Master Thesis

Collaboration portfolios and outcomes of nanotechnology research projects: A study of economic value creation and utilization of nanotechnologies in the Netherlands

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Document Number

Management and Governance – s0006815

UNIVERSITEIT TWENTE.

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Keywords: Nanotechnology R&D projects, University-Industry technology transfer, networks, complementarity, embededness, commercialization, collaboration

Abstract

Several studies indicated the importance of the role of Public R&D in the technology transfer and commercialization of nanotechnology. So far, few studies focused on University Industry interaction and collaboration performance with a focus on the micro network of the projects. In this study strength, fit and structure characteristics were applied to the micro networks to investigate the impact of the composition of participant groups on performance of publicly funded multi-partner nanotechnology research projects. For this study a database was used on utilization of technology research projects from the Dutch Technology Foundation STW. To test the hypotheses, 169 nano-technology research projects were selected from the database. The projects were started in a five year period from 1998 until 2003. Project performance in the form of product availability and financial performance is measured five years after completion of the project. Findings show a strong positive impact of commitment and value chain complementarity for both types of performance measures; a positive effect was also found for partners without embededness in the technological network. Having multiple Research Institutes in the project had a negative effect on product availability performance of the projects. The framework introduced in this study allows an evaluation of the effects of partner portfolios and commitment on the invention and financial performance of Public R&D projects.

1. Introduction

Utilization and value creation of nanotechnologies are expected to cut across established professional, occupational and organizational boundaries and threaten to disrupt existing practices (Walsh, 2004) making the need for collaborating and forming partnerships highly important for the private sector. This suggests that the ability to integrate knowledge (scientific, technological, commercial, regulatory) distributed across professional groups, companies, and research organizations seems crucial for nanotechnology development. Thus, successful technological development in the case of nanotechnology entails close collaboration between different players. The industry however, is reluctant to invest in the technology because of the uncertain and early phase of the development (Palmberg, 2008), making the universities initiator of the technology field putting a strong focus on the University-Industry interaction.

The developing technology field of the Nanotechnology is no exception as the technology transfer from University to Industry has to cope with the immaturity and uncertainty of the developing technology field of the Nanotechnology which creates discrepancies between the expectations of both parties (Palmberg, 2008).
Nanotechnology is expected to be both enabling and disruptive as technology and roadmaps 'are used to link the end targets of nanotechnology implementation with the development strategies and portfolios necessary to accelerate the implementation process' (Kostoff, Koytcheff, & Lau, 2007, p. 1735).

As a technology, Nanotechnology is seen as an interdisciplinary field (Meyer & Persson, 1998; Nikulainen & Palmberg, 2010; Porter & Youtie, 2009) which is important for the necessity of partner management as different disciplines are integrated. Nanotechnology is a technology not following the expected path of the biotechnology in R&D as it seems that nanotechnology was depending on revolutionary inventions made in biotechnology (or other disciplines) and therefore a different pattern in collaboration is expected (Rothaermel & Thursby, 2007).

As mentioned by Rothaermel & Thursby (2007), it is still questionable whether nanotechnology follows the path of the biotechnology as it thrives of important innovations in other disciplines and can be typified as an enabling technology. This requires a range of complementary technological and organizational innovations (Nikulainen & Palmberg, 2010).

Knowledge transfer of basic research coming from University-Industry interactions has been a base for a lot of academic research throughout the years (see for a review Bozeman, 2000). Various empirical studies have looked into the roles of licensing, science parks, spinoff activities and studied the evidence coming from the patent structures. The difficulties in researching technology transfer stem from the numerous forces influencing the process which 'are almost always difficult to separate from other parts of organizational life' (Bozeman, 2000, p. 627).

Technology transfer, for which cooperation in R&D projects is evidently important, is viewed as one of the more important interactions that define success of commercializing basic research. According to Bozeman (2000) technology transfer is defined in many different ways and differs in line with the discipline or purpose of the research. For this paper the definition of Nikulainen, Pajarinen &Palmberg (2010) is used: "Technology transfer is the active interaction between public sector researchers, from universities or research institutes, and private sector. It covers the transfer of research information and results from the public research sector to private sector and the related knowledge in a broader sense, thus including both codified and tacit types of knowledge." When referring to basic research, the type of knowledge that is developed in R&D

programs in the public domain is meant[1] (OECD, 1993).

Initiatives to close the gap between basic research conducted by Universities and solutions that can be used by firms, the University-Industry interaction process, have been supported, for example the creation of University Offices of Technology Transfer (f.e. Swamidass & Vulasa, 2009) and incubators, technology parks and clusters (Markman, Siegel, & Wright, 2008).

Research on this topic of University-Industry Technology Transfer has multiple focuses Markman et al mentioned that a combination of different theories is necessary to typify Technology Transfer (2008, p. 1419). For this paper focus will be on different research areas in the research field and therefore needs such a mixed approach, as the resources, networks and governance of relationships are researched. A mixed approach is therefore adopted in this paper.

University-Industry interaction is important because scientific knowledge is found to be of great importance for firms active in the fast developing technology sectors (Mowery, 1998). The importance from the industry point of view was described by Cohen and Levinthal (1990) who acknowledged the importance of having access to external information, the ability to internalize it and commercializing it to innovative capabilities of the firm.

A lot of the research conducted focuses on performing R&D through cooperation, collaboration and forming alliances. Most research however, has focused on R&D cooperation with a single competitor (Belderbos, Carree, & Lokshin, 2006). The focus in this paper will be on the full set of partners following the conception of Belderbos et al (2006).

In this research, R&D cooperation between University researchers and institutional and non-institutional partners is under review using the portfolio approach. No exact definition of this mechanism was found, but for this research it shared a lot of similarities with the way the cooperation mechanisms work for the patterns of R&D cooperation in the definition of alliances. Alliances are described as ' a voluntary arrangement among firms that exchange or share resources and that engage in the co-development or provision of products, services, or technologies' (Gulati, 1998).

According to Lavie (2007) an alliance portfolio can create value for a firm in three different ways: the network resources can directly extend and enhance the opportunities for value creation; resources provided by partners can generate value; and indirect benefits can be gained in a form that partners prominence can legitimize the focal firm (Lavie, 2007); these benefits are in line with the research areas defined bu Hoang & Antoncic (2003). In this paper however, the user group of a single R&D project is under investigation. According to Belderbos et al (2006) a single competitor was the main focus of the theoretical models when it comes to R&D cooperation and performance. The focus in this paper is on the complete portfolio of partners linked to an R&D project creating a hybrid approach between alliance portfolios and partner portfolios.

Every collaboration has certain achievements as goals, and these achievements define the success of the cooperative relationship (Mora-Valentin, Montoro-Sanchez, & Guerras-Martin, 2004). Collaboration success can be measured through two points of view; objectively, from the perspective of the relationship (e.g. Davenport, Davies, & Grimes, 1999), or subjectively, from the perspective of the

[1] This was adopted from Mora-Valentin et al. (2004), who cited the Frascati Manual and defined basic research " as experimental or theoretical work undertaken primarily to acquire new knowledge of the underlying foundations of phenomena and observable facts, without any particular application or use in view. Its results are generally sold but are usually published in scientific journals or circulated to interest colleagues" (OECD, 1993).

partner satisfaction(Mohr & Spekman, 1994).

Central research question

In analogy with research conducted on the firm level by Echols an Tsai (2005) on network embededness, in collaborating with other R&D projects in the industry, a R&D project involves itself in an inter-firm network that contains useful information and resource flows (Echols & Tsai, 2005) thus creating opportunities for the development of nanotechnology projects/firms. For this paper the focus was on government sponsored University-Industry R&D projects.

These government sponsored R&D consortia work well when focusing on basic research (Branstetter & Sakakibara, 2002). Baum et al (2000) found that heterogeneity in partners lead to a better performance. But what configuration of characteristics improves the success rate of nanotechnology project remains uncertain, because of the different characteristics of the industry (enabling or disruptive, immaturity, uncertainty, high expenses, public uncertainty, long development paths). Nikulainen and Palmberg (2010) acknowledged the research on this question as lacking in the literature although this research is on the macro level networks, as they conclude that he interaction is a consequence of public R&D programs and conferences, whereas the aim of this paper is on the micro networks involved in R&D projects in the University-Industry context. Reasoning from the resource based view, partnerships exist because of the strategic resource needs of the R&D projects and therefore these projects can be for the motivations of cooperation and partner characteristics next to each other (Vuola & Hameri, 2006).

This leads to the following research question:

To what extent explain collaboration portfolios and network characteristics the performance of University-Industry collaboration projects

The main research question spans three different characteristics of network literature which were derived from main research areas; governance, network content and structure. (Hoang & Antoncic, 2003)[2]. For this paper, they were translated as: strength, fit and structure. Fit and structure line up with governance and structure; fit was a translation as in this paper the nature of the content was exchanged for how the partners complement each other.

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[2] (1) governance mechanisms in relationships; (2); the nature of the content that is exchanged between actors; and (3) the network structure created by the cross-cutting relationships between actors.

2. Hypotheses

Strength factors

In collaborative projects the resources sharing benefits increase when partners actually combine skills, share knowledge and make investments (Ahuja 2000). Without commitment and trust resource sharing is difficult. Commitment was defined Anderson & Weitz (1992, p.19) as the 'desire to develop a stable relationship, a willingness to make short-term sacrifices to maintain the relationship and a confidence in the stability of the relationship.'

The pre-competitive nature of University-Industry cooperation, a consequence of the early stage of the research, causes information asymmetries and endangers the exploitation of the positive outcomes of the cooperation (Veugelers & Cassiman, 2005). This might lead to a gradual buildup of commitment towards the project (Mody, 1993).

The link of commitment was already found by numerous studies according to Mora-Valentin et al (2004). All the studies show a positive effect of a higher degree of involvement and participation of the partners in cooperation; the question that remains is therefore why that could be different for nanotechnology R&D projects (see f.e. Bonaccorsi & Piccaluga, 1994; Davenport et al., 1999).

Palmberg (2008) described the Nanotechnology field as immature and uncertain. Roco & Bainbridge (2005) put the contribution of nanotechnology to general economic growth in their anticipated list, meaning that the empirical issue on this research is yet to be positively answered. This means that there is still a large amount of risk involved for companies to commit themselves to R&D.

Uncertainty pressures commitment; therefore it is the question that a commitment pattern consistent with the literature could be found and therefore, the first hypothesis is:

H1: Commitment of partners in a nanotechnology related research project has a positive influence on the early performance of the project.

Fit factors

Partners are resources in a way that they provide tangible and intangible assets, which is in analogy with Eisenhardt & Schoonhoven (1996). Furthermore, partners that are complementary in their offerings minimizes opportunistic behavior (Veugelers & Cassiman, 2005). Consequently, the view in this paper on the fit of the partners is viewed in a resource based perspective. This perspective views need for complementarity of resources as the driving force behind partnerships (Vuola & Hameri, 2006).

As collaboration provides access to complementary assets that can support either or both value creation and technological development (Hagedoorn, 1993) And the innovative technology R&D projects provide need to be combined with the technological capabilities of the partners and/or assets to be successfully commercialized. (Chiu, Lai, Lee, & Liaw, 2008) To further strengthen this claim with an example, Lane and Lubatkin (1998) found that alliances between firms and a research institute have an better overall performance than alliances which are formed between firms only.

More evidence was found in the work of Un et al (2010) in which R&D projects on product innovation from companies with universities, competitors, suppliers and customers were identified as successful; however, this link was focused on firm R&D projects and no portfolios were identified.A same sort of claim was made by Monjon & Waelbroeck (2003) who found a connection between cooperating with a university and the increased probability of a successful market launch of an innovation.

This can be provided by the partners of the projects and consequently, the following hypothesis could be proposed:

H2: Value chain complementarity of partners in a nanotechnology related research project has a positive influence on the early performance of the project.

Cooperation in the value chain is considered vertical R&D cooperation, and is most common when the goals of the R&D are new, of complex nature or without a defined market (Arranz & Fdez. de Arroyabe, 2008) which is the case in Nanotechnology. In contrast to much research (Belderbos et al., 2006), this research is focused on the complete partner portfolio of a research project. This could include multiple companies, research institutes or other partner types. All the mentioned types could have conflicting goals between them, creating a competing, thus negative, effect.

The success therefore, was not a given which implies that cooperation was vital to make the project a success. To be certain that there is no overlapping effect of particular groups, separate groups will be taken into account in the tests in the form of the third hypothesis in which competition is tested. This also provides information on some characteristics of working portfolios

H3: Having more than one partner of a certain type in a nanotechnology related research project has a negative influence on the early performance of the project.

Structure factors

Nanotechnology was already mentioned as a multidisciplinary field of technology (f.e. Porter & Youtie, 2009). Therefore it is important for upstart projects to be well represented in the technology field by your R&D partners, or well integrated in the network which spans the core technology of the project to have availability of all the necessary knowledge and resources.

Structural embededness is the concept of representation in the field or macro-network and to which degree the field has an effect on the actions of the organization (Lin, Fang, Fang, & Tsai, 2009). The concept is mainly about the position and configuration of the organization in the macro-network and provides information about the possible information flows (Inkpen & Tsang, 2005). Because this research is about a multidisciplinary field (f.e. Porter & Youtie, 2009), having a favorable position in the technology field can speed up the process of knowledge flow and create an environment of inter-organizational learning for improving the inter-organizational technology transfer (Powell, Koput, & Smith-Doerr, 1996). A high Embededness of the partners in the macro-network and is therefore imperative to provide the necessary access to the other disciplines.

As users have a high centrality in that particular field, that user has a lot of connections within the nanotechnology field. According to Freeman (1979) determining the centrality can give information about organizations that can control the flow of information in a diffusion process and act as a gatekeeper or connect remote regions of the network. Or the organization with a high betweenness can perform as a broker when information is exchanged(Freeman, 1979). This implies that having a strong player in the macro-network has a positive effect on the outcome of the project. Therefore the fourth hypothesis, focusing on the set of partners is:

H4: A relative high centrality of the users in the network of a projects' user groups has a positive influence on the early performance of the project.

Having more network ties is an indication that more information on for example new technologies is directed towards your organization (Ahuja, 2000; Powell et al., 1996). A key player has a lot of network ties and having a key player in the network as a project is could therefore be instrumental for the information flow (Robinson, Rip, & Mangematin, 2007).

Being a key player is different from high centrality in a way that it is expected from organizations in the network that they are highly involved in the network. A key player in this paper is a company with a certain position in the network. This is to see whether commercialization is improving with a strong non-institutional player in the network is better than with smaller players. Therefore the fifth and final hypothesis, focusing on the key is:

H5: Availability of a key player in the network of a projects' user group has a positive influence on the early performance of the project.

Synthesis

All parts of the theoretical framework, presented in figure 1, are not implying that these three points of view explain all of the project performance; they are observed as effects on the process of technology transfer. To determine the effectiveness of the technology transfer was characterized as "daunting" by Bozeman (2000); it cannot be expected of this paper to prove him otherwise.

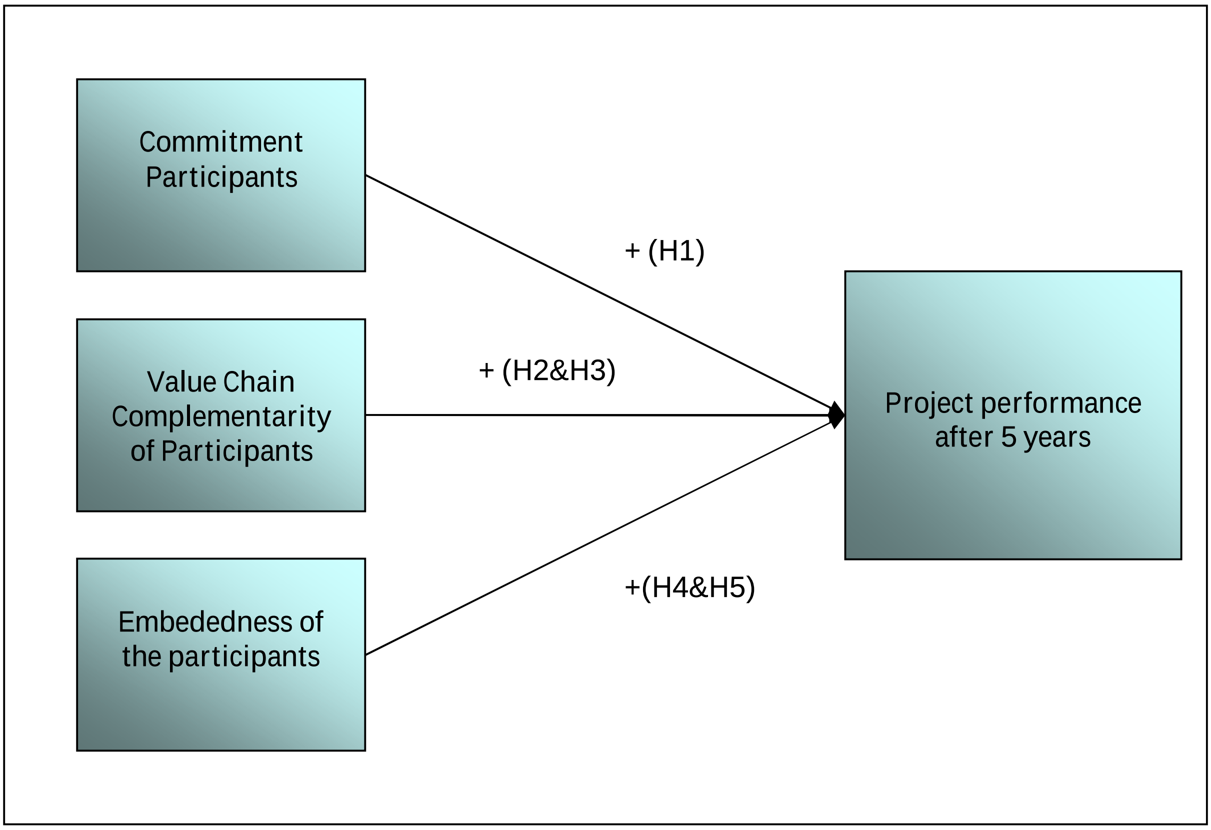

Figure 1: theoretical framework and hypotheses

3. Research Methods

Data description and setting

Data provided by STW was used for this research. The technology foundation STW is the program of Dutch Ministry of Economic Affairs and the Dutch Ministry of Education, Culture and Science (through the Dutch Organization for Scientific Research NWO), which provides the funding of technology projects. To obtain funds from STW a request is made by a university and a firm, after which a committee is formed which consists of the researchers and potential users of the knowledge provided by the projects. These users provide monetary incentives and non-monetary incentives in the form of knowledge and research possibilities for the project. The potential users could be of all types of organizations who could possibly benefit from the knowledge –small, medium and large businesses, as well as all non-profit organizations involved in R&D- and by joining a user group could benefit from early access to the results.

To test the hypothesis data is used describing partners, budgets and performance measures after a 5 year period of scientific technology projects in the Netherlands. The data set consists of 174 nanotechnology projects which were started in a five-year period from 1998 until 2003, and is compiled from the database of the Dutch technology foundation STW, which consisted of a total of 417 Dutch technology projects. The selection was made by an expert panel with extensive knowledge of and experience in nanotechnology. For this selection the definition of National Nanotechnology Initiative's definition was used: 'Nanotechnology is the understanding and control of matter at dimensions of roughly 1 to 100 nm, where unique phenomena enable novel application' (Balogh, 2010; Bozeman, Laredo, & Mangematin, 2007). A total of 5 cases were excluded because they did not feature a user group and therefore could not be tested for network effects.

A complete network was constructed out of this dataset, and was combined with characteristics and information of the users provided by STW and other sources using the following steps: first, all of the users in the user groups were classified using 6 types. These partner types were 1)companies, 2)governmental parties, 3)research institutes, 4) (academic) hospitals/medical institutions, 5) universities/schools and 6) special interest groups. Secondly, the dataset was checked for duplicate names and misspellings and firm levels were consolidated up to the holding level. A visual representation of the network used can be found in appendix 1.

Dependent variables

Two performance measures were used for testing the hypotheses, being product performance and Financial performance.

Product availability is defined as whether or not a feasible product has been produced as a result of the project and the presence of financial returns from the project. The operationalization of the product variable was: 0 was a failed project; A meant that no tangible product was produced; B stood for existence of a preliminary model, a principal or a concept method; C was for the existence of a tangible product, working prototype or patent, which ensured the user something it could work with without further support.

Financial performance is defined as whether or not a stable amount of revenues was generated from the project. For the financial performance the operationalization was: 0 for a failed project; A was for no revenues so far; B stood for initial revenues, which could also mean value created for the society; C mean a stable stream of revenues, or future revenues following preliminary agreements.

Figure 2: Amount of observations per variable

	N Product	N Revenue
0	1	4
A	46	119
B	70	32
C	52	14
Total	169	169

Independent variables

Partner commitment. For the first hypothesis the *commitment* of the partners was measured by questionnaire STW. To measure this commitment STW uses extensive questionnaires, interviewing the researchers, project leaders and users. STW uses an ordinal scale for scoring the projects: 0 was missing; a score of A means that users showed interest by taking a seat in a users committee; B says that users are actively participating in the project, but the actions delivered (money, materials e.g.) are relatively small; C says that there is extensive participation of the users in the project, with large support and often contractual ties to the cooperation.

Value Chain Complementarity. Secondly, the way the *skills* of the partners complement each other, or network complementarity, was measured by measuring the network efficiency, or efficiency of skills of the project. In analogy with the research conducted by Baum et al(2000), a measure based on the Hirschman-Herfindahl index was composed. Following Burt's (Burt, 1992) conception of structural equivalence—in which firms participating in the same line of business are considered equivalent in the set of skills, relationships, and assets they embody—assumed was that alliance partners of a given type are roughly structurally equivalent (Baum et al., 2000). The efficiency was calculated through:

$$Complementarity = \frac{\left[1 - \sum_{ij}\left(propP_{ij}\right)^2\right]}{noP_i}$$

in which $propP_{ij}$ is the proportion of partners of type *j* that the R&D project *i* has, and noP_i is the total amount of partnerships of R&D project *i* .

Overlapping skills. To further test the network efficiency there was tested whether having *overlapping skills* of partners would have an effect on the firm performance; with this measure was tested whether the effect of the network efficiency was influenced by a negative effect when having multiple partners of a particular type was there in the sample as mentioned by Arranz and Fdez. de Arroyabe (2008).

Partner embededness. Embededness is measured by betweenness centrality which, according to Burt (1992, p.35) referring to Freeman (1977), is an indication that an effect is in place that 'measures the extent to which a person brokers indirect connections between all other people in the network'. Freeman (1979) defines betweenness centrality as the number of geodesic paths that run trough one of the nodes. It is calculated by measuring the proportion of the paths from A to B that run through C and consequently sum all of the proportions of the possible combinations that run through C. The sum is the betweenness centrality of C. You can compare it with a soccer game; when properly played most attacks run through certain player, mostly the centerfielders. The centerfielders can be seen as the players with the highest betweenness centrality. Betweenness was measured using UCINET (Borgatti, Everett, & Freeman, 2002), creating the two node network, for which the data was suitable to make into, and make it into the one node network necessary for measuring the betweenness. The one node network was formed by removing the projects of the network; remaining will be the network which spans the nodes within the nanotechnology network of STW R&D projects. (A visual representation of the 2-node network can be found in Appendix 2) The betweenness centralities were categorized in 5 categories spanning the local minima of the betweenness. As 5 categories is considered being sound by statisticians, the relation between having a high amount of high-betweenness partners in your network and project success will be measured. With this measure a betweenness portfolio of each project was established.

Key player availability. The availability of a key player in the network was derived from the betweenness centrality. The players with the highest betweenness were appointed as key players, excluding institutions that have the goal of promoting and supporting R&D projects leaving firms with a normalized betweenness over 2 in the constructed network as key players.

Control Variables

Amount of partners. For the control variable the total amount of partners was tested because this variable could also be explaining parts of the model; the link between size of the network and economic performance was found by Belderbos et al (2006) as a significant factor.

Several variables that didn't factor in the final model were tested as well. The complementarity factor was controlled for proportional presence as well as the total presence of all the partner types identified removing the possibility that the success would be explained by a dominating partner type. To thoroughly test the possibilities dummy variables were created to test whether presence of a certain type would be a factor; no explanation for the model was found testing these variables, keeping them out of the final model.

The same approach was followed for the betweenness variables. Al categories were tested for proportional presence and a dummy was created for overall presence of a partner in that particular category. Both of these variable types didn't factor in the final model.

Analysis

Insignificant numbers of observations were neglected in the tests. This was the case with the amount of observations in the extended tests of the network efficiency for the government type partners and the special interest organization type of partners.

This was also the case with the dependent variables graded zero which were very small numbers for both. They were viewed as missing variables by removing the cases for the particular tests; the categories consisted of insignificant amounts, and were not combined as was done with other variables. This was not done because of the theoretical difference between the zero category and the A category, which is the difference between little success yet and a discontinued or failed project.

The revenue variable was combined; the second and third category were not significantly different enough to assess correctly and did not contain enough observations . Therefore the two were combined into a single variable, creating a category which consisted of 46 observations making the financial performance measure a binary variable.

4. Results

Figure 3: Descriptive Statistics

Descriptive Statistics

Variable	Description	N	Minimum	Maximum	Mean	Std. Deviation
Product Availability after 5 years	Product Availabilty after 5 years	168	1	3	2,03	,762
Revenues after 5 years	Revenues after 5 years	165	1	2	1,28	,449
Commitment of the partners	Graded active contribution of partner portfolio	169	1	3	2,01	,671
Value Chain Complementarity of Partners	Complementarity in value chain HH index	169	0,00	0,25	0,076	0,063
Overlap of Companies >1	Dummy	169	0	1	,81	,393
Overlap of Governmental Institutions >1	Dummy	169	0	1	,01	,107
Overlap of Research Institutes >1	Dummy	169	0	1	,07	,254
Overlap of Hospitals >1	Dummy	169	0	1	,07	,264
Overlap of Universities >1	Dummy	169	0	1	,20	,398
Key Player Availability	Most embedded private sector players available	169	0	1	,57	,496
Amount partners Betweenness Zero	Embededness around zero	169	0	7	1,56	1,650
Amount partners Betweenness Low	Embededness <1%	169	0	7	1,17	1,223
Amount partners Betweenness Medium	Embededness <2%>1%	169	0	5	,57	,755
Amount partners Betweenness High	Embededness <5%>2%	169	0	3	,63	,715
Amount partners Betweenness Very High	Embededness >5%	169	0	4	,87	,887
Amount Participants Per Project	Number of partners	169	0	13	4,83	2,473
Valid N (listwise)		165				

Descriptive statistics

An overview of the descriptive statistics can be found in figure 3, whereas the correlation part of the descriptive statistics can be found in appendix 3.

Some conclusions could be drawn already from the descriptive statistics. The amount of possibilities where there could be a competition between Governmental Institutions is too low (proportion = 0,01) to discriminate enough. Therefore it was removed from the further proceedings for the regressions to be of no influence on the definitive model. The proportions of the cases of Research Institutes and Hospitals were also relatively small, but were just big enough to factor in the model.

The two dependent variables Product and Revenue had a different valid N compared to the total available projects. This is because some projects were left out of the model because they had one or two of the dependent variables calculated as zero. This meant that the project failed on the particular area. There was decided to leave them out because it was not certain that the failure could be attributed to the cooperation, perhaps unfairly negatively influencing the model. The uncertainty came of the fact that the project might not have been technically feasible or overtaken by the presence, both factors that were not a direct consequence of the cooperation.

The descriptive statistics revealed a limitation of the research. The maximum size of the user group was 13; this limits the research in a way that the conclusions will only be suitable for relatively small R&D collaboration portfolios. This could also be a result of the research population that consisted of solely Dutch R&D projects. Further implications of this limitation will be dealt with in the conclusion.

When looking at the correlations in appendix 3 it directly becomes clear that commitment is strongly correlated with both the dependent variables. The other strongly correlated variables are total amount of partners to the development of the product and the correlation between revenue and the amount of low centrality partners in the network.

Figure 4: Ordinal Logistic Regressions for Product to Project Characteristics

Dependent Variable: PRODUCT

	1			2			3			4			5			6		
	B	s.e.	p	B	s.e.	p	B	s.e.	p	B	s.e.	p	B	s.e.	p	B	s.e.	p
[Product = 1]	1,117 ***	,478	,019	1,409 ***	,537	,009	2,117 ***	,711	,003	1,978 ***	,724	,006	3,226 ***	,827	,000	2,884 ***	,795	,000
[Product = 2]	3,091 ***	,533	,000	3,397 ***	,593	,000	4,143 ***	,768	,000	4,016 ***	,778	,000	5,457 ***	,901	,000	5,062 ***	,864	,000
Commitment of the partners	1,072 ***	,235	,000	1,102 ***	,238	,000	1,126 ***	,243	,000	1,116 ***	,243	,000	1,340 ***	,261	,000	1,223 ***	,252	,000
Value Chain Complementarity of Partners				2,987	2,379	,209	4,158 *	2,599	,110	4,074 *	2,603	,117	7,119 ***	2,859	,013	6,749 ***	2,777	,015
Overlap of Companies >1							,623 *	,449	,165	,724 *	,459	,115	-,119	,539	,825	-,099	,533	,852
Overlap of Research Institutes >1							-,489	,582	,401	-,451	,583	,439	-1,162 **	,667	,081	-1,103 **	,648	,088
Overlap of Hospitals >1							,255	,726	,726	,135	,737	,855	-,724	,791	,360	-,422	,774	,586
Overlap of Universities >1							,453 *	,395	,251	,488	,396	,218	-,250	,492	,612	-,155	,466	,740
Key Player Availability										-,331	,314	,292	-,218	,405	,590	-,129	,335	,700
Amount partners Betweenness Zero													,415 ***	,118	,000	,229 **	,125	,067
Amount partners Betweenness Low													,048	,141	,735			
Amount partners Betweenness Medium													,622 ***	,228	,006			
Amount partners Betweenness High													,344 *	,242	,155			
Amount partners Betweenness Very High													,205	,226	,364			
Amount Participants Per Project																,185 **	,102	,071
Cox & Snell Pseudo R²	,123			,131			,153			,159			,251			,227		
Chi-Square	22,115 ***		,000	23,683 ***		,000	27,914 ***		,000	29,014 ***		,000	48,539 ***		,000	43,191 ***		,000

N=168 * p<0,20; **p<0,10; *** p<0,02; one-sided test   Link function: Logit

Figure 5: Logistic Regressions for Revenues to Project Characteristics

Dependent Variable: REVENUES

	7			8			9			10			11			12		
	B	s.e.	p	B	s.e.	p	B	s.e.	p	B	s.e.	p	B	s.e.	p	B	s.e.	p
[Constant]	-3,989 ***	,751	,000	-4,596 ***	,855	,000	-5,162 ***	1,120	,000	-5,002 ***	1,130	,000	-5,254 ***	1,227	,000	-5,009 ***	1,183	,000
Commitment of the partners	1,409 ***	,322	,000	1,491 ***	,332	,000	1,495 ***	,338	,000	1,468 ***	,338	,000	1,554 ***	,356	,000	1,461 ***	,339	,000
Value Chain Complementarity of Partners				5,305 **	3,030	,080	6,195 **	3,485	,075	6,128 **	3,485	,079	6,638 **	3,700	,073	6,019 **	3,631	,097
Overlap of Companies >1							,423	,605	,485	,513	,616	,405	,607	,692	,381	,486	,683	,477
Overlap of Research Institutes >1							-,079	,705	,910	-,019	,708	,978	-,177	,790	,822	-,062	,765	,935
Overlap of Hospitals >1							,314	,891	,724	,212	,908	,815	,420	,950	,658	,203	,928	,826
Overlap of Universities >1							,622 *	,480	,195	,655 *	,482	,174	,928 *	,610	,128	,603	,567	,288
Key Player Availability										-,312	,405	,441	-,075	,530	,887	-,355	,430	,409
Amount partners Betweenness Zero													-,032	,150	,828	-,049	,158	,757
Amount partners Betweenness Low													,044	,170	,795			
Amount partners Betweenness Medium													,182	,265	,492			
Amount partners Betweenness High													-,438 *	,323	,174			
Amount partners Betweenness Very High													-,100	,295	,736			
Amount Participants Per Project																,033	,128	,795
Cox & Snell Pseudo R²	,129			,146			,157			,160			,177			,161		
Chi-Square	22,858 ***		,000	25,970 ***		,000	28,242 ***		,000	28,833 ***	,000		32,143 ***		,001	28,944 ***		,001

N=165 * p<0,20; **p<0,10; *** p<0,02; one-sided test

Interpretation of the models

For the product variable an ordinal logistic regression was calculated, which is slightly different to a binary logistic regression in a way An ordinal logistic regression should be interpreted the following way. A threshold is created which indicates the border for a project to get to the next level. The coefficient of the model then tells how much one the variable adds to reach that threshold. For example, a project that is judged using the 2nd model, with a commitment mark of C, and a 1,102 + 0,25 x 2,987 ≈ 4,05. This grade gives the project probability to get in the category [3] 1(A in the data) of $\frac{1}{1+e^{-(1{,}409-4{,}05)}} \approx 6{,}65\%$.

For the second category, this percentage has become $\frac{1}{1+e^{-(3{,}397-4{,}05)}} \approx 33{,}6\% - 6{,}65 \approx 26{,}95\%$. The percentage of the first category is deducted because the probability of category 1 and 2 is calculated.

You get the probability to get in the third product availability performance category by calculating 100% - the calculation of the second category, which is approximately 66,4%.

Figure 4 indicates that the second threshold is very close to being the exact double of the first threshold, indicating the right model was chosen. This threshold differential was maintained throughout the evolvement of the model, further indicating the strength of the model.

[3] $prob(event\ j) = 1 / (1 + e^{-(threshold-B)})$

In the case of the product variable, a two staged threshold could be maintained. For the revenue variable, an binary logistic regression was used, because of the combined outcome following the assessment that categories B an C did not contain enough cases.

The relation between commitment of partners and project success

Hypothesis 1 positively relates commitment of the partners in the user group to the product and revenue success. The (ordinal) logistic regression in figures 4 and 5 show this relation in a very strong way throughout the development of the model and keeps its strength when adding variables, for both dependent variables.

The amount that commitment as a variable could add to a score to pass the threshold is very large. A maximum commitment score gives the project over 75% of the required estimate score to put the R&D project in the second level of the revenue variable. For the product variable, having the B score is enough to get to the second level out of three (barring negative factors).

Complementing or overlapping?

Hypothesis 2 and Hypothesis 3 determined whether partners delivered complementary assets or that heterogeneity caused by multiple partners of the same mould caused the effect of competition, negatively influencing the product and revenue development.

The estimate B of the complementarity indicates a very big impact on the model; maximum complementarity in the data set was 0,25 reducing the effect to a maximum of $1/4^{th}$ of the estimate. Still, as the outcomes indicate, having complementary partners can provide a significant portion of the amount needed to pass the threshold(s) of both of the researched dependent variables.

There should be noted that for the product variable, the measurement became robust when extra variables were added to the equation, whereas with the revenue variable the value chain complementarity remained robust throughout the formation of the model.

In Hypothesis 3 a negative effect was expected from the different types of partners. The negative effect was found for all types within the product variable; the company universities and hospitals variables had a positive effect for the revenue variable. The only significant effect observed however was the rather large negative impact of 2 or more research institutes in a user group with the product dependent variable. And on second thought, some outcomes might be more logical than at first sight.

In this framework of pre-competition and vertical cooperation pure competition does not exist. But still there will be some form of politics of partners forcing the project their way if they can which might have a negative impact. This is a result of having a certain intent when joining an University-Industry relationship. Universities and Hospitals on the other hand, should at all costs pursue success of the project, simply because they conduct research (and have restricted budgets). The observed significant negative effect of Research Institutes however can be understood that most research institutes have a clear focus and goal, which could conflict with the focus and goals of other research institutes, clarifying the negative impact when having multiple partners of this particular type in an R&D projects' partner portfolio.

The role of embededness and key partners

Good representation of the partners in the user group in the field of Nanotechnology and finding out whether lead to a better performance is where Hypothesis 4 and 5 were about. With these hypotheses there was tried to confirm the gatekeeper and broker role for information flows described by Freeman (1979).

In model 5 three significant positive effects were found on the centrality of the partners; having a large amount of partners without a network position and partners with a medium sized position had a strong positive effect on the outcome of the product availability; a less robust positive effect was found for partners with a high embededness. This was somewhat opposite of the expected effect, being the higher success of projects with highly or very highly central players in their particular user group.

The revenue dependent variable in model 11 showed mixed small positive and small negative results, with the only significant being the high betweenness category which showed a negative estimate.

In the final model all of the betweenness factors were removed to take out the scale of the local minima, which was used. This was done because partners with a betweenness of zero, which means no big role in the researched network, was the only accurate assessment that could be made after looking at the model. This was reinforced when looking at the correlations in appendix 3, in which the betweenness categories strongly correlated with the control factor 'amount of participants'. The second reason was that the model suggested that there might be evidence for the structural hole theory of Ahuja (2000).

For the product variable the zero betweenness groups proved to have a significant effect on the product success. There was no effect found on the revenue variable. This could indicate that the zero betweenness group support projects because they are strongly in need for the technology for their own cause, but do so in a parasitizing way by only taking what they need and adding less to the revenue success of the project. The negative effect was not very large for the dependent variable product and not significant.

Key player availability in the user groups has a negative effect throughout the buildup of the model for both dependent variables, although it is a small non-significant effect. This is in contrast with the theory which expected a large contribution of the key players to the project success factors as they should act as gatekeepers or broker in the nanotechnology macro-network (Freeman, 1979).

The control variable amount of participants showed a significant positive effect for the product availability, and a positive but non-significant effect for the financial performance. Looking at the co-variance, the variable showed no co-variance for the main concepts; it did show an effect on the variables that were determined by the amount of participants, which is logically the case.

5. Conclusion & Discussion

In this paper, the strength, fit and structure of network characteristics of public nanotechnology R&D projects and their effect in technology transfer were under review on how they had an effect on the product developmental and financial performance. While previous research conducted focused on mainly the macro network (Nikulainen & Palmberg, 2010) or a single cooperation (Belderbos et al., 2006), this research was focused on the micro networks of the R&D projects.

In analogy with multiple research papers (f.e. Mora-Valentin et al., 2004) a strong positive effect of commitment was found for both performance types. With the evolvement of the model it became clear that commitment was the biggest contributor to the performance measures. This suggest that commitment to the relationship is the most important factor to the success of University-Industry interaction.

Compelling evidence was found for the positive effect of complementarity of partners in the value chain. When digging deeper, research showed that not all partner types had a positive effect when present more than once in the micro-network; having multiple Research institutes showed a negative, competing effect on the utilization for knowledge. This was the sole significant effect. The outcomes suggest that being complementary in the value chain has a positive effect on the outcome, but you have to be beware of having too many, or more than one, Research Institutes in the user group of the R&D project.

No evidence was found for the theory of Freeman (1979), regarding the broker role and information flows in the macro network. In contrast, a significant positive effect was found for the product availability for partners with no embededness in the technology field.

In contrast with common knowledge and research (Robinson et al., 2007) key players don't have a positive effect as a partner in a projects' network further strengthening the claim that commitment of the members of the user group to the project is more important than having a big name in the industry.

The control variable showed no real co-variance with the main concepts strengthening the research; it also made clear that for the product availability performance measure it is useful to have input from as much partners as possible. For the financial performance no significant effect was found

Discussion issues for this research

To address the issues for this research, the four types of validity used by Shadish, Cook & Campbell (2002).

Internal validity. The standard questions for assessing the internal validity, being cause preceding effect, cause and effect are related and no plausible other explanations were answered sufficiently. Measuring the effect after 5 years, answered the first; the statistical tests the second and third. Common knowledge on social research views the explaining percentages of 22,7 % and 16,1% for the final models as good.

Selection of the partners can be seen as a form of self-selection as both researchers conducting the R&D and the possible members of the user groups choose to be part of a project, and are not assigned randomly.

External validity. Generalizability of the research outcomes is somewhat problematic as the maximum size of the cooperation portfolios is 13. This is relatively small when looking at larger scale R&D projects that exist on for example a European scale.

The dataset was composed from data from a Dutch Governmental institution, and the focus was on Dutch R&D cooperation. Geographical implications such as distance between partners, density etcetera, make that the model should be applied very carefully when addressing a different situation.

In hindsight, the size of the partner might have an influence on the success. This was partially covered by the key player variable as it takes a lot of resources to be involved in multiple collaborations. A fact remains that there was not enough time to determine the company size to incorporate it. Belderbos et al (2006) ruled out firm size as an effect in their paper on complementarity. A search on the betweenness was inconclusive.

Construct validity. The main influence on the outcomes of the research was the influence of the secondary data that was used. Three variables from STW were used, being commitment, product and revenue, These variables were composed by ST and were represented by a 3 outcome ordinal scale. The data on how these scales were composed could not be obtained so there had to be trusted on the quality of the research conducted by the other organization. The problem in this situation is not so much the data being secondary, but the difficulty of addressing the quality of the secondary data is more problematic.

The pre-composed scales, or secondary data, leave some more questions to be answered: the answer on the question what all the different partners bring to the table could not be answered. It could for example be the case that a certain project has ten partners in its portfolio; but only eight of them have a very strong commitment with the project and the other two members riding the wave created.

Local minima determination is a point of discussion. The betweenness was impacted with the determination of these minima. The same could be said for the determination of the key players; the way key players were identified in this paper was based on their position in the nanotechnology network from STW. The players with profit motives of this particular network with a normalized betweenness centrality of 2 or more were selected. This approach did not provide insights on the position in the Dutch economy. However, given the density and completeness of the dataset the estimation is that more than 80% of the projects would have a key player in the Dutch economy in their portfolio, creating doubt that this approach would discriminate sufficiently.

Statistical conclusion validity. A problem that was encountered was the choice of statistical model. For an ordinal logistic regression the dependent variables needed to be categorical which was the first choice; if the variables were categories a multinomial logistic regression was the right model. The parallel tests were right on the border of being significant, making the ordinal logistic regression usable for testing, but with reservations.

Only several types of partners were found as competing. This could be a result of the small size of the user groups (max 13, mean 4,83).

Relevance for practitioners

The findings of this study suggests that R&D projects should have a strong focus on commitment of the partners. Without a commitment of C it is very hard to gain a big enough estimate score to go over the threshold.

Complementarity of the partners is important for the success of both product development and revenue generation. It is imperative for the R&D projects to line up their partners and create a balanced partner portfolio to improve their chances of a successful technology transfer between University and Industry. When looking at the overlap within the partner portfolios some observations should be considered. Research institutes in the portfolio should be limited to one or not be contrasting in focus and goal. This is particularly the case for the product development.. This could be caused by the fact that Research Institutes focus on a particular technology field.

Having partners with no role in the network has a positive effect on the product development; this means implies that partners with no role in the network really need the project to succeed (although the correlation with commitment is low) but only on the technology/product part.

The key player role and the role of gatekeeper or broker didn't return in the outcomes of this research strengthening the claim that the focus of R&D projects should be on assuring the partners are fully committed to the project.
This finding, combined with the positive effect of partners without representation in the field shows that the big companies have a divide and conquer strategy to assure that they don't miss out on something they might be needing.

Issues for further research

Because of following the conception of structural equivalence used by Baum et al (2000) there was no possibility to identify good working and bad working combinations in the complementarity set up. This was because most of the test variables didn't make the final model for being non-significant or redundant and the way the complementarity was measured; not all different possible setups were tested. Neither did the data set available lend itself for these types of tests.

Further identifying the role of low betweenness partners with commitment; does a parasitizing relationship exist?

To further explore the questions raised by this observation; complementarity was found very important for revenue generation; having a large amount of partners with no network representation was observed as a negative factor for the same dependent variable. Question is whether complementarity provided by zero betweenness partners has the same effect. The correlations in appendix 3 show a strong negative effect, but the way complementarity is calculated, with the amount of partners in the denominator, could be of a large influence. The influence of size of the partners was earlier in this paper subject of discussion and this question was strengthened with this observation.

Embededness from the partners in the macro-network, although mostly inconclusive, is not the most important, contrasting common knowledge; having no embededness at all is a positive however. This fuels the possible evidence for the structural holes theory of Ahuja (2000). Further research is necessary for this claim.

One of the limitations that was raised earlier in the paper was the maximum size of the user groups of 13. This is threatening the generalizability as was concluded. Expanding the size of the user portfolios is imperative for improving the research.

Size of the firm and R&D cooperation has a positive Link (Miotti & Sachwald, 2003). Size of the partner was not addressed in this research, but could have an influence. Therefore further specification of this research using these types of characteristics could further clarify the keys for successful technology transfer.

6. Concluding remarks

The aim of this research was to fill a hole/void in the theory that was acknowledged by Nikulainen and Palmberg (2010). Filling that hole raised a lot of questions for further research on this topic, but the start was made in this research.

Despite the influence of having secondary data, this research produced robust result confirming some of the hypotheses, while surprisingly rejecting some other hypotheses.

Commitment and complementarity were positively confirmed as positive effects on the early outcome of Nanotechnology R&D projects with some competition effects for a single type of partner. Rejected were the expected effects of having strong players in the field in the collaboration portfolio; having partners with no network strength in this particular network at all were shockingly found as positive effect.

The conclusion therefore is that when addressing their partner portfolio, R&D projects are more likely to have success with partners strongly committed to the projects and an even distribution of the partner types than having partners with a strong network position.

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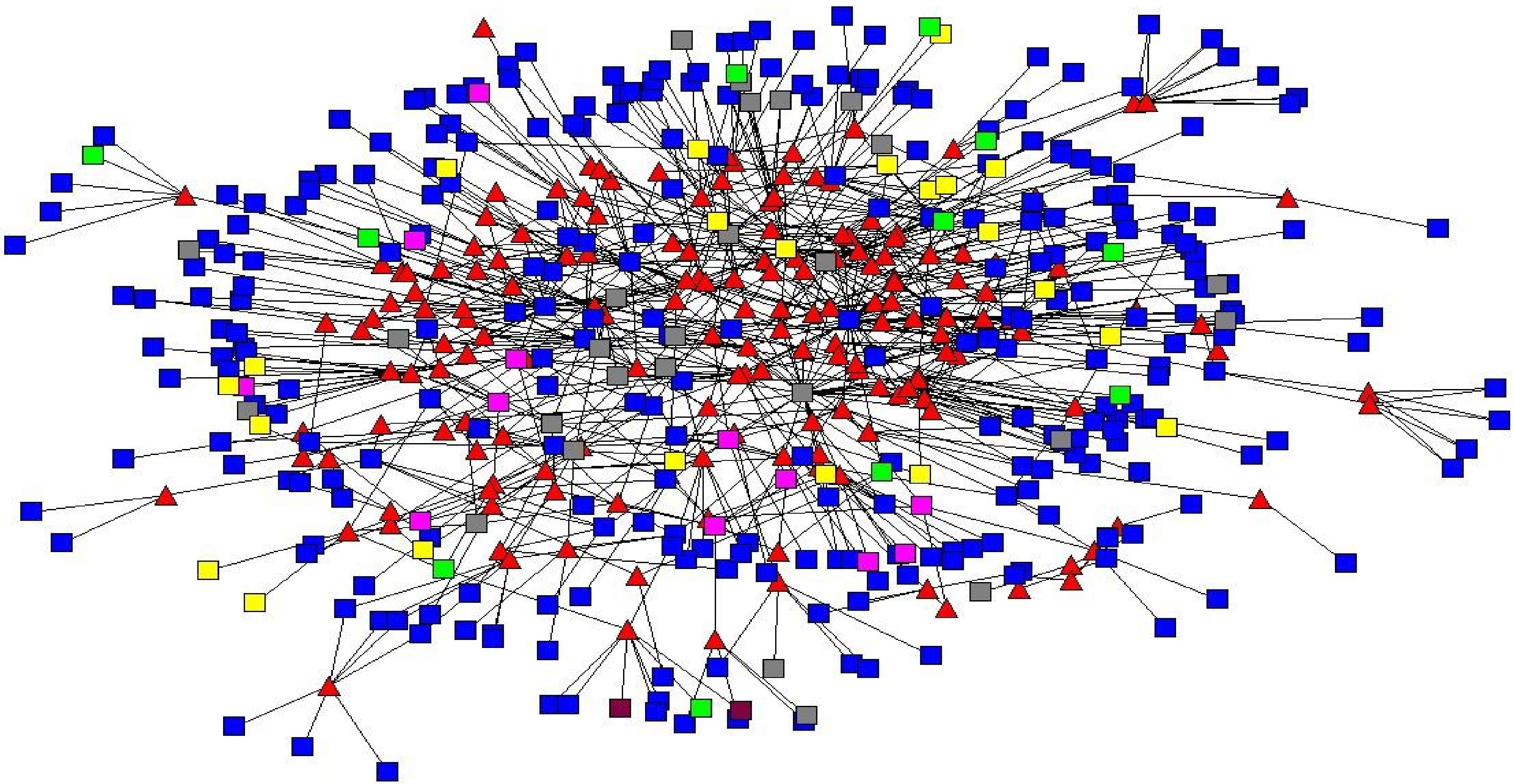
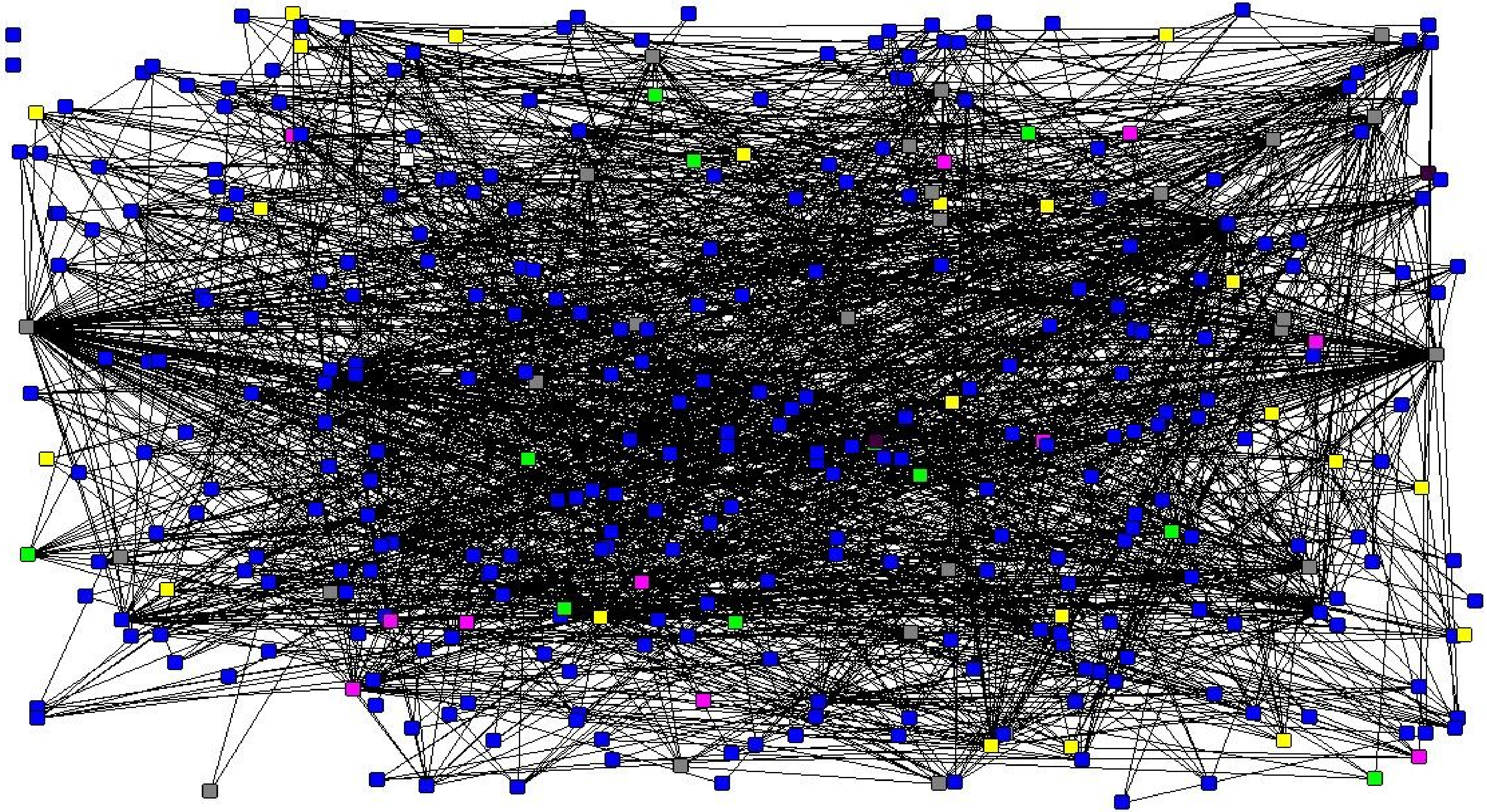
8. Appendix

Appendix 1: the 2-mode network (Borgatti, 2002) Triangle = R&D project, Bleu = firm; Green= Government; Yellow = Research Institutes; Pink = Hospitals; Grey = Universities; Dark Purple = Special Interest Organizations



Appendix 2: the 1-mode network (Borgatti, 2002) Bleu = firm; Green= Government; Yellow = Research Institutes; Pink = Hospitals; Grey = Universities; Dark Purple = Special Interest Organizations



Appendix 3: Correlations between variables

		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1	Product Availability after 5 years	1															
2	Revenues after 5 years	,473	1														
3	Commitment of the partners	,322	,370	1													
4	Value Chain Complementarity of Partners	,079	,094	-,110	1												
5	Overlap of Companies >1	,116	,097	,040	-,345	1											
6	Overlap of Governmental Institutions >1	-,003	,057	,162	,003	,049	1										
7	Overlap of Research Institutes >1	-,008	,048	,129	,059	-,125	,183	1									
8	Overlap of Hospitals >1	,029	,001	,034	,130	-,200	-,024	-,062	1								
9	Overlap of Universities >1	,107	,091	,007	,092	-,050	-,050	-,004	-,028	1							
10	Key Player Availability	-,083	-,071	-,043	-,102	,213	-,132	,042	-,212	,059	1						
11	Amount partners Betweenness Zero	,248	,040	,019	-,255	,300	,225	,066	,070	,146	-,168	1					
12	Amount partners Betweenness Low	,064	,133	,185	-,072	,180	-,019	,198	-,038	,141	-,106	-,101	1				
13	Amount partners Betweenness Medium	,127	,051	-,075	-,095	,117	,131	,088	,047	,059	-,019	,048	,092	1			
14	Amount partners Betweenness High	,068	-,057	-,033	,083	,094	-,023	-,091	,148	,222	,234	-,040	-,066	-,154	1		
15	Amount partners Betweenness Very High	,030	,020	,055	,080	,108	-,111	,164	-,099	,374	,485	-,090	,125	-,118	,082	1	
16	Amount Participants Per Project	,272	,109	,088	-,186	,414	,140	,208	,050	,398	,084	,609	,506	,303	,220	,377	1