivasyon olduğunu belirtmişlerdir.

Türkiye'deki üniversitelerde görevli nanobilimcilerin sanayi ile bilgi ve teknoloji transferi ilişkisine girme eğilimlerini etkileyen faktörlerin neler olduğunu ortaya koymak üzere ikili probit analizi kullanılmıştır. Bu amaçla öncelikli olarak, kuramsal ve görgül çalışmalardan yola çıkarak çok katmanlı bir model oluşturulmuştur. Bu modele göre bir nanobilimcinin sanayi ile ilişki kurma eğilimi etkileyen çok farklı faktörler bulunmaktadır; bunların bir kısmı nanobilimcinin kendi beşeri ve sosyal sermayesine bağlıyken bir kısmı da görev yaptığı üniversitenin sahip olduğu kaynaklara ve örgütsel yapıya ilişkin olabilir. Ayrıca, üniversite-sanayi ilişkilerinde yakın çevrenin etkisinin olabileceği ve bir akademisyenin sanayi ile ilişki kurmak konusunda çevresindeki diğer akademisyenlerden etkilenebileceği, onlardan öğrenebileceği de göz önünde bulundurulmuştur. Şekil 1'de bu faktörlere ilişkin oluşturmuş olduğumuz modelin görsel bir sunumu yer almaktadır.



Şekil 1. Üniversite-sanayi ilişkilerini etkileyen faktörlerin analizi için çok katmanlı bir model önerisi

Bu modelde kişisel kaynak ve yeteneklerin üniversite-sanayi ilişkilerinin kurulmasına etkisini ölçmek üzere aşağıdaki değişkenler kullanılmıştır. Beşeri sermayenin etkisini ölçmek için nanobilimcilerin (i) araştırma deneyimi ki bu değişken doktoranın tamamlandığı yıldan araştırmanın yapıldığı 2010 yılına kadar geçen süre olarak hesaplanmıştır, (ii) son beş yıl içinde yapmış oldukları nanobilim ve nanoteknoloji makalelerinin sayısı, (iii) nanoteknoloji ile ilgili patent ve patent başvurusu sayıları, (iv) yaptıkları araştırmanın sanayinin ihtiyaçlarını karşılama derecesi ve (v) toplam araştırma bütçesi içinde sanayi ve kamu fonlarının payı değişkenlerinden yararlanılmıştır. Nanobilimcilerin sahip olduğu sosyal sermaye ise, analizlerde, Türkiye'deki üniversitelerde görev yapan nanobilimcilerle ne sıklıkta ilişki kurdukları ile yakınsanmaya çalışılmıştır. Nanobilimcilerin sanayi ile kurdukları ilişkilerin çevresel faktörlerden ne ölçüde etkilendiğinin tahmin edilebilmesi amacıyla nanobilimcilere etraflarında tanıdıkları bildikleri akademisyenlerin sanayi ile ilişkilerine 5'li Likert ölçeğinde (1=çok güçlü değil ve 5= çok güçlü) değerlendirmeleri istenmiştir.

Örgütsel faktörler 3 gruba ayrılmıştır. Bunlardan ilki üniversitelerde nanoteknoloji ile ilgili ekipman ve alt yapıların etkisini içermektedir. Fiziksel kaynakları yakınsamak üzere iki cevaplı bir değişken kullanılmıştır; eğer üniversitede nanoteknoloji araştırma merkezi, araştırma grubu ya da laboratuvarı varsa fiziksel kaynaklar değişkeni 1 değilse 0 değerini almaktadır. Üniversitedeki insan kaynağının kalitesini ölçmek içinse iki farklı değişken kullanılmıştır. Bunlardan biri o üniversitedeki akademisyenler tarafından yayımlanan toplam ISI-WoS SCI veritabanına kayıtlı nanobilim ve nanoteknoloji makalelerinin aldığı toplam atıf sayısıdır. Diğer değişken ise yine üniversite tarafından yayımlanan nanobilim ve nanoteknoloji makalesi başına düşen yurtdışı bağlantıların sayısıdır. Örgütsel yetenekler ise üniversitelerin sanayi ilişkilerde nanobilimcilere sağladığı desteğin derecesi ile yakınsanmıştır. Nanobilimcilere sanayi ile ilişki kurmalarında üniversite yönetimlerince sağlanan desteğin o üniversitede üniversite-sanayi ilişkilerinin kurulmasına yönelik örgütsel yetenekleri yakınsayacağı düşünülmüştür. Ayrıca kontrol değişkeni olarak nanobilimcilerin görev yaptığı fakülteye ilişkin değişken modele dahil edilmiştir. Burada iki değer alan "mühendislik" değişkeni kullanılmıştır; diğer bir deyişle eğer nanobilimci mühendislik fakültesinde görev yapıyorsa bu değişken 1 değerini değilse 0 değerini almaktadır. Diğer kontrol değişkeni de nanobilimcilerin araştırma sonuçlarının ticarileştirilmesine yönelik motivasyonlarıdır. Bu değişkenin hesaplanmasında faktör analizi kullanılmış; faktör analizi sonucunda her bir gözlem için elde edilen faktör yüklemeleri bu değişkenin elde edilmesinde kullanılmıştır.

İkili probit kestirim sonuçlarına göre nanobilimcilerin araştırma deneyimleri ile onların sanayi ile ilişki kurma eğilimi arasında herhangi bir ilişki / korelasyon bulunmamaktadır. Aslında araştırma deneyimi beşeri ve sosyal sermayeyi olumlu yönde etkileyeceği için nanobilimcilerin sanayi ile ilişki kurma eğilimini de olumlu yönde etkilemesi beklenebilirdi. Fakat bizim araştırmamız, nanoteknoloji alanında üniversite-sanayi ilişkilerinin kurulmasında araştırma deneyiminin anlamlı bir etkisinin olmadığını göstermektedir.

Diğer yandan, bir nanobilimcinin son beş yıl içinde yapmış olduğu nanobilim ve nanoteknoloji makalelerinin sayısı ile onun sanayi ile bilgi ve teknoloji transferi ilişkisine girme eğilimi arasında istatistiksel olarak anlamlı ama ters yönde bir ilişki olduğu görülmektedir. Diğer bir deyişle, nanobilim ve nanoteknoloji makalelerinin sayısı artıkça nanobilimcinin sanayi ile ilişki kurma olasılığı düşmektedir. Bu sonuç Türkiye'de üniversitelerde uygulanan atama kriterleri ile bağlantılı olabilir; söz konusu atama kriterlerinde akademik yayınların etkisi yüksek olduğu için akademisyenler zamanlarını sanayi ile ilişki kurmak için değil akademik çalışmalarını artırmak için kullanmak isteyeceklerdir. Bilimsel makale sayıları sanayi ile ilişkileri olumsuz yönde etkilerken, bir nanobilimcinin patent ve patent başvurusu sayıları ile onun sanayi ile ilişki kurma eğilimi arasında istatistiksel olarak anlamlı ve pozitif bir ilişki olduğu gözlemlenmektedir. Patent ve patent başvurusu sayısı artıkça bir nanobilimcinin sanayi ile bilgi ve teknoloji transferi ilişkisine girme olasılığı da artmaktadır. Bir nanobilimcinin yapmış olduğu araştırmaların sanayiye uygunluğu da yine onun sanayi ile ilişki kurma eğilimi istatistiksel olarak anlamlı ve pozitif yönde etkilemektedir. Buna göre, nanobilimcinin yaptığı araştırmaların sanayiye uygunluk derecesi arttıkça onun sanayi ile ilişki kurma olasılığı da artmaktadır. Türkiyedışındaki ülkelerde yapılan görgül çalışmalar sanayi tarafından üniversitelerdeki akademisyenlere sağlanan fonların üniversite-sanayi ilişkilerinin kurulmasında olumlu etkileri olduğunu gösterse de, bu çalışmada, Türkiye'de en azından nanobilimciler açısından sanayi tarafından sağlanan araştırma fonları ile üniversite-sanayi ilişkilerinin kurulması arasında anlamlı bir ilişkisi olmadığı gözlemlenmiştir. Diğer yandan, probit analizi sonuçları nanobilimcilerin kamu fonlarına ulaşma dereceleri ile sanayi ile ilişki kurma eğilimleri arasında anlamlı ve pozitif bir ilişki olduğunu ortaya koymuştur; kamu fonlarına ulaşma derecesi artıkça sanayi ile ilişki kurma olasılığı da artmaktadır.

Nanobilimcilerin sosyal sermayelerinin, diğer bir deyişle diğer üniversitelerdeki nanobilimcilerle kurdukları sosyal ilişkilerin üniversite-sanayi ilişkilerine etkisine bakıldığında bu iki değişken arasında istatistiksel olarak anlamlı ve pozitif bir ilişki olduğu görülmektedir. Bu sonuca göre, bir nanobilimci diğer üniversitelerde görevli nanobilimcilerle görüşme sıklığı artıkça sanayi ile ilişki kurma olasılığı da artmaktadır. Diğer yandan, analiz sonuçları çevresel etkinin üniversite-sanayi ilişkileri üzerindeki olumlu etkisine ilişkin kuvvetli kanıtlar sağlayamamaktadır. Daha önce başka ülkelerde yapılan görgül çalışmalar, akademisyenlerin etraflarındaki diğer akademisyenlerin sanayi ile olan ilişkilerinden olumlu yönde etkilenebileceklerini ortaya koymuştur. Oysa bizim çalışmamıza göre bir nanobilimcinin tanıdığı bildiği akademisyenlerin sanayi ile ilişkilerinin kuvvetli olma derecesi ile o nanobilimcinin sanayi ile ilişki kurma eğilimi arasında beklendiği kadar anlamlı bir korelasyon bulunamamıştır.

Bir nanobilimcinin görev yaptığı üniversitenin sahip olduğu kaynaklar ve örgütsel yeteneklerin o nanobilimcinin sanayi ile ilişki kurma olasılığını nasıl etkilediğine ilişkin sonuçlara geldiğimizde fiziksel kaynakların ve örgütsel yeteneklerin üniversite-sanayi ilişkilerinin kurulmasında istatistiksel olarak anlamlı ve pozitif etkileri olduğu görülmektedir. Üniversitede nanoteknoloji araştırma merkezinin, araştırma grubunun ya da laboratuvarının olması o üniversitede görev yapan nanobilimcilerin sanayi ile bilgi ve teknoloji transferi ilişkisi kurmasını pozitif olarak etkilemektedir ve bu etki istatistiksel olarak anlamlıdır. Benzer bir şekilde üniversite yönetimi tarafından nanobilimcilere sanayi ile kurdukları ilişkilerde sağlanan desteğin derecesi ile o üniversite görevli nanobilimcilerin sanayi ile ilişki kurma eğilimleri arasında pozitif ve anlamlı bir ilişki olduğu gözlemlenmektedir. Diğer bir deyişle, üniversite yönetimlerinin üniversite-sanayi ilişkilerine verdiği desteğin derecesi artıkça o üniversite görevli nanobilimcilerin sanayi ile ilişki kurma olasılığı da artmaktadır. Fakat benzer bir ilişkiyi üniversitenin insan kaynağı kalitesi ve o üniversitede görevli nanobilimcilerin sanayi ile ilişki kurma eğilimleri arasında gözlemlemek mümkün olmamıştır. Probit analizi sonuçlarına göre üniversitenin nanobilim ve nanoteknoloji makaleleri başına düşen yurtdışı akademik ilişkilerinin sayısı o üniversitede görevli nanobilimcilerin sanayi ile ilişkilerini ters yönde etkilemektedir ve bu etki istatistiksel olarak anlamlıdır. Diğer bir deyişle, üniversitenin nanobilim ve nanoteknoloji alanındaki uluslararası akademik işbirlikleri artıkça o üniversitede görevli nanobilimcilerin sanayi ile ilişki kurma eğilimi azalmaktadır. Öte yandan, üniversitenin nanobilim ve nanoteknoloji makalelerine yapılan atıfların sayısı ile o üniversitede görevli nanobilimcilerin sanayi ile ilişki kurma eğilimleri arasında pozitif bir ilişki olsa da analiz sonuçları bu ilişkinin istatistiksel olarak anlamlı olduğuna dair çok kuvvetli kanıtlar sunmamaktadır. Dolayısıyla, üniversitedeki nanoteknoloji insan kaynağı kalitesinin o üniversite de görevli olan nanobilimcilerin sanayi ile ilişki kurma eğilimini olumlu etkilemediği ileri sürülebilir. Nanobilim ve nanoteknoloji alanında akademik başarısı

yüksek olan üniversitelerde görev yapan nanobilimciler bu ortamdan etkilenerek daha kaliteli ve daha çok akademik çalışma yapma eğilimine girebilirler; bu durumda üniversite-sanayi ilişkilerine değil akademik çalışmalara daha fazla vakit ayırmak isteyecekleri için sanayi ile ilişki kurma eğilimleri azalabilir.

Kontrol değişkenlerine baktığımızda, bir nanobilimcinin mühendislik fakültesinde görev yapmasının sanayi ile ilişki kurma eğilimi üzerinde istatistiksel olarak anlamlı bir etkisinin olmadığını söyleyebiliriz. Öte yandan, bir nanobilimcinin akademik araştırma sonuçlarını ticarileştirmek konusundaki motivasyonunun o nanobilimcinin sanayi ile ilişki kurma eğilimini olumlu etkilediği gözlemlenmektedir ve etki istatistiksel olarak anlamlıdır.

Dolayısıyla, bu tezde Türkiye'deki üniversitelerde görevli nanobilimcilerle yaptığımız çalışmanın sonuçlarına göre daha çok patent alan ya da patent başvurusu yapan, sanayinin ihtiyaçlarına uygun araştırmalar yapan, kamu fonlarından daha fazla yararlanan, Türkiye'deki üniversitelerde görev yapan nanobilimcilerle sosyal ilişkileri daha güçlü, çalıştığı üniversitede nanoteknoloji ile ilgili ekipman ve alt yapıya sahip ve aynı zamanda üniversite yönetimi tarafından sanayi ile ilişkileri desteklenen nanobilimcilerin sanayi ile ilişki kurma eğiliminin daha yüksek olduğunu göstermektedir.

Bu tezde yer alan üçüncü görgül çalışma ise nanoteknoloji alanında AR-GE çalışması yapan ya da nanoteknoloji ürün ve üretim süreçlerinde kullanan firmalara odaklanmaktadır. Bu özelliklere sahip 21 firmanın üst düzey yöneticileri ile derinlemesine mülakat yapılmış ve üniversitelerle kurdukları ilişkiler ve bu ilişkilerin kurulmasını etkileyen faktörlerle ilgili bilgi ve enformasyon toplanmıştır. Söz konusu 21 firma büyüklük, sektör ve nanoteknoloji AR-GE çalışmaları açısından oldukça büyük bir çeşitlilik göstermektedir. Toplanan bilgilerin daha iyi analiz edilebilmesini sağlamak amacıyla firmalar iki ana grupta toplanmışlardır. Bunlardan A grubunda yer alan firmalar farklı sektörlerde faaliyet gösteren büyük üretim firmalarıdır ama nanoteknolojiyi kendi ürünlerinin geliştirilmesinde diğer bir deyişle ürün inovasyonlarında kullanmaktadırlar. Dolayısıyla, uzmanlık alanları nanoteknoloji değildir. İkinci grup olan B grubunda yer alan firmalar ise küçük, yeni kurulmuş yüksek-teknoloji firmalarıdır. Bu firmalar farklı nanoteknolojilerin geliştirilmesinde uzmanlaşmış AR-GE firmalarıdır. B grubunda yer alan firmaların bazıları (B1 grubundakiler) halen üniversitelerdeki görevlerine devam eden nanobilimciler tarafından üniversitelerde yaptıkları çalışmaların geliştirilmesi ve ticarileştirilmesi amacıyla kurulmuşlardır. Tablo 2, A ve B gruplarında yer alan ve görüşme yapılan firmaların sayılarını vermektedir. Tablo 2'den de görülebileceği üzere Türkiye'de nanoteknoloji alanında AR-GE çalışması yapan ya da nanoteknolojiyi ürünlerinde ve üretim süreçlerinde kullanan firmaların neredeyse yarısıyla görüşme yapılmıştır.

Tablo 2. Mülakat yapılan firmaların A ve B gruplarına göre dağılımı

Grup	*Tüm firmalar*	*Görüşülen firmalar*	*Oran*
A	15	8	**% 53**
B	25	13	**% 52**
B1	14	7	**% 50**
B2	11	6	**%54**
TOPLAM	**40**	**21**	**%52.5**

Görüşme yapılan A grubu firmaları tekstil, seramik, kimya, elektrik ve elektronik ile ilgili alanlarda üretim yapan ve en az bir nanoteknoloji ile ilgili ürünü bulunan firmalardır. Fakat bu firmalardan ikisinin nanoteknoloji ürünleri henüz AR-GE aşamasında olup henüz pazara sürülmemiştir. Ayrıca bu firmalardan sadece ikisinde nanoteknoloji alanında kullanılabilen ekipmanlar bulunmaktadır; diğerleri test ve analizler gibi ihtiyaçları için çoğunlukla üniversiteleri kullanmaktadır.

Görüşme yapılan 13 B grubu firmanın neredeyse yarısı (6 firma) fonksiyonel nanomalzemeler geliştirmektedir. Bu malzemeler uygulandıkları yüzeye yanmazlık, yağ tutmazlık, su tutmazlık, kolay temizlenebilirlik, anti-bakteriyel olma gibi bazı özellikler kazandırmaktadır. Diğerleri arasında iki firma nano-biyoteknoloji üzerinde çalışırken, beş firma ise nanoteknoloji enstrümanları, ekipmanları geliştirilmesi üzerinde AR-GE çalışmaları yapmaktadır.

Verilerin analizinde tematik analiz yöntemi kullanılmıştır. Bu analiz yöntemi kalitatif çalışmalarda oldukça sık kullanılan bir yöntemdir. Buna göre yapılan görüşmeler ilk olarak metne dökülmüş daha sonra belli temalar altında kodlar oluşturularak sınıflandırılmıştır. Türkiye'deki üniversitelerde görev alan nanobilimcilerle yapılan görgül çalışmada olduğu gibi bu çalışmada da firmaların sanayi ile ilişki kurma eğilimlerinin kişisel ve örgütsel düzeyde faktörlerden kaynaklandığı gözlemlenmiştir. Bu araştırmadan çıkan en önemli sonuçlardan biri firmalarda görev yapan bazı yönetici ve AR-GE personelinin üniversitelerle ilişki kurmak konusunda anahtar rol oynadığıdır.

Üniversiteler ile firmalar arasında ilişki kurulmasında bu anahtar rolü oynayan kişilerin sosyal ve beşeri sermayeleri etkili olmaktadır. Görüşme yapılan pek çok kişi üniversitelerdeki akademisyenlerle konferanslar, seminerler sırasında tanıştığını ya da bunların bir kısmı ile aynı üniversitelerde eğitim gördüklerini ya da daha önceki projelerde birlikte çalıştıklarını ve bu tanışıklığın üniversitelerle ilişki kurmak konusunda kendilerine olanaklar sağladığını belirtmişlerdir. Firmalarda nanoteknoloji ile ilgili AR-GE çalışmalarına katılan üst düzey yöneticilerin akademisyenlerle sosyal ilişkileri ve kişisel bağlantıları olması firmaların üniversiteler ile ilişki kurma eğilimini pozitif yönde etkilemektedir. Araştırmamız firmalarda çalışan uzmanlar açısından da üniversiteler ile ilişki kurmanın en yaygın yolunun enformal ve kişisel ilişkiler olduğunu göstermektedir. Akademisyenler ve firma çalışanları arasındaki kişisel ilişkiler her iki grup açısından karşılıklı güveni beslemekte ve bu güven sayesinde üniversiteler ve firmalar arasında bilgi ve teknoloji transferinin gerçekleşmesi kolaylaşabilmektedir. Araştırmamıza katılan firma yöneticilerinden birisinin bahsettiği gibi Türkiye'de bilgi ve teknoloji transferini sağlayacak teknoloji transfer ofislerinin olmaması ve formal ilişkilerin çok yaygın olmaması bu güven ilişkisinin önemini daha da fazla ortaya çıkarmaktadır.

Firma yöneticileri ile yapılan derinlemesine mülakatlar firma yönetici ve uzmanlarının sosyal ilişkilerinin yanı sıra beşeri sermayelerinin de üniversiteler ile ilişki kurmak konusunda önemli olduğunu göstermiştir. Üniversiteler ile firma arasındaki ilişkiyi sağlayan kişiler belli bir akademik formasyondan geçmiş, nanoteknoloji alanındaki akademik çalışmaları takip eden, bu konuda araştırma ve laboratuvar deneyimi olan kişilerdir. Bu nedenle firma tarafında ilişkileri sağlayan kişinin akademik dile hakim olmasının iletişimin sağlanması açısından oldukça önemli rol oynadığı gözlemlenmektedir. Bu kişilerin sadece firma dışındaki bilgiye ulaşmalarını sağlayacak ilişkilere sahip olması yeterli olmayacaktır; aynı zamanda firma dışındaki bu bilgiyi anlayabilecek ve sonrasında firma içine aktarılmasını sağlayacak yeterliliklere sahip olmaları hem firma dışındaki hem de firma içindeki dile ve kodlara hakim olmaları gerekir. Nanoteknoloji söz konusu olduğunda, akademik dile ve bilgiye hakim olmak ve alanda araştırma deneyimine sahip olmak önemli rol oynamaktadır. Sonuç olarak firma adına üniversiteler ile ilişki kuran firma uzmanlarının akademik bilgi birikimleri ve deneyimlerinin üniversiteler ile bilgi ve teknoloji transferi ilişkisi kurulmasını olumlu yönde etkilemesi beklenebilir.

Araştırmamızın sonuçları, firma düzeyinde üniversite-sanayi ilişkilerinin kurulmasında sadece bu ilişkileri sağlayan firma uzman ve yöneticilerinin sahip olduğu yeteneklerin değil örgütsel bazı kaynak ve yeteneklerin de önemli olduğunu ortaya koymaktadır. Örgütsel düzeydeki bu faktörlerden en önemlileri firmanın özümseme kapasitesi ve firma kültürüdür. Firma dışından elde edilen bilginin firma tarafından kullanılması firmanın bu bilgiyi özümseme kapasitene bağlıdır. Firmanın özümseme kapasitesi firmanın AR-GE süreçlerine bağlı olarak gelişir. Firma AR-

GE yapıyorsa dışıardan aldığı bilgiyi özümseme kapasitesi artacaktır. Görüşme yaptığımız çoğu firma nanoteknoloji alanında AR-GE çalışması yürütmektedir. Sadece A grubunda yer alan 3 firma nanoteknoloji AR-GE çalışmaları konusunda firma dışı kaynaklardan yararlanmakta ve firma içi AR - GE çalışması yürütmemektedir. Bu üç firma dışında kalan A grubu firmalar şirket içi AR-GE çalışması yürütmektedir. Bu AR - GE çalışmaları çoğunlukla nanoteknoloji geliştirmeye yönelik değil ama şirket dışında geliştirilen nanoteknolojilerin ürün ve üretim süreçlerine uygulanmasına odaklanmaktadır. B grubu firmalarının tamamı şirket içi nanoteknoloji AR-GE çalışması yürütmektedir. Yaptığımız görüşmeler AR-GE çalışması yapan dolayısıyla özümseme kapasitesi yüksek firmaların üniversiteler ile ilişki kurma eğiliminin daha yüksek olduğuna işaret etmektedir.

Firmaların üniversiteler ile kurdukları ilişkiyi etkileyen diğer bir örgütsel faktör ise firmanın inovasyon kültürüdür. Araştırmamız sırasında, inovasyon kültürü gelişmiş, firma üst yönetimin firma dışı bilgiye ulaşmak konusunda çalışanları desteklediği, daha açık inovasyon kültürüne sahip ve işbirliğine açık firmaların üniversiteler ile daha fazla ilişkiye girdikleri gözlemlenmiştir.

Firmaların üniversiteler ile ilişkiye girmesinin arkasında pek çok neden yatmaktadır. Bunların içinde en önemlilerinden biri üniversitelerdeki nanoteknoloji ekipmanlarına, laboratuvar ve altyapıya ulaşmak bunlardan yararlanabilmektir. Görüşme yapılan firma yetkililerinin neredeyse tamamı üniversitelerle bu fiziksel kaynaklara ulaşmak için ilişki kurduklarını, üniversite laboratuvarlarında yapılan test ve analizlerin kendileri açısından çok önem taşıdığını belirtmişlerdir. İkincisi, firmalar üniversitelere yeni ürün fikirleri bulmak için değil, kafalarındaki bir fikri nasıl hayata geçirecekleri hakkında bilgi almak için başvurmaktadır.

Türkiye'de nanoteknoloji alanında üniversite-sanayi ilişkilerinin kurulmasının önündeki en önemli engellerin ne olduğu sorusuna firma yöneticilerinin büyük çoğunluğu akademisyenlerin sanayi ile ilişkilere yeterli vakit ayırmaması cevabını vermiştir. Görüşme yapılan firma yöneticilerine göre, akademisyenler firmalara çok fazla vakit ayıramamakta bu nedenle firmalar için acil gerine getirilmesi veya cevap alınması gereken durumlarda beklendiği kadar hızlı davranmamaktadırlar. İkinci problem sanayi ile akademi arasındaki enformasyon eşitsizliğinden kaynaklanmaktadır; diğer bir deyişle firmalar hangi üniversitelerde hangi akademisyenlerin kendi ihtiyaç duydukları alanlarda çalışma yaptıklarını bilmediklerini belirtmişlerdir. Firma yöneticileri akademide kimle ilişki kurmaları gerektiğini bilmediklerini ve bunun da üniversite ve sanayi arasında bilgi ve teknoloji transferi bağlarının kurulmasını engellediğini belirtmişlerdir. Üçüncü olarak gösterilen engel ise akademik çalışmaların çok fazla uygulamaya yönelik olmamasıdır. Firma yöneticileri, üniversitelerde yapılan araştırmaların çoğunlukla akademik kaygılar göz önünde bulundurularak yapıldığını bu nedenle sanayinin ihtiyaçlarını karşılamadıklarını belirtmişlerdir.

Sonuç olarak, Türkiye'deki üniversitelerde görev yapan nanobilimciler ve yine Türkiye'de nanoteknoloji alanında AR-GE yapan ya da nanoteknolojiyi ürün veya üretim süreçlerinde kullanan firmalarla yapılan iki görgül araştırma üniversite-sanayi ilişkilerini etkileyen çok sayıda faktör olduğunu ortaya koymuştur. Diğer yandan, bu çalışma üniversite-sanayi ilişkilerinin kurulmasını etkileyen faktölerin çok katmanlı yapısına dikkat çekmiştir. Sadece örgütsel faktörler değil kişisel yetenek ve kaynaklar da üniversiteler ve sanayi arasında bilgi ve teknoloji transferi kanallarının oluşmasında anahtar rol oynamaktadır.

Bu araştırmanın sonuçlarından yola çıkarak bilim ve teknoloji politikasına ilişkin bazı çıkarımlar yapılabilir. Öncelikli olarak, bu çalışma hem akademinin kendi içinde hem de üniversiteler ve sanayi arasında işbirliklerinin zayıf olduğunu göstermiştir. Bu işbirlikleri ve ilişkilerin geliştirilmesi için uygulanabilecek pek çok politika ve strateji geliştirilebilir. Örneğin, işbirliği fonlarının artırılması, kamu fonlarında yararlanmak üzere yapılan başvurularda işbirliği, projelerden birden fazla kurumun dahil edilmesi gibi şartların aranması gibi stratejiler uygulanabilir. Öte yandan, bölgesel düzeyde teknoloji platformları oluturularak, üniversiteler, firmalar ve kamu kurumları arasındaki işbirlikleri için uygun bir ortam sağlanabilir. Kurulan teknoloji platformları sayesinde farklı kurumlar birlikte araştırma yapmayı öğrenebilir, birbirlerinin yaptıkları çalışmalardan haberdar olabilir ve işbirliği yapabilirler. Nanoteknoloji alanında bu tür bölgesel teknoloji platformlarının oluşturulması işbirliklerinin geliştirilmesi açısından yeni olanaklar sağlayacaktır. Üniversite-sanayi arasında ilişkilerin geliştirilmesi için sanayi-doktora programları geliştirilebilir ya da doktora öğrencilerinin araştırmalarının sanayi tarafından desteklenmesi sağlanabilir. Bunlar ve benzeri bilim, teknoloji ve inovasyon politikaları uygulanarak nanoteknoloji alanında üniversite-sanayi ilişkilerinin geliştirilmesi desteklenebilir.

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INTERESTS

Technology and innovation management, technology transfer, governance of science, economics of science, technology development