Knowledge complementarity and the volatility of relationships in the Dutch life sciences industry network seen from two perspectives

Does knowledge complementarity have an influence on volatility?

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Astrid van den Berg
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Utrecht University – Faculty of Geosciences

A. T. (Astrid) van den Berg
a.t.vandenberg@students.uu.nl
Student number: 3048322

Supervisors:
dr. J. (Jan) Faber
Associate professor of innovation science, Utrecht University
J.J.M. (Jaap) Veldkamp, MSc
Researcher and consultant, Dialogic

Abstract

The life sciences industry is considered as very important for stimulating future economic development. In order to let this industry flourish and grow, collaborations between organizations in this industry are very important for the survival of organizations and will be considered in this study. This is due to the diverse specialties of the organizations within this industry and the rapid development of techniques, skills and resources. Organizations are thus forced to collaborate with other organizations. For one organization it is impossible to have all the competences and resources needed to develop a new product in-house. So, organizations are forced to collaborate in order to acquire technological knowledge complementarities. The organizations themselves also indicate that this is one of the most important motives for organizations to collaborate. The life sciences industry is a knowledge intensive industry and it takes a long time to develop a product. So, in order to innovate long term inter-organizational collaborations are expected. However, within the Dutch life sciences industry a highly volatile network was discovered. This resulted into the following research question:

To what extent does knowledge complementarity influence the volatility of relationships in the Dutch life sciences industry network from 2002-2005 from both a relational and organizational perspective?

This research question will be answered with the help of the Resource Based View (RBV) and the Resource Dependence View. Two perspectives are taken regarding this question indicating two different operationalizations of the concept knowledge complementarity. In the relational perspective knowledge complementarity will be operationalized as patent citations and within the organizational perspective a more Resource Based View is taken where knowledge complementarity is operationalized as the number of patents which an organization owns or has access to.

For the relational operationalization no analysis could be done. Within the network there were so little patent citations between collaborating partners that a decent analysis was impossible. In order to give at least an indication of knowledge complementarity on a relational level a patent class analysis has been conducted. However, it turned out that only 40% of the organizations within the life sciences industry in the Netherlands own one or more patents. Again no analysis could be done.

At the organizational level first more insight needs to be gained into the dynamics of the Dutch life sciences network. It turned out that the number of relationships has a two wave influence on the number of aborted and newly formed relationships. Organizations with a lot of relationships abort the less beneficial ones. This behavior continues over time. Organizations with only a few relationships will form new relationships and then again will form new relationships, but from the set of previously formed relationships they will abort the least beneficial ones. So it seems that having a few relationships is an incentive to form new ones. These two patterns are continued over time, however the effects deteriorate over time.

After that, different RBV variables (the amount of acquired venture capital, R&D intensity, size, age, type and the total number of relationships) and knowledge complementarity have been added to the model. Then it turns out that knowledge complementarity indeed has a negative influence on the volatility of the relationships in the network. However, it turned out that it also had a positive influence (i.e. because of the subdivision of the volatility into the number of aborted and newly formed relationships). This seems to be the effect of

knowledge leaking or the fact that expected knowledge complementarities were not really present. Knowledge leaking happens when one of the two collaboration partners also has relations with other organizations. The exchanged knowledge can then more easily leak to third parties. This can lead to network effects like shorter collaborations despite the fact that the organizations have a high rate of knowledge complementarity.

Next to this some other conclusions can be drawn from this analysis. The explanatory variables are very time dependent and the effects of the explanatory variables are also volatile over time. It turned out also that the earlier found result that organizations with less relationships first form new ones and then select and abort the least beneficial, is due to the fact that their resources are changing over time which could be deduced from the volatility of the explanatory variables over time. From the time dependency of the explanatory variables it can be concluded that the needs of organizations within the industry change over time.

These results have some implications for those obtained in other studies and give an important suggestion for further research. In this study it is shown that the effects from Resource Based View variables are time dependent and volatile over time. This demands a more dynamic model and explanation since there seems to be no sound structural Resource Based View model. Furthermore, it would be interesting to link this more dynamic model to the phase of product development and the phase of industry/network development.

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1 Introduction

1.1 Research problem

Technological knowledge is necessary for innovations in high-tech industries. However, sometimes a part of the required technological knowledge lies outside an organization's core competences. This is often the case within high-growth and technology-intensive industries, such as the life sciences industry (Hagedoorn, 2002). There are a few different ways of acquiring this technological knowledge that organizations do not have in-house; make, buy or cooperate. The decision between making or buying knowledge is the same as the decision between external technological knowledge sourcing and conducting in-house R&D which are considered substitutes. Cooperation allows organizations to exchange resources, to share costs and uncertainties, to realize economies of scale and scope, to win government support, to exploit synergies from complementarities and also to lose knowledge (Cassiman & Veugelers, 1999; Beneito, 2003; Becker & Dietz, 2004).

Especially during the last decades the need to collaborate has grown. Since the mid 1980's the number of inter-organizational collaborations has grown rapidly because of technological learning and new knowledge creation (Hagedoorn, 1993; Duysters & de Man, 2003). Two possible explanations for this rapid growth of inter-organizational collaborations are resource interdependencies and resource (knowledge) complementarities (Pfeffer & Nowak, 1976; Nohria & Garcia-Pont, 1991). The phenomenon of resource interdependencies and resource (knowledge) complementarities is due to the fact that resources required for innovations can be increasingly complex and multi-disciplinary. Because of these reasons, innovations do necessarily need interactions and cooperation between organizations in order to acquire complementary resources and technological knowledge (Arora & Gambardella, 1990; Howells et al., 2003). Also the decrease of the number of internal R&D departments and the decrease of the advantages of in-house R&D activities has stimulated this need for collaboration, because this has reduced the amount of internal knowledge of organizations (Chesbrough, 2003).

In order to assess how a collaboration becomes successful, Nooteboom et al. (2007) constructed the concept of optimal cognitive distance. This concept consists out of two different effects; a novelty effect and an absorption effect. The optimal cognitive distance suggests that when two organizations share too little perceptions, values, knowledge etc. (i.e. a large cognitive distance) these organizations will not benefit optimally from a collaboration between them because it is much harder to understand each other. However, when two organizations have a very small cognitive distance between them it will be much harder for them to learn from each other because they already possess large parts of the knowledge which the other also has. Here the novelty and absorption effect are shown. In the middle there is an optimal point in which both organizations can benefit most from the collaboration. The concept of optimal cognitive distance is in line with the idea of 'absorptive capacity' from Cohen and Levinthal (1989, 1990). Absorptive capacity relates the ability of an organization to identify, assimilate and exploit external knowledge that is additional to its own current, internal knowledge. Thus, an organization's internal attempts to create new knowledge encourage the use of external knowledge sources and increase the ability of an organization to exploit these external knowledge sources more successfully. This implies that the more an organization attempts to create its own knowledge internally, the larger the effects of external knowledge acquisition are on the innovative performance of an organization (Vega-Jurado et al., 2009).

A lot of literature has been written about the formation of inter-organizational collaborations (e.g. Hagedoorn, 1993; Rothaermel & Boeker, 2008; Mitsuhashi & Greve, 2009; Ahuja, 2000). Next to this literature about the formation of collaborations, also literature is written about the termination of collaborations. For instance, Olk and Young (1997) found that the departure from a relationship indicates its poor performance. The decision whether or not to stay in a relationship depends on the degree of a member's dependence on the relationship and on its commitment to the relationship or to the other partners. However, there can also be another reason for a partner to leave a relationship. When a member learns from another member via the relationship, the likelihood that this member will leave increases (Olk & Young, 1997).

The duration of such inter-organizational collaborations is, however, an aspect of cooperation which has almost not been investigated yet. Length is also an important characteristic of collaborations. As it takes in, for example, biotechnology 10-12 years to bring an invention to the market (e.g. Moors & Faber, 2007), one might expect long-term collaborations between partner organizations. However, in other industries where product development times are much shorter, shorter collaborations can be expected. Lunnan and Haugland (2008) did investigate the performance of strategic alliances over time. They were not specifically interested in the length of inter-organizational collaborations, but because they conducted a longitudinal research of the same alliances the duration of collaborations was included. More specifically, they found that the short-term performance of an alliance is primarily stimulated by the access to complementary resources. The long-term performance is stimulated by other causes, namely the investments in human capital and the partner's ability to develop and expand alliance activities over time. However, it should be noted that this study was done in manufacturing industries.

Because technological knowledge, especially within the life sciences industry, is complex and multidimensional (or multi-disciplinary), organizations in this industry have developed diverse specialties. This is also due to the rapid development of techniques, skills and resources. Because of these two aspects it is not feasible for an organization within the life sciences industry to produce all the required technological knowledge in-house necessary to develop a product. So, it becomes necessary for an organization's survival to collaborate with other organizations in order to acquire technological knowledge complementarities (Powell et al., 2005). Organizations within the life sciences industry themselves indicate this as one of the two most important reasons to partner with other organizations (Hu & Mosmuller, 2008). Consequently, within this industry it might be expected that in order to optimally benefit from knowledge complementarities and collaboration, those collaborations should last for a sufficient long time.

However, van der Valk (2007) observed the contrary. She found that within the life sciences industry in the Netherlands inter-organizational collaborations are highly volatile and often last on average less than one year. As can be seen in Table 1, of the 189 relations in 2002 only 47 relations still existed in 2004 and of the 198 relations in 2004 only 62 still existed in 2005. Also the percentage of short-living collaborations (which only existed in 2004) is 75% and is thus rather high. The number of new relations is high in both years, in 2004 151 relations and in 2005 86 relations. This results in a rather high volatility of the collaborations in the network. This is a paradoxical outcome contrary to what would be expected.

		total 2002	2004 conn.	2004 disconn.	2004 org. exit	total 2004	2005 conn.	2005 disconn.	2005 org. exit
DDLSFs	connected	64	33	26	5	77	45	32	
	disconnected	18	18			26	16		10
	org. entry		26				3		
DDLSFs	total 2004 / 2005		77	26	5		64	32	10
Partner Orgs.	connected	137	48	89[1]		131	48	83	
	org. entry		83				48		
Partner Orgs.	total 2004 / 2005		131	89			96	83	
Collab. Relations	establ. relations	189 (77%)	47	130	12	198	62[2]	136[3]	
	new relations from: - disconn. orgs.		90				76[4]		
	- org. entry		61				10		
Collab. Relations	total 2004 / 2005		198 (81%)	130	12		148 (90%)	136	

[1] Disconnected partner organizations, in principle, exit the network.
[2] This set of 62 surviving collaborative relations contains 25 collaborative relations that already existed in 2002.
[3] This set of 136 terminated collaborative relations contains 114 (136-(47-25)) only in 2004 existing relations of the 151 (90+61) relations started between 2002 and 2004.
[4] This set of 76 new collaborative relations contains only 7 repetitions of the 130 collaborative relations in 2002 that were terminated in 2004.

Table 1. Ecologies of DDLSFs, partner organizations and their collaborative relations in the period 2002-2005 (Faber & Meeus, 2010)

According to Gay and Dousset (2005) organizations in the industry have a preference for novelty. This implies that the organizations within the industry are constantly searching for the most promising and newest complementary technologies. A lot of the relations build on these motives are likely to already strand in the first phase of the collaboration, because then the organizations will discover that they cannot acquire knowledge complementarities from each other and will search for more beneficial relationships. This would imply that knowledge complementarity has a positive influence on the length of inter-organizational relationships and thus a negative influence on the volatility of the relationships in the network. At least this paradoxical outcome raises some questions.

Is the role of knowledge complementarities less important in high-tech inter-organizational collaborations than presumed before? Or is the expected relationship between knowledge complementarities and the continuation/volatility of inter-organizational collaborations in the network different from that between knowledge complementarities and the formation of collaborations? In order to answer these questions, this study investigates the relationship between knowledge complementarity and the volatility of relationships in the Dutch life sciences industry network.

1.2 Research question

In this study the relationship between knowledge complementarity (independent variable) and the volatility of relationships in the network within the Dutch life sciences industry (dependent variable) will be investigated. This results in the following research question:

To what extent does knowledge complementarity influence the volatility of relationships in the Dutch life sciences industry network from 2002-2005 from both a relational and organizational perspective?

As can be seen in the research question, this study will be conducted from two different perspectives: the relational and the organizational perspective. The concept of knowledge complementarity can be seen as a relational concept because there are two actors needed in order to determine whether or not certain knowledge is complementary to the current internal knowledge. So, here a relational perspective is in place. However, it is also interesting to see this from an organizational need perspective, because of the large differences amongst the characteristics of the organizations within the life sciences industry (Arora & Gambardella, 1990). Then knowledge complementary can be seen as a resource of an organization. In order to give an answer to the research question two sub questions are derived:

- *To what extent is knowledge complementarity a prerequisite for enduring inter-organizational collaboration between organizations in the Dutch life sciences industry?*
- *To what extent is knowledge complementarity an organizational resource affecting inter-organizational collaborative behavior in the Dutch life sciences industry?*

The first sub question is related to the relational perspective and the second sub question includes the organizational perspective.

As already said before organizations within the life sciences industry indicate knowledge complementarity as one of the two most important reasons to partner with other organizations. This was found with the help of a survey in which the organizations could choose from a few motives for partnering (Hu & Mosmuller, 2008). In this study on the influence of knowledge complementarity on the volatility of the relationships within the network, knowledge complementarity will be measured in a quantitative way. Because the life sciences industry is a high-growth and technology-intensive industry and products have a long development time, it is likely that almost all technological knowledge will be protected with the help of patents (e.g. Powell et al., 2005; Gersten, 2005). Compared to other industries this is quite a lot. According to Powell et al. (2005: 1142) "*the high rate of technical renewal is reflected in patent data*". Therefore patents are conceived to be a reliable indicator for the amount of technological knowledge and patents and their characteristics will be used in order to develop the operationalizations of the concept knowledge complementarity.

1.3 Relevance & justification

1.3.1 Newsworthiness & usefulness

The life sciences industry is characterized by the fact that it is knowledge intensive and it takes a long time to develop a product (Moors & Faber, 2007). Also inter-organizational collaborations are needed here in order to develop a product (Powell et al., 2005) and one of the most important incentives for these collaborations is knowledge complementarities (Hu & Mosmuller, 2008). Therefore long term inter-organizational collaborations based on knowledge complementarities might be expected. However, within the Dutch life sciences industry network a high volatility of relationships was found (van der Valk, 2007; Faber & Meeus, 2010). The question now is how this volatility of relationships can be explained, since organizations do need collaborations and thus knowledge complementarities in order to survive and grow.

However, literature is not conclusive about the effects of complementarity of internal and external knowledge sources on the organization's innovative performance (Vega-Jurado et al., 2009). According to the Resource Based View, external knowledge should complement internal R&D instead of substituting it. There is empirical evidence on the importance of the organization's internal knowledge for the ability to identify and acquire external knowledge (e.g. Mowery, 1983; Cohen & Levinthal, 1990; Arora & Gambardella, 1990, 1994 and Freeman, 1991). However, its effect on an organization's innovative performance in terms of the length of collaborations necessary for product development has not been investigated yet.

1.3.2 Scope

This research will only focus on one industry, namely the life sciences industry, because this is a high-growth and technology-intensive industry in which collaborations are needed in order to grow and survive as an organization and where it is remarkable that products have a long development time and the volatility of the collaborations in the network is high. It is likely that within this kind of industry almost all technological knowledge will be protected with the help of patents (e.g. Powell et al., 2005; Gersten, 2005). These patents are then a reliable indicator for the amount of internal technological knowledge.

Only the life sciences industry in the Netherlands will be investigated. The life sciences industry in the Netherlands is an interesting industry because it is a developing and expanding industry and is rising in the world rankings (Amsterdam BioMed Cluster, 2010). Also can be seen from Table 2 and Figure 1 that the Netherlands are quite well represented with respect to the number of patent applications. Also according to van Geenhuizen (1998), the Netherlands has a reasonably good position based on the number of biotechnology patents.

Region (Territorial Level 2)		Biotechnology patents	Share (%) in total
San Jose-San Francisco-Oakland	US	1 510	5.5
Boston-Worcester-Manchester	US	1 422	5.2
New York-Newark-Bridgeport	US	1 090	4.0
Washington-Baltimore-N.Virginia	US	811	3.0
Tokyo	JP	792	2.9
San Diego-Carlsbad-San Marcos	US	782	2.9
Los Angeles-Long Beach-Riverside	US	613	2.2
Philadelphia-Camden-Vineland	US	587	2.2
Nordrhein-Westfalen	DE	506	1.9
Hovedstadsregionen	DK	454	1.7
Capital region (Seoul - Incheon - Gyeonggi-do)	KR	404	1.5
Île de France	FR	379	1.4
Bayern	DE	375	1.4
Osaka	JP	368	1.3
West-Nederland	NL	351	1.3
Raleigh-Durham-Cary	US	336	1.2
Ontario	CA	302	1.1
Baden-Württemberg	DE	294	1.1
East of England	GB	262	1.0
Seattle-Tacoma-Olympia	US	261	1.0
Ibaraki	JP	248	0.9
South-East (England)	GB	246	0.9
Chicago-Naperville-Michigan City	US	235	0.9
Québec	CA	230	0.8
Houston-Baytown-Huntsville	US	219	0.8
Minneapolis-St. Paul-St. Cloud	US	213	0.8
Hessen	DE	209	0.8
London	GB	201	0.7
Berlin	DE	198	0.7
Vlaams Gewest	BE	196	0.7
Rhône-Alpes	FR	190	0.7
Kyoto	JP	189	0.7
Denver-Aurora-Boulder	US	186	0.7
Victoria	AU	176	0.6
Detroit-Warren-Flint	US	165	0.6
St. Louis-St. Charles-Farmington	US	162	0.6
Zuid-Nederland	NL	161	0.6
New South Wales	AU	158	0.6
Atlanta-Sandy Springs-Gainesville	US	148	0.5
Madison-Baraboo	US	144	0.5
Niedersachsen	DE	139	0.5
Chiba	JP	138	0.5
Beijing	CN	137	0.5
Chungcheong region	KR	134	0.5
Aichi	JP	129	0.5
Hyogo	JP	119	0.4
Stockholm	SE	116	0.4
Indianapolis-Anderson-Columbus	US	110	0.4
Saitama	JP	108	0.4
Etela-Suomi	FI	108	0.4

Table 2. Top 50 regions in biotechnology PCT patent applications, 2004-2006 (OECD, 2009)

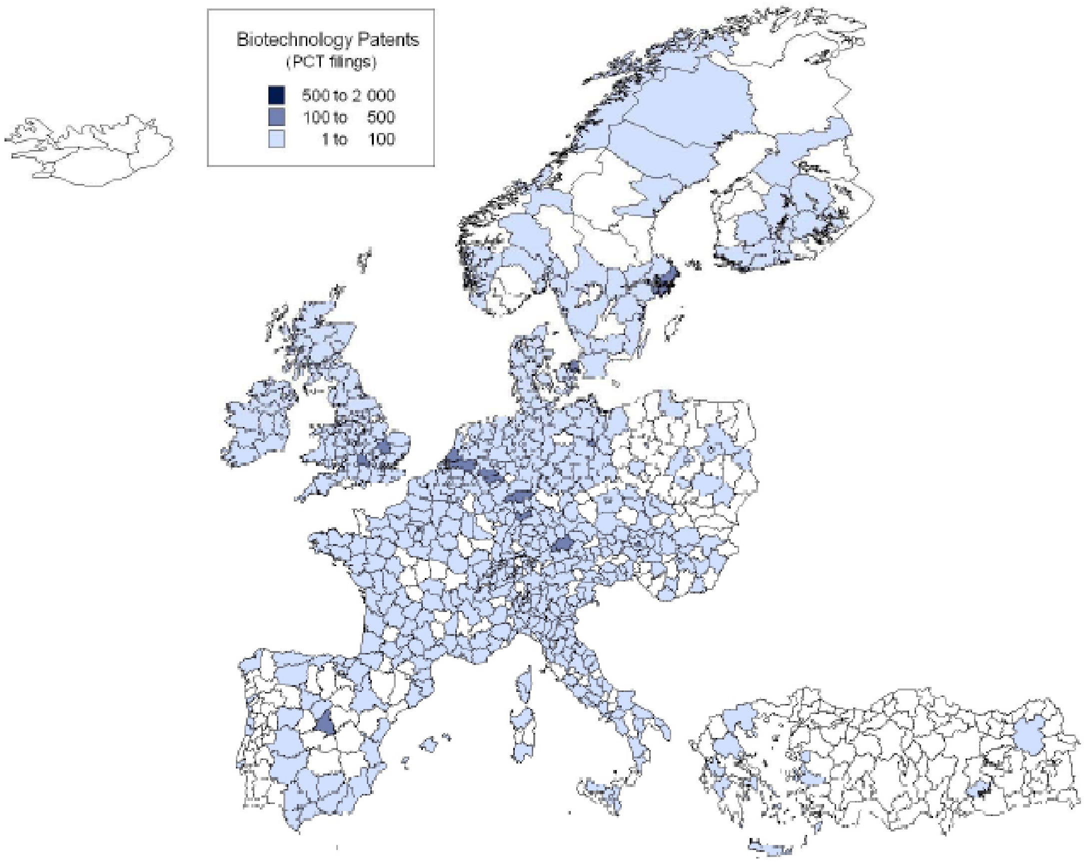

Figure 1. Number of biotechnology patents: Europe, 2004-2006 (OECD, 2009)

1.3.3 Innovation studies

In this research, the relationship between knowledge complementarities and the volatility of inter-organizational collaborations as prerequisites of innovation within the Dutch life sciences industry will be investigated. This is important for innovation studies because inter-organizational collaborations are important for innovations to arise particularly within the Dutch life sciences industry. This industry is an interesting industry for innovation studies because it is considered to be an emerging industry and of importance for stimulating future economic development (Ministry of Economic Affairs, 2004; van der Valk, 2007).

1.4 Outline

First in chapter 2 more insight will be given into the background of collaborations in the life sciences industry in the Netherlands and the related network dynamics. Subsequently, in chapter 3 a theoretical framework will be developed. The Resource Based View and the Resource Dependence View will be elaborated upon. Also the dependent, independent and control variables will be explained. These variables and their relationships constitute the conceptual model and hypotheses about the relationships will be formulated. After that, the variables will be operationalized from a relational and an organizational perspective. In chapter 4 the data collection and the methodology will be elaborated upon. There will be attention for the different ways in which the data are collected. Furthermore, the various research methods to be applied will be discussed. In chapter 5 the results of the analysis for the first sub question will be presented. Chapter 6 will give the results of the analysis for the second sub question. Chapter 7 will entail the discussion and the conclusion of the research, gives some policy recommendations and some suggestions for further research.

2 Background

In this part of the report the background situation of inter-organizational collaborations in the Dutch life sciences industry will be presented. First, the life sciences industry in the Netherlands will be explicated. After that, some general remarks about inter-organizational collaborations in the life sciences industry will be made. Also a model for network dynamics will be developed.

2.1 Collaborations in the Dutch life sciences industry

2.1.1 Life sciences in the Netherlands

The life sciences industry is one of the most competitive and knowledge-intensive industries in the economy (Gay & Dousset, 2005). According to Powell et al. (2005), this industry is characterized by a wide dispersion of sources of basic technological knowledge and rapid development of new products so that actors within the industry are forced to collaborate with each other. Organizations within the life sciences industry can be typified as science-based organizations. According to Vega-Jurado et al. (2009) these organizations are expected to have a high use of external knowledge-sourcing strategies due to their technological opportunities. Accordingly, some typical agents can be distinguished: universities, small/medium sized research-intensive enterprises (New Biotechnology Firms) and large established chemical and pharmaceutical corporations. These agents all have complementary assets to generate, develop and commercialize new life sciences products. So, it seems logical that these agents have numerous collaborations between them (Arora & Gambardella, 1990).

In this research the following definition of organizations within the life sciences industry will be used: "*those firms that apply the possibilities of organisms, cell cultures, parts of cells or parts of organisms, in an innovative way for the purpose of industrial production. They may also supply related services, and hardware and software*" (BioPartner, 2005: 188). Next to this definition some other boundaries for the inclusion of organizations for this study are: 1) the organization conducts R&D activities in technological fields belonging to the life sciences; 2) the organization is located in the Netherlands; 3) the organization is registered at the Dutch Chamber of Commerce; and 4) the organization is an independent entity (BioPartner, 2005: 188).

The life sciences industry has an impact on many other industries, including pharmaceuticals, chemicals, agriculture and food. Because of the pervasive character of this industry the developments within this industry are considered to be very important for stimulating future economic development in the Netherlands (Ministry of Economic Affairs, 2004). The life sciences industry in the Netherlands is a very young industry and still in a nascent stage of development and can be considered as emerging (van der Valk, 2007).

The Dutch Ministry of Economic Affairs describes the life sciences industry as follows: "*life sciences is a dynamic science and technology area that includes a constantly renewing toolbox of techniques and processes to analyze forms of biological life and to use for the development of better products and production processes in many application areas*" (Ministry of Economic Affairs, 2005: 7). From the beginning of the 1980's life sciences in the Netherlands received attention from the innovation policy of the Ministry of Economic Affairs. First, the focus was on the building of knowledge on biotechnology (for instance within the IOP, Innovatiegericht Onderzoekprogramma Biotechnologie). Since the second half of the 1990's the policy became more targeted on one of the most important bottlenecks for innovation in the Netherlands, the collaboration between the firms and the knowledge institutions (Ministry of Economic Affairs, 2004).

The life sciences industry within the Netherlands thus acquired a strong science base, particularly within biomedical and agro-food life sciences. However, later on, it seemed as if the life sciences industry was falling behind. Particularly the number of life sciences researchers who started new companies was falling behind (Ministry of Economic Affairs, 1999). Also some other problems were found; a lack of business culture in Dutch knowledge institutes (i.e. results of scientific research were not enough commercialized), not enough venture capital available, a shortage of facilities and too few managers which can act as coach and mentor (Hu & Mosmuller, 2008). In 1999 the Ministry of Economic Affairs decided that entrepreneurship in the life sciences should be boosted. So the 'Action Plan Life Sciences 2000-2004; breaking away from the pack' (Ministry of Economic Affairs, 1999) was launched, which was focused on the following points: entrepreneurship, simplification of the regulatory framework, keep the knowledge base strong, part of strong international networks, good communication (Horning, 2004).

In 2000 the BioPartner programme was launched as a part of this Action Plan by the Ministry of Economic Affairs in order to stimulate entrepreneurship within the life sciences and to stimulate the entire life sciences industry within the Netherlands (Ministry of Economic Affairs, 1999; Hu & Mosmuller, 2008). This programme provided advisory services and seed capital for life sciences based new product development of Dutch ventures and start-ups. Also the programme registrated and monitored the Dutch organizations which were active in the life sciences industry (Hu & Mosmuller, 2008). The BioPartner programme also founded some BioPartner Centers in the Netherlands. These centers offer suitable housing and all kinds of services for start-ups in the Dutch life sciences industry. These Centers are very important in the facilitation of start-ups in their region. They are situated in (see Figure 2):

- Amsterdam
- Groningen
- Leiden
- Maastricht
- Utrecht
- Wageningen (BioPartner, 2005)

Figure 2. The Ducth life-sciences sector map (BioPartner, 2005)

The programme lasted until 2005 (BioPartner, 2005). Nowadays the life sciences industry in the Netherlands is rising in the world rankings (Amsterdam BioMed Cluster, 2010).

2.1.2 Collaborations in the life sciences industry

Within the life sciences industry resources become more and more complex and multi-disciplinary. Also the pace of technological change and development is very rapid. These two aspects play an important role in partnering. Techniques, skills and resources develop so rapidly that it is impossible for an organization within the life sciences industry to produce all the required technological knowledge in-house necessary to develop a product and consequently they cannot rely on in-house R&D only. They need to collaborate with other organizations in the industry to acquire the needed technological knowledge complementarities in order to be able to survive and grow (Powell et al., 2005).

These inter-organizational collaborations within the life sciences industry are expected to last for a sufficient long time because of the needed knowledge complementarities (Hu & Mosmuller, 2008) and the long time to market for a product. Within the biotechnology industry it takes about 10-12 years to bring an invention to the market (e.g. Moors & Faber, 2007). So, long-term collaborations between partner organizations are expected.

Organizations within the life sciences industry have a preference for novelty and thus will search for the most promising and newest technologies. This implies that organizations will often switch between their partner organizations (Gay & Dousset, 2005). However, these relationships are not likely to be based on knowledge complementarity and integration because of the short character of the relationships.

2.2 Network dynamics

According to van der Valk (2007) and Faber and Meeus (2010) the Dutch life sciences industry network is a highly volatile network. This has to do with the individual relationships and the importance which was attached to certain partners.

The volatility of the relationships in a network is caused by the abortion and formation of collaborative relations. However, the numbers of aborted and newly formed relationships depend on the total number of relationships that an organization has. Organizations with many relationships are able to abort many relationships. They are less dependent on individual relationships and can more easily abort the less beneficial relationships. Also they have a larger capacity for collaborations and are more attractive for other organizations within the network to partner with. Therefore they can more easily form new relationships (Ahuja, 2000; Powell et al., 2005). So, organizations with many inter-organizational collaborations can more easily abort as well as form new relationships.

This results in the following model:

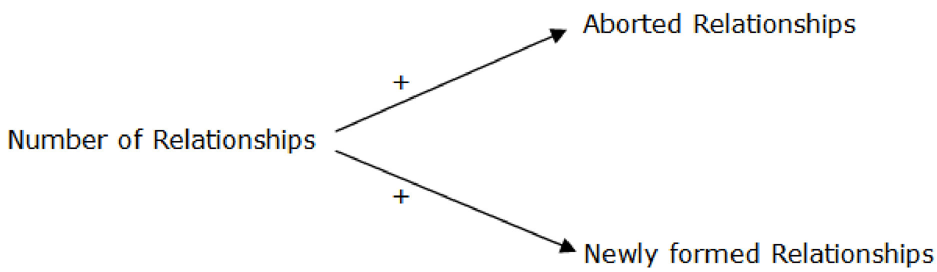

Figure 3. Network dynamics

3 Theoretical Framework

In this section the theoretical framework of the research will be elaborated upon. Different theories, crucial variables, the central hypothesis, the conceptual model and the operationalization of the variables will be discussed.

3.1 Theoretical background

3.1.1 Resource Based View

The Resource Based View (RBV) of the firm explains how innovations come about from a firm perspective. Within this view of the firm, firms (or organizations) are seen as bundles of resources. Differences in these resources between organizations can lead to sustainable competitive advantages (Penrose, 1959; Wernerfelt, 1984).

According to Wernerfelt (1984: 172) resources are "*anything which could be thought of as a strength or weakness of a given firm*". However, he mentions also a more formal definition: "*a firm's resources at a given time could be defined as those (tangible and intangible) assets which are tied semi permanently to the firm (see Caves, 1980)*" (Wernerfelt, 1984: 172).

Resources also have some distinct features. At first, they create value for the organization. They can reduce costs or heighten prices (Barney, 1986). Resources are also firm(organization)-specific. They are unavailable outside the organization which has created them or the resource's value diminishes when it is separated from the organization which has created it (Dierickx & Cool, 1989). Another feature of resources is that it takes time to develop them. They cannot be developed instantaneously (Dierickx & Cool, 1989).

At first this view of the firm focused on the internal resources of an organization (Penrose, 1959; Wernerfelt, 1984). However, later it turned out that critical and necessary resources can also reside outside an organization's boundaries (Dyer & Singh, 1998). Due to this, the RBV of the firm has been extended with "*firms needing to exchange each others' complementary resources, and, in particular, knowledge*" (Sammarra & Biggiero, 2008: 802).

Since organizations within the life sciences industry are not able to have all the resources in-house necessary for developing an innovation (Powell et al., 2005), according to this theory, they have to collaborate with other organizations in order to get access to the needed resources.

3.1.2 Resource Dependence View

The Resource Dependence View is an extension of the Resource Based View. Here organizations are dependent on other organizations in their value chain and environment for gaining access to certain resources. The main question here is how organizations can reduce uncertainty with help of the use of such external sources (Pfeffer & Salancik, 1978).

Organizational success is in this theory defined as organizations maximizing their resourcing power (Kanter, 1979). This theory is about modifying an organization's power relations based on exchanges of resources with other organizations. Organizations which need a certain resource that they do not have in-house, have to establish relationships with other organizations in order to acquire the needed resource. In this way, the organization which needs the resource makes itself dependent upon the organization with whom it is going to collaborate. Organizations will try to change their dependence relationships by minimizing their own dependence or by increasing the dependence of other organizations on them. Also with resources this is the case; organizations will try "*to acquire control over resources that minimize their dependence on other organizations*" and they will try "*to acquire control over resources that maximize the dependence of other organizations on themselves*" (Ulrich & Barney, 1984: 472).

3.1.3 Inter-organizational collaborations

In this study the following definition for inter-organizational collaborations stated by van der Valk (2007) will be used; *"... an inter-organizational relationship is defined as a cooperative agreement of multiple organizations which can focus on different stages of product or process development and commercialisation, including R&D, production, marketing and distribution.*" (van der Valk, 2007: 15). As already mentioned earlier, for a high-tech organization the development and establishment of inter-organizational collaborations has advantages. However, organizations cannot connect with all other possible organizations in a certain industry. This implies that organizations only interact with a limited number of organizations within an industry. These interactions are not chosen at random (Gay & Dousset, 2005).

The choice to collaborate or not with another organization depends on a few aspects. According to Ahuja (2000) this has to do with inducements and opportunities. Inducements, or incentives, are the triggers to which an organization establishes a linkage. These triggers are the strategic or resource needs of the organization. However, organizations should also be attractive for potential partners. This is reflected in their opportunities. These determine the ability of an organization to form new relationships based on the position of the organization in the prior network structure or on the strategic and resource needs of other organizations. This is due to the structural sociological perspective which argues that "*the patterns of observed interfirm linkages reflect the prior patterns of interfirm relationships*" (Ahuja, 2000: 317).

However, the mechanisms and motivations to form alliances with certain partners may differ from the causes of the (dis)continuation of inter-organizational collaborations. With respect to collaborations different phases can be distinguished; attention arousal, exploration and exploitation. Often collaborations are started on the basis of the reputation of the organizations. The continuation of such relationships is, however, based on the content of the relationship. When the different phases are considered, the phase of attention arousal is purely based on reputation. In the exploration phase a shift occurs towards content-related motives. The last phase of a collaboration (before termination), exploitation, is strongly based on content (Powell et al., 2005; Gulati & Gargiulo, 1999). This would entail that collaborations which are based on the content of the relation (for instance knowledge complementarities) last longer than collaborations which are based on previous motives, such as reputation.

3.1.4 Resources, relationships and volatility

The Resource Dependence View could be of influence on the volatility of the collaborations in the network. When a member learns from another member within the relationship, the likelihood that the first member will leave increases, because the first member becomes less dependent on the relationship (Olk & Young, 1997). Consequently that member will gain greater bargaining power and has less need to stay in the relationship (Hamel, 1991). In this situation only one member will learn from the other member and will gain the benefits of the collaboration, while the other stays behind. This will be called asymmetrical learning.

Participating in a relationship does not only entail advantages. There are also disadvantages. For instance, the fact that organizations will lose their unique features. This happens when they work together in order to innovate and because they learn from each other in the process (Cowan et al., 2002). When two members learn from each other and both experience the benefits and the disadvantages of learning from each other, this will be called symmetrical learning. With symmetrical learning there can be knowledge leaking. This can lead to network effects like shorter collaborations despite the fact that the organizations can learn from each other. In the literature, collaborations (and particularly joint ventures) are presented as relations which have the goal of jointly developing a product (symmetrical learning). However, it could also be that this collaboration has the aim of exchanging unique resources in order to enable each organization to develop its own product.

This symmetrical and asymmetrical learning has to do with the Resource Dependence View. Here organizations will try to acquire resources without being dependent on other organizations and they will try to make other organizations more dependent on them. This is also related to the volatility of relationships in the network. It is more likely that when asymmetrical learning occurs, relationships will last shorter then when symmetrical learning (in which both members of the relationship acquire advantages) occurs. When knowledge complementarities within the life sciences are considered, it is expected that collaborations are based on symmetrical learning and thus will last for a sufficient long time. Now these concepts will be elaborated upon in more detail.

3.2 Variables

3.2.1 Volatility of relationships

The dependent concept of this study will be the (high) volatility of relationships in the Dutch life sciences industry network.

This network is build up of inter-organizational collaborations. As a definition for these inter-organizational collaborations the former mentioned definition from van der Valk (2007) will be used.

The volatility of the relationships in the network will be measured in this thesis in two different ways because of the two different perspectives used here. From a relational perspective, the volatility of collaborations in the network is reflected in the duration of individual collaborative relationships over time. From an organizational perspective, the volatility of relationships in the network is reflected in the successive numbers of aborted and newly formed relationships by each organization over time. A more detailed description of the operationalization of both concepts of the volatility of relationships in the network will be given later on in this chapter.

3.2.2 Knowledge complementarity

The independent concept of this thesis will be the rate of knowledge complementarity between organizations active within the Dutch life sciences industry.

Knowledge complementarity consists of two parts; an internal part and an external part. More precisely, external and internal technological knowledge acquisition can be complementary activities in an organization’s innovation strategy. The effects of external knowledge sources on innovative performance depend on the internal knowledge sources, or the internal capabilities of the organization to exploit that external knowledge (Vega-Jurado et al., 2009).

According to Antonelli (2003: 597) *"... the production of knowledge is viewed as the result of both knowledge transactions and the cooperative interactions, ..., of agents undertaking complementary research activities."* He also mentions the famous Newtonian understanding of the production of science as 'standing on giants' shoulders'. According to him cumulative complementarity between different vintages of knowledge *"consists of the reorganization of elements of knowledge acquired in the past with new bits and insights recently elaborated*" (Antonelli, 2003: 597). Thus, "*the production of knowledge requires the combination of, and hence the access to, diverse and yet complementary bits of knowledge*" (Antonelli, 2003: 604).

Another aspect which contributes to the definition of complementarities is the following: "*the whole is more than the sum of its parts*" (Milgrom & Roberts, 1995: 184). This implies that the value of the internal and the external knowledge together is higher than the separated values summed up because it creates new opportunities.

So, it seems that knowledge complementarity has some different aspects; the combination and reorganization of current knowledge in order to construct new knowledge and that this new knowledge has a higher value than the former pieces of knowledge apart from each other. This will also be used in this study as knowledge complementarity.

From a relational perspective, knowledge complementarity reflects the relatedness of the knowledge assets possessed by two organizations involved. This can be related to the concept of cognitive distance (Nooteboom et al., 2007) and the concept of absorptive capacity (Cohen & Levinthal, 1989, 1990), which were already explained before, because these are also relational concepts in which two organizations are needed to determine the value. From an organizational perspective, knowledge complementarity is reflected in the knowledge assets owned and accessed by an organization. Here the concepts of inducements and opportunities from Ahuja (2000) are more in place, because these reflect the resources (or resource needs) of an organization.

3.2.3 Hypothesis

The research question of this study investigates the influence of knowledge complementarity on the volatility of the relationships within the Dutch life sciences industry network. As a preliminary answer to the research question, the main hypothesis can be formulated as:

MH: The rate of knowledge complementarity has a ***negative*** *influence on the volatility of the relationships in the Dutch life sciences industry network.*

The main hypothesis and its rejection can result in a few different possible outcomes of this research, shown in the table below[1].

[1] The scales used in this table are not the ones used in this research, however, in order to make it more clear this simplified table will be used here.

Volatility of the relationships in the network

Rate of knowledge complementarity	Low	High
Low	X	X
High	X	X

Table 3. Possible outcomes

The combination of a low rate of knowledge complementarity and a high volatility of the relationships in the network and the combination of a high rate of knowledge complementarity and a low volatility of the relationships in the network correspond with what is expected (MH). This would entail a negative relationship between the rate of knowledge complementarity and the volatility of the relationships in the network. If two collaboration partners are complementary concerning their knowledge, it is likely that they will collaborate longer and are less prone to abort the relationship because they can gain more benefits from their relationship. Contrary to this, it is likely that organizations who are not or hardly complementary with respect to their knowledge will collaborate shorter and are more prone to abort the relationship and search for a relationship in which the partners are more knowledge complementary enabling more benefits from the relationship. This is because in such a relationship the collaborating partners have less to learn from each other and gain fewer benefits from their collaboration. For these organizations it would be wiser to leave this relationship and to look for other organizations from which they can gain more benefits in a relationship, which entails an external resource need and thus an inducement (Ahuja, 2000).

The combination of a high rate of knowledge complementarity and a high volatility of the relationships in the network is a rather remarkable and surprising one. This would entail a positive relationship between the rate of knowledge complementarity and the volatility of the collaborations in the network. However, this could happen when there is ‘knowledge leaking’. When one of the two organizations involved also has relationships with other organizations, knowledge leaking could happen. In this way knowledge can leak to third parties through a common node. So, knowledge leaking via diffusion increases. This will lead to network effects like shorter collaborations despite the fact that the organizations can still learn from each other and also have a high rate of knowledge complementarity (Stuart, 1998). Another explanation could be that organizations which are expected to be knowledge complementary (and thus form an opportunity (Ahuja, 2000)) turn out to be not that knowledge complementary as expected at forehand. Relationships are then formed on the expectations of a high rate of knowledge complementarity, however, when it turns out that these organizations are not that knowledge complementary the relations will be aborted. This will contribute to the volatility of the relationships in the network. Eventually, this will thus coincide with the main hypothesis, however, the expectations are then contrary to this.

The combination of a low rate of knowledge complementarity and a low volatility of the relations in the network could also result from this research. This would entail a positive relationship between the rate of knowledge complementarity and the volatility of the relationships in the network. This indicates that the motives for collaboration have little to do with the rate of knowledge complementarity between the collaborating organizations. Instead of knowledge complementarity there are other motives for collaborating. This could have to do with certain characteristics of the organizations (for instance their age, size, R&D intensity, collocation or type). Some characteristics of the collaboration (its type and intensity) could also be of importance here.

It may also happen that there is no relation found between the rate of knowledge complementarity and the volatility of the relationships in the network. This indicates, for instance, that there are other motives for collaborating than the rate of knowledge complementarity. This could also have to do with particular characteristics of the organizations or collaborative relationships studied.

3.2.4 Control variables

For the control variables two different sets are used, because of the different units of analysis in this thesis. For the first sub question the units of analysis are the collaborative relationships between the organizations in the Dutch life sciences industry. For the second sub question the units of analysis are the Dutch dedicated life sciences firms (DDLSFs), because of their need for external resources (Powell et al., 2005). First, the set of control variables for the first sub question will be given, and subsequently, the set for the second sub question will be presented. After that all the control variables will be explained.

As control variables for the first sub question the following variables derived from key-articles will be included (e.g. Nooteboom et al., 2007; Powell et al., 2005; Vega-Jurado et al., 2009). As characteristics of the firm: venture capital acquisition, R&D intensity, size, age, type and collocation. As characteristics of the collaboration: the collaboration type. The variables R&D intensity, size and age will be measured for the biotech organizations only, because these are mainly of interest for industries which are in the early phase of development like the life sciences industry. Only the collocation and type variables are also measured for the partner organizations. Since the majority of the partner organizations are established science-based public and private organizations, the variables R&D intensity, size and age are less interesting to take into account for these organizations, because these characteristics are obvious and will be all in place with little variations.

For the second sub question the following control variables will be included, which have some overlap with the control variables of the first sub question: venture capital acquisition, R&D intensity, size, age, type and the total number of collaborative relationships with other organizations.

- Venture capital acquisition; For small and young organizations in the life sciences industry venture capital is a very important factor for growing and surviving in the industry (BioEnterprise, n.d.). This could also be of influence on the volatility of the relationships within the network. When organizations acquire more venture capital they do need less collaborations with external sources as they can develop the needed knowledge in-house or buy the needed knowledge from other organizations. When an organization does not acquire much venture capital, they are not able to develop the knowledge in-house and they have to acquire knowledge by collaborating with external sources, which will constitute an inducement for the organization. However, when an organization acquires much venture capital, it becomes attractive for other organizations in the network to partner with and becomes an opportunity (Ahuja, 2000). These effects will have an influence on the volatility of the individual relationships within the network, because the earlier described mechanisms will have an influence on the abortion and formation of relationships and thus also on the (dis)continuation of relationships. The variable venture capital is thus expected to have either a positive or negative influence on the volatility of the relationships in the network, since the concepts of opportunities and inducements constitute two competing hypotheses.

- R&D intensity; R&D expenditures are likely to have an effect on inter-organizational collaborations. However, this amount of R&D expenditures is likely to be highly dependent on the size of the organization, since larger organizations are able to have higher R&D expenditures. In order to separate these size effects from the R&D effects, R&D intensity will be included here (Hall and Ziedonis, 2001). When an organization has a high R&D intensity it will have less need to collaborate because it is likely that the organization will have much of the needed knowledge in-house. So, when an organization has a low R&D intensity there is an inducement for the organization to form new relationships in order to acquire the needed knowledge from external resources. However, when an organization has a high R&D intensity it becomes more attractive for other organizations to collaborate with because of its internal resources (Ahuja, 2000). So, here again two competing hypotheses can be distinguished. The R&D intensity is expected to have either a negative or a positive influence on the volatility of the relationships in the network.

- Size: Often large organizations have a larger portfolio of activities. So, for these organizations it is more likely that they already have the needed knowledge in-house (Nooteboom et al., 2007) and they do not need to search for this knowledge outside the boundaries of their own organization. The organization's size has also another influence on inter-organizational collaborations. This has to do with the acquired legitimacy of an organization (van der Valk, 2007). Larger organizations can attract more easily external capital for in-house R&D and therefore they will have less need for collaborations. So, the organization's size is expected to have a negative influence on the volatility of the relationships in the network because large organizations are expected to be less dependent on knowledge from external resources and thus on collaborations, because of the lack of inducements (Ahuja, 2000). However, according to the concept of opportunity from Ahuja (2000) these organizations will also be attractive for other organizations in the network to partner with and thus will have a positive influence on the volatility of the relationships in the network. Again two competing hypotheses can be distinguished.

- Age: The age of an organization influences its inter-organizational collaborations. This has again to do with the acquired legitimacy of an organization (van der Valk, 2007). Also past experience, accumulated learning from the past and trustworthiness will be of influence in this study and are related to the age of an organization. So, the organization's age is expected to have a negative influence on the volatility of the collaborations in the network because older organizations are expected to contain more knowledge and experience and thus have no inducements to form new relationships. Again however, they are more attractive for other organizations in the network to partner with because of these internal knowledge and experience resources (Ahuja, 2000). This opportunity will result in a positive influence on the volatility of the collaborations in the network. So, again two competing hypothesis can be distinguished.

- Type: The type of the organization can have an influence on inter-organizational collaborations. This is mostly seen when spin-offs are considered. A spin-off from a university is likely to have more intensive and longer relations with that university (and its network) than with other universities or organizations (Sapienza et al., 2004), because the employees of the spin-off and the university (or other organizations in its network) already are more familiar with each other and its activities are more likely to be mutually coherent. However, it is not clear whether this would have a positive or negative effect on the volatility of the relationships in the network. The relationship with the mother organization is likely to sustain but for relationships with other organizations it is hard to say what happens.

- Collocation: From earlier research (e.g. Maggioni & Uberti, 2009; Olson & Olson, 2000) it seems that distance matters for collaborating. The distance between two organizations could determine, for instance, the degree of trust within a relationship (Steinbuch, 2010). So, when two organizations are located very near to each other (for instance in the same science park or cluster of organizations), this could induce a higher degree of trust within the relationship. This could have a positive influence on the collaboration and its length. So, when two organizations are located in the same science park or cluster of organizations this could contribute to a lower volatility of the relationships within the network. Distance, measured in this way of collocation, is thus expected to have a negative influence on the volatility of the relationships in the network.
- Collaboration type: Different collaboration types entail different characteristics. One of these characteristics can be the volatility of the collaboration. In this study a difference will be made between collaborations based on licensing and collaborations based on other types of cooperation. Licensing is an agreement between the owner of the patent and the licensee. When a licensing agreement is established the licensee gets permission to use the knowledge captured in the patent. As a compensation the licensee pays the owner of the patent an indemnity (Octrooicentrum, n.d. a). This agreement is based on contracts which should last for a sufficient long time in order to be able to develop a product or service on the basis of the exchanged knowledge. This will probably have a negative influence on the volatility of the relationships in the network because these collaborations are based on contracts and thus will last for a sufficient long time.
- Total number of relationships: In order to look at the abortion and formation of relationships it is also important to know how many relations an organization has. Because when an organization does not have many relations, this organization is not able to abort many relations. However, it is hard to say whether this variable will have a positive or negative influence on the volatility of relationships. It can have a positive influence when the number is high leading to a lot of aborted relationships, but it can also have a negative influence when the number is low leading to the formation of many new relationships. Also the concepts of inducements and opportunities play an important role here. When an organization already has many relationships, its inducement to form new ones is low, because it already is embedded in the network and has access to various external resources. However, when such an organization has many relationships it becomes also more attractive for other organizations to collaborate with, because of its reputation and its larger capacity for collaborations (Ahuja, 2000; Powell et al., 2005). So, here again two competing hypotheses can be distinguished.

3.3 Model specification

3.3.1 Conceptual model

The former mentioned variables constitute the following conceptual model.

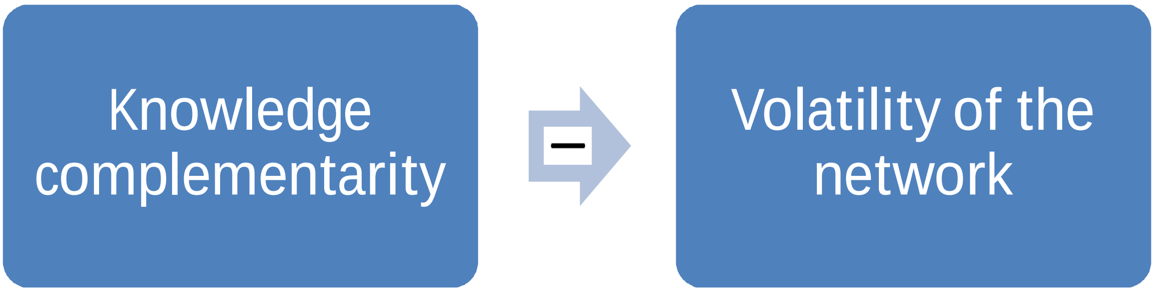

Figure 4. Conceptual model

As shown in Figure 4 the volatility of the relationships in the network is negatively influenced by the rate of knowledge complementarity. The dependent variable in this model is the volatility of the relationships in the network. This dependent variable is expected to be negatively influenced by the independent variable, the rate of knowledge complementarity.

The set of control variables for both operationalizations of the concept of knowledge complementarity differs. In Figure 5 the set of control variables for the first operationalization (the relational perspective) in the conceptual model is shown and in Figure 6 the set of control variables for the second operationalization (the organizational perspective) in the conceptual model is shown.

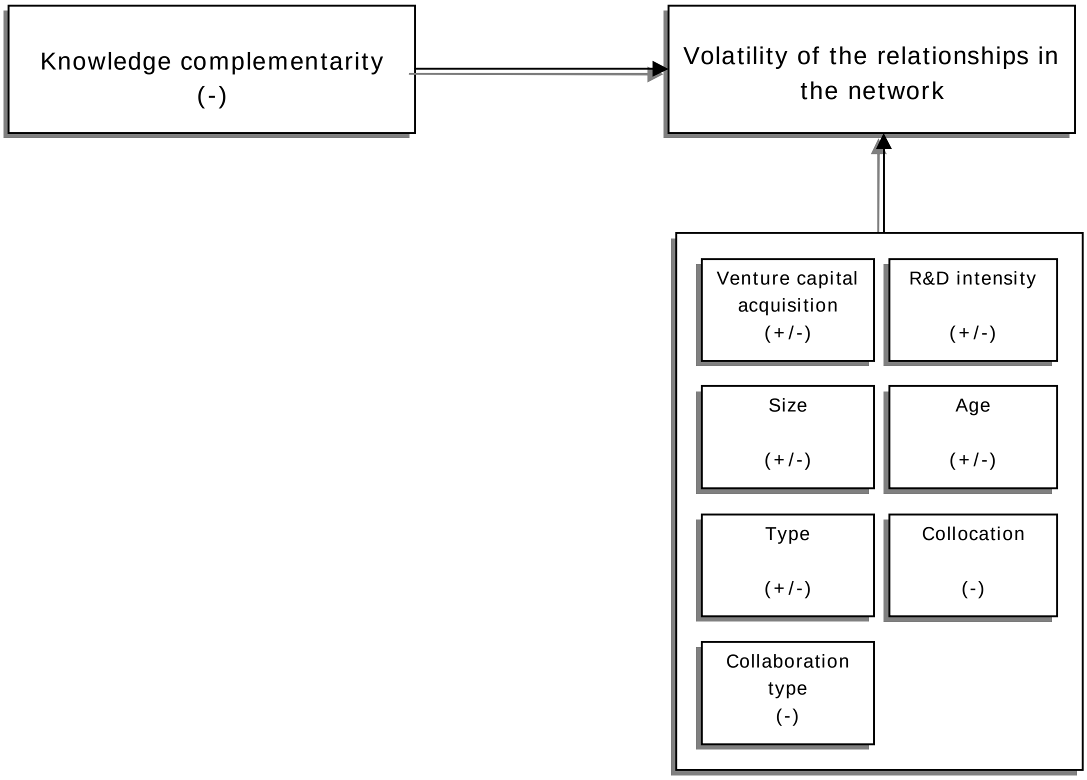

Figure 5. Conceptual model according to the operationalization of the relational view

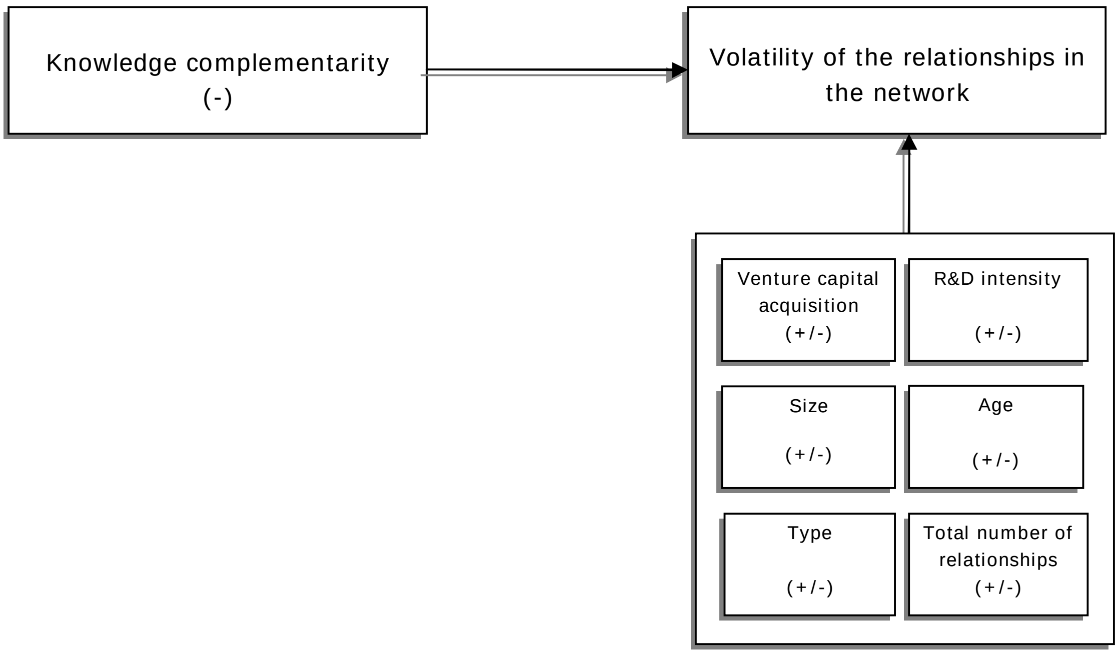

Figure 6. Conceptual model according to the operationalization of the organizational view

3.4 Operationalization

As said before, the concept of knowledge complementarity will be operationalized in two different ways because of the different perspectives used in this study. First the operationalization according to the relational perspective will be explained and then the operationalization according to the organizational perspective will be explained. After that the operationalizations of all variables will be presented in Table 5.

3.4.1 Relational level

Within the Dutch life sciences industry the majority of the collaborations (more than 70% (van der Valk, 2007)) are R&D collaborations. These collaborations are very important, since they are focused on the co-development of new products and/or services based on combining patented technological knowledge sources. Almost all technological knowledge within the life sciences industry is protected with the help of patents (e.g. Powell et al., 2005; Gersten, 2005). Therefore patents are a reliable indicator for the amount of technological knowledge. Technological knowledge complementarities can then be measured on patent citations. This is done because when a patent of one organization is cited by another organization, the latter organization really used the technological knowledge of the first organization. So, we then can assume that the latter organization really builds upon the knowledge of the former organization and speak of knowledge complementarities. Research also has been done with the help of patent classes (e.g. Nooteboom et al., 2007). However, this will not be used here because this only gives an indication of whether organizations are building on knowledge within the same cluster of knowledge.

As patents we will use published patent applications for several reasons. First, published patent applications already signal unique technological knowledge. Secondly, before patents are granted, patents are applied for by organizations. The time between the applying for a patent and the granting of a patent usually consists of several years. In order to avoid contamination of effects due to this time lag, patent applications will be used here. Another reason is that patent applications at first are kept secret for the public. Only the organization which applies for the patent and the agency which grants the patents know of the existence of the patent applied for. After a period of 18 months the patent application will be published. From then on the knowledge to be protected becomes public and other organizations can cite this patent application (Stoop, 2009/2010).

The patents applied for by an organization are taken for a time period of five years before the year under examination. This is the appropriate time window for assessing their technological impact (Stuart & Podolny, 1996; Ahuja, 2000). Knowledge capital diminishes very rapidly and it loses most of its economic value within five years (Griliches, 1984). So, a moving window of five years is appropriate here.

Also the dependent variable will have a slightly different operationalization. In this part the volatility of the relationships in the network is measured inversely as the length of each individual relationship. This is the most detailed measurement possible of this variable on the relational level.

3.4.2 Organizational level

From an organizational perspective, the Resource Based View is very much in place here. This view considers the organization as a bundle of resources. One of these unique resources is an organization’s knowledge assets. Within the life sciences almost all technological knowledge is protected with the help of patents (e.g. Powell et al., 2005;

Gersten, 2005). Patents are thus a reliable indicator for the amount of technological knowledge possessed by organizations in this industry and act as an indicator of the quality of the underlying knowledge. This technological knowledge determines whether organizations can be knowledge complementary with other organizations. So, from an organizational perspective, the number of patents is a good approximation of knowledge complementarity.

However, within this operationalization there are two possibilities. A patent could be owned by an organization but it could also be that an organization only has access to a certain patent, which indicates an external resource need or inducement (Ahuja, 2000) (for instance by the licensing of such a patent). According to Grant and Baden-Fuller (2004) and Hitt et al. (2000) access to resources is more essential than the actual acquisition of these resources. When this is taken into account it seems like the actual acquisition of patents is less important than having access to these patents. However, owning more patents makes the organization more attractive for other organizations, which constitutes an opportunity (Ahuja, 2000), in giving the first organization access to their patents. Because of these reasons here a differentiation will be made between owning patents and having access to patents. The number of patents to which an organization has access is more than the number of patents an organization has. So, in order to avoid duplications, one variable will be measured as the number of patents an organization owns and another variable will be taken as the difference between the number of patents an organization has access to and the number of patents an organization owns in order to measure the number of patents owned by other organizations to which the organization concerned has access.

The patents which an organization owns are taken for a time period of five years before the year under examination. Just like the operationalization on relational level, a moving window of five years is appropriate here (Stuart & Podolny, 1996; Ahuja, 2000; Griliches, 1984).

The dependent variable will also have a slightly different operationalization. It is not possible to determine the length of collaborations because that is not an organizational characteristic. Here the amount of differences in relationships will be taken. More specifically the number of newly established relationships (NR) and the number of aborted relationships (AR) will be taken here. When a relationship is aborted or newly started a score of 1 will be assigned to the variable. In the table below an example is illustrated;

		2002	2004	2005	**AR 2004**	**NR 2004**	**AR 2005**	**NR 2005**
Organization A	Organization B	0	1	0	0	1	1	0
Organization A	Organization C	0	0	1	0	0	0	1
Organization A	Organization D	1	0	0	1	0	0	0
Organization A	Organization E	1	0	1	1	0	0	1
Organization A	Organization F	0	1	1	0	1	0	0
Total					2	2	1	2

Table 4. Construction of the aborted relations (AR) and newly formed relations (NR) variables

3.4.3 Operationalization table

The different variables will be operationalized as shown in Table 5. The acronym DDLSF in Table 5 stands for Dutch dedicated life sciences firm.

Concept	Level	Indicator	Scale	Acronym
Dependent variable				
Volatility of the network	Operationalization relational level	The number of years a collaboration lasted calcuted by the times a partner organization is mentioned by a DDLSF	Discrete	LREL
	Operationalization organizational level	The number of newly establised relationships a DDLSF has in 2002-2005	Discrete	NR
		The number of relationships a DDLSF has aborted in 2002-2005	Discrete	AR
Independent variable				
Knowledge complementarity	Operationalization relational level	The amount of patent citations between the collaborating partners from 1997-2002/2004	Discrete	PATC
	Operationalization organizational level	The amount of patents a DDLSF has acquired from 1997-2002/2004	Discrete	PATP
		The difference between the number of patents which are available to a DDLSF and the acquired patents in 2002/2004	Discrete	ACPAT
Control variables				
DDLSF's venture capital	Operationalization relational and organizational level	The amount of venture capital a DDLSF has acquired	Ratio	VC
DDLSF's age	Operationalization relational and organizational level	Number of years	Ratio	AGE
DDLSF's size	Operationalization relational and organizational level	Number of employees	Ratio	SIZE
DDLSF's R&D intensity	Operationalization relational and organizational level	The amount of R&D expenditures divided by the turnover	Ratio	RDI
DDLSF's type	Operationalization relational level	Whether the organization is a spin-off from the partner organization or not	Binary	TYPE
	Operationalization organizational level	Whether the organization is a spin-off or not	Binary	
Partner organization's type	Operationalization relational level	1: Life sciences firm 2: University or governmental laboratory 3: Pharmaceutical firm 4: Association 5: Other firms	Binary Binary Binary Binary	TYPEPO
Location	Operationalization relational level	Whether the collaborating organizations are situated in the same BioPartner Center or not	Binary	LOC
Collaboration's type	Operationalization relational level	Whether the collaboration is based on licensing or not	Binary	TYPECOL
Number of relations	Operationalization organizational level	The total number of relations a DDLSF has	Discrete	NoREL

Table 5. Operationalization table

The ways in which the dependent variable and the independent variable are measured for both levels is described above. For the venture capital variable the amount of acquired venture capital will be measured. For the biotech organization's age variable the age will be measured in number of years. The organization's size variable will be measured as the number of employees an organization has. For the R&D intensity variable the amount of R&D expenditures will be divided by the organization's turnover. The type of organization will be measured as a binary variable, whether the biotech organization is a spin-off (1) or not (0) (for the operationalization on the relational level it can also be decided whether or not it is a spin-off from the partner organization). For the type of the partner organization five different categories are distinguished; life sciences firm, university or governmental laboratory, pharmaceutical firm, association and other firms. These will be measured according to four dummy variables in which the category life sciences firm acts as a reference category. The collocation will be measured as a binary variable and will constitute a 1 when the two organizations are situated in the same BioPartner Center (see 2.1.1) and 0 when they are not. Also the collaboration's type variable will be measured as a binary variable. It will be a 1 when the collaboration is based on licensing and a 0 when the collaboration is not based on licensing. The number of relations variable will be measured as the total number of relations an organization has.

For the relational level all values of the control variables are taken for the year in which the inter-organizational collaboration has started. For the organizational level all values of the control variables for the years 2002 and 2004 are taken.

4 Methodology

In this chapter the data collection is described and how these data are revised before they could be used. Additionally the different methods of analysis are discussed and also the quality of the research design.

4.1 Data collection

4.1.1 BioPartner survey

The data that will be used in this study mostly originate from annual surveys, which were conducted during the BioPartner Programme (see section 2.1.1). These surveys were distributed across all Dutch organizations within the life sciences industry. Participation in these surveys was obligatory for organizations which received funding from the programme. In this study the editions of 2002, 2004 and 2005 are used. The response rates of the years 2002, 2004 and 2005 of the surveys were respectively 87%, 66% and 54%. The survey of 2003 has not been used here, since this survey did not ask for the inter-organizational collaborations between the organizations. In the other surveys (2002, 2004 and 2005) the organizations were asked to name the five most important partner organizations. Of course, this entails a limitation and truncation of the data. However, the organizations were also asked for their total number of relationships. The data on actual partnerships represents approximately 80% of the total partnerships (Faber & Meeus, 2010). So this will still be a representative part of all partnerships.

4.1.2 Additional data

Next to the data which is gathered from the BioPartner survey, some additional information is needed in this study.

Patent data

In order to be able to acquire a patent on a technological invention it has to meet some requirements. These are: it has to be novel, it has to be inventive and it has to be industrial applicable (Octrooicentrum, n.d. b). However, a new patent can make use of the knowledge which is already captured by another patent. Then this new patent needs to cite the former patent, these are called patent citations.

The patent citations for this research are drawn from the PATSTAT database. This stands for EPO Worldwide Patent Statistical Database. This database has been specifically developed for the use by private and public institutions, universities, policy institutes, medium-sized to large-scale enterprises, professional patent information providers and IP consultants. It includes patent data from over 80 countries and is mainly developed for statistical research (European Patent Office, n.d.).

The data on the actual acquisition of patents is drawn from the Esp@cenet website. This database contains patent data from over 90 countries (Esp@cenet, n.d.).

Additional information

Next to the data from the BioPartner survey and the patent data only some data was needed about the locations of the organizations. This was gathered with the help of the websites of the organizations themselves.

4.1.3 *Revision of the data*

Some of the data had to be revised in order to be of any use in this study;

- Not all of the organizations completed the survey every year, so for these organizations not all the data is available for every year. However, some variables can be complemented for these 'missing' years on the basis of combining available data. For instance the age variable. When an organization has filled in the survey of 2002 and only mentioned its age there, the age of the same organization in the years 2004 and 2005 can be constructed. Also the type of the organization can be complemented for the missing years. Since organizations will not switch between being a spin-off or not, once an organization has answered this question in one single year, the same information can be used for the other years. In this way, the database is made as complete as possible.
- For the variable R&D intensity some different questions from the survey are put together. R&D intensity is the ratio of an organization's research and development expenditures compared to the organizations sales (About.com, n.d.). In this study the data from the questions from the survey about R&D expenditures and turnover are used and the R&D expenditures were divided by the turnover of the organizations.
- For the variable of the number of patents which an organization has access to, the question from the survey of how many patents they have in their portfolio is used. This question is build up of some different parts. Here the parts of how many patents they have and how many patents they have in-licensed will be summed up. In order to avoid duplications the number of patents which an organization owns (according to the Esp@cenet database) is subtracted from the number of patents which the organization has access to.
- For the construction of the relation variables somewhat more adaptations to the raw data had to be made. This has already been explained in section 3.4.2.

4.2 Analysis

4.2.1 *Multiple linear regression*

In this study the influence of one independent and some control variables on the dependent variable will be tested. This is done with the help of a linear regression. The hypothesis in section 3.2.3 is specified in a linear model. With this linear model a multiple regression analysis will be performed. Regression analysis measures the effects of an independent variable (X_i) on the dependent variable (Y_i) between which a causal effect is assumed. A multiple regression is chosen when a dependent variable (Y_i) is likely to be effected by multiple independent variables (X_i) (Huizingh, 1998). This regression analysis is done in the computer programme SPSS (de Vocht, 2008). Before this analysis was done, an appropriate correlation matrix was estimated as input for the regression analysis. This correlation matrix is estimated by using the computer programme PRELIS. This programme is chosen because of the non-normal distributions of the observed binary, discrete and continuous variables specified. PRELIS estimates the correlations between normally distributed latent variables underlying these observed variables (Jöreskog & Sörbom, 1996).

Relational level analysis

For the patent citation analysis the length of the relationships is influenced by the number of patent citations and the control variables which will constitute the following equation;

(a) $LREL = \beta_1 PATC + \beta_2 VC + \beta_3 AGE + \beta_4 SIZE + \beta_5 RDI + \beta_6 TYPE + \beta_7 TYPEPO + \beta_8 LOC + \beta_9 TYPECOL$

Where:

β_i is the regression coefficient of each independent variable. The value of β_i represents the influence of an independent variable on the dependent variable, controlled for the influence of the other independent variables.

Organizational level analysis

Within this part of the study some different equations will be tested. In order to be able to give an answer to the second sub question and give more insight into the dynamics of the network, first the number of aborted relations and the number of newly established relations are specified to depend on the total number of relationships an organization has; equations (b), (c), (d) and (e) for the years 2004 and 2005 (see 2.2). When these relations are tested it also is interesting to see whether the number of aborted relations and newly established relations in the period 2004-2005 are dependent on the earlier collaborative behavior (of the period 2002-2004); equations (f) and (g). This results in the following equations;

(b) $AR_{2004} = \beta_1 NoREL_{2002}$

(c) $NR_{2004} = \beta_1 NoREL_{2002}$

(d) $AR_{2005} = \beta_1 NoREL_{2004}$

(e) $NR_{2005} = \beta_1 NoREL_{2004}$

(f) $AR_{2005} = \beta_1 NoREL_{2004} + \beta_2 AR_{2004} + \beta_3 NR_{2004}$

(g) $NR_{2005} = \beta_1 NoREL_{2004} + \beta_2 AR_{2004} + \beta_3 NR_{2004}$

Where:

β_i is the regression coefficient of each independent variable. The value of β_i represents the influence of an independent variable on the dependent variable, controlled for the influence of the other independent variables.

These equations represent the following model in which the dynamics of the Dutch life sciences industry in the period 2002-2005 are depicted.

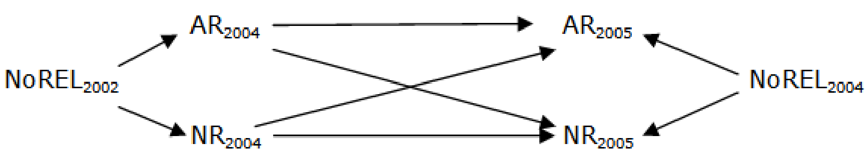

Figure 7. Network dynamics for the period 2002-2005

Next, a more extended Resource Based View perspective will be taken in order to explain the dynamics of the Dutch life sciences industry. Here the number of relationships, the Resource Based View knowledge complementarity variables and the Resource Based View control variables for 2002 and 2004 are included in the equations to explain the number of aborted relations and the number of newly formed relations in the years 2004 and 2005;

(h) $AR_{2004} = \beta_1 PATP_{2002} + \beta_2 ACPAT_{2002} + \beta_3 VC_{2002} + \beta_4 AGE_{2002} + \beta_5 SIZE_{2002} + \beta_6 RDI_{2002} + \beta_7 TYPE_{2002} + \beta_8 NoREL_{2002}$

(i) $NR_{2004} = \beta_1 PATP_{2002} + \beta_2 ACPAT_{2002} + \beta_3 VC_{2002} + \beta_4 AGE_{2002} + \beta_5 SIZE_{2002} + \beta_6 RDI_{2002} + \beta_7 TYPE_{2002} + \beta_8 NoREL_{2002}$

(j) $AR_{2005} = \beta_1 PATP_{2004} + \beta_2 ACPAT_{2004} + \beta_3 VC_{2004} + \beta_4 AGE_{2004} + \beta_5 SIZE_{2004} + \beta_6 RDI_{2004} + \beta_7 TYPE_{2004} + \beta_8 NoREL_{2004}$

(k) $NR_{2005} = \beta_1 PATP_{2004} + \beta_2 ACPAT_{2004} + \beta_3 VC_{2004} + \beta_4 AGE_{2004} + \beta_5 SIZE_{2004} + \beta_6 RDI_{2004} + \beta_7 TYPE_{2004} + \beta_8 NoREL_{2004}$

Where:

β_i is the regression coefficient of each independent variable. The value of β_i represents the influence of an independent variable on the dependent variable, controlled for the influence of the other independent variables.

4.2.2 Differences between time periods

Within the organizational part of this study different periods of time are considered for the same variables. In order to test whether or not it really makes a difference when the same variables are considered in different time periods t-tests of the regression coefficients will be done.

These t-tests are based on the formula for differences in two means of matched samples from Wonnacott and Wonnacott (1990: 269);

$$\Delta = \bar{D} \pm t.025 \frac{SD}{\sqrt{n}}$$

When this is converted for differences between regression coefficients of matched samples, the following formula is derived;

$$T = \frac{\beta 1t\text{-}1 - \beta 1t}{\sqrt{((((SE(\beta 1t\text{-}1))^2)/Nt\text{-}1)+(((SE(\beta 1t))^2)/Nt))}}$$

Where:

B_{1t} and $SE(\beta_{1t})$ are the estimated values of a particular regression coefficient and its standard error.

4.3 Quality of research design

The quality of this research design will be assessed with the help of four important concepts: construct, internal and external validity and reliability (Yin, 2003).

4.3.1 Construct validity

A concept or variable possesses construct validity when it actually measures what it is intended to measure.

The independent variable ‘the rate of knowledge complementarity’ will be measured by using references to and from patents and by using the number of patents an organization has access to or owns. When a patent cites another patent, the technological knowledge of this previous patent is used in the construction of the new patent. Here thus arise knowledge complementarities. When looked at from an organizational perspective the unique knowledge resources of an organization determine whether the collaborating partners are complementary. However, not all technological knowledge is captured in patents. With the industry chosen in this study (the life sciences industry) this problem will be minimalized since almost all technological knowledge in this industry is patented (e.g. Powell et al., 2005; Gersten, 2005). Therefore this is an indicator for knowledge complementarity with a high construct validity.

The dependent variable ‘volatility of the relationships in the network’ is measured by using a question from the survey in which the organizations have given their top five of organizations with whom they collaborate. This will provide another valid indicator, because it actually measures what it is intended to measure since a network consists of inter-organizational collaborations.

4.3.2 Internal validity

The internal validity has to do with the establishment of a causal relationship based on measures used and the research setting and design of the study.

In this study a causal relationship between the volatility of relationships within the network and knowledge complementarity is expected. However, other factors could also contribute to the volatility of the relationships within the network. So, in order to control for these disturbing factors, these variables are also included within the conceptual model. This will increase the internal validity of this study.

4.3.3 External validity

External validity is the extent to which the results of a study can be generalized towards other domains.

This study will be done within the life sciences industry in the Netherlands. Since this industry has some distinct features which are prerequisites for this study to be performed, the results of this study cannot be generalized towards other industries (or these industries have to have the same features as the life sciences industry). These features are already explained and include, for instance, the importance of collaborations in this industry, the unique role of patents, the early phase of development etcetera. However, the results of this study can be generalized towards life sciences industries in other countries. The same industry features will then still hold. So, there is some external validity, but not towards other industries.

4.3.4 Reliability

A measurement is said to be reliable, when the same measurement is repeated and will result in approximately the same outcome.

A part of the data which is used in this study comes from the PATSTAT or the Esp@cenet database and the internet, which can be acquired by everyone. This contributes to the fact that a repeated measurement will result in the same outcomes. Also there is no interaction between an interviewee and the researcher. Therefore there can be no miscommunications or misinterpretations between the interviewee and the researcher, which potentially could lead to other, wrong, outcomes. The PATSTAT, Esp@cenet and BioPartner data are all acquired by asking the same questions in different years. So, the same instrument is used. This increases the reliability of the data for successive years.

5 Results relational level analysis

In this chapter the relational level analysis results will be described. First the descriptive statistics of the research population will be given. Then in 5.2 the results of the patent citation analysis are elaborated upon.

5.1 Descriptive statistics

The research population of this part of the thesis is, as already said before, the inter-organizational collaborations between Dutch life sciences organizations and their partner organizations. So the units of analysis are the collaborations between the organizations. From the three surveys used 280 inter-organizational collaborations were derived.

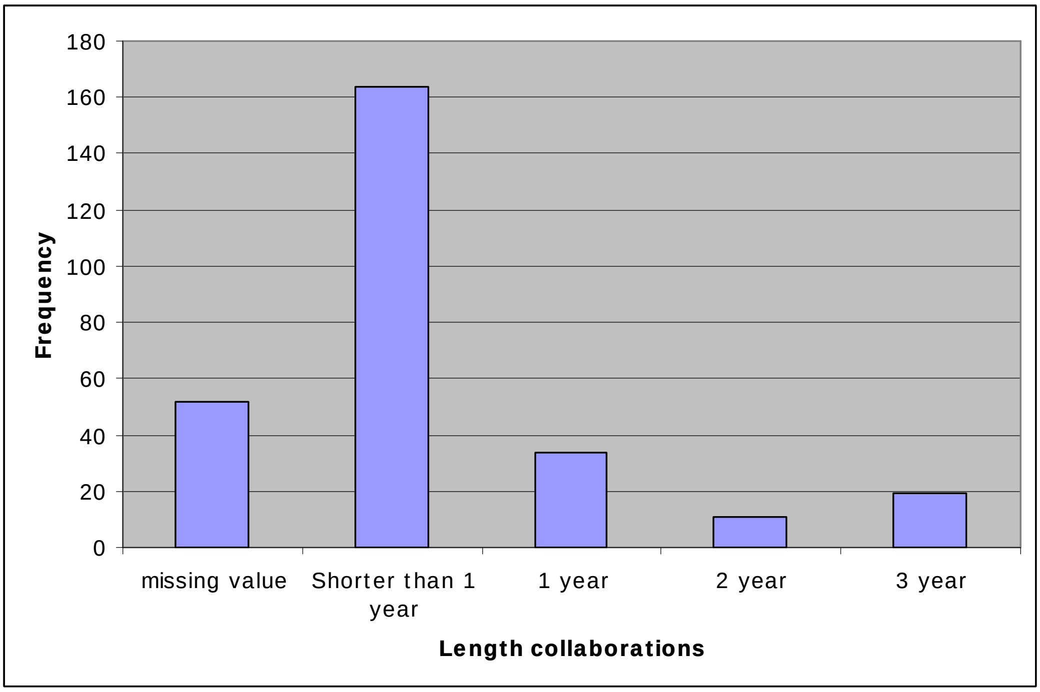

Figure 8. Frequency distribution of the length of collaborations (N=280)

Figure 8 shows that these collaborations on average do not last longer than one year. This was already said before and concluded by van der Valk (2007).

5.2 Analysis relational level

5.2.1 Patent citation analysis

The gathered data on patents showed that within only two relationships the organizations cited patents of the other organization in their own patents. These are the firms Vironovative and Medimmune and Pharma and Merck. Both relations lasted shorter than one year and one of these collaborations was based on licensing.

Focal organization	Patner organization	Number of patent citations	Length collaboration	Type collaboration
Vironovative	Medimmune	13	Shorter than one year	Licensing
Pharma	Merck	2	Shorter than one year	Unknown

Table 6. Patent citations

No decent analysis can be done with these data since they are too little to be able to draw any kind of conclusion regarding the relationship between knowledge complementarity and the duration of dyadic collaborations in the Dutch life sciences industry.

5.2.2 Patent class analysis

Earlier in this study patent classes were already mentioned, which can be used in order to give an indication of possible knowledge complementarities. Since the patent citations did not give any feasible data, patent classes will be used as a second best method in order to give an indication of knowledge complementarities. Such a patent class analysis has already been performed by Nooteboom et al. (2007) in order to test their concept of optimal cognitive distance.

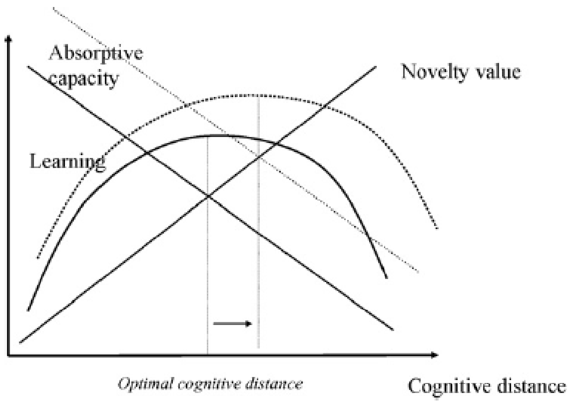

Figure 9. Optimal cognitive distance (Nooteboom et al., 2007)

As can be seen in the figure above, this concept consists of two different components; the absorptive capacity and the novelty value. When two organizations collaborate with each other they have to take into account the following two aspects. In order to be able to benefit most from the relationship, they have to share some perceptions, values, knowledge etc. and they need to be able to tell the other organization something new. So, they need to understand each other but they also need to be able to learn something from the other. Here the novelty and absorption component can be seen. When these two are optimally combined, the optimal cognitive distance is found and the innovative performance (which is set out on the y-axis) will be the highest (Nooteboom et al., 2007).

This optimal cognitive distance can be applied to a patent class analysis. All patents are classified according to a certain system, the International Patent Classification (IPC). This classification system is most commonly used and known. It consists of some characters and some numbers. Each character or number narrows down the subject of the content of each patent (WIPO, n.d.). For instance, a patent can belong to the patent class
A 61 K 39 / 125. So, the patent class consists of five characters or numbers. When two organizations own patents of which only the first character is the same, these organizations are too far apart from each other in terms of the absorptive capacity, because the organizations will not be able to understand each other. When the opposite occurs (when two organizations own patents of which all of the numbers and characters are the same), the novelty value plays an important role. Then organizations are not likely to be able to

tell the other something new and thus be able to learn from each other. These issues will be translated into different categories as follows:

A	61	K	39 /	125
0	1	2	1	0

So, a cognitive distance of 0 constitutes the least optimal cognitive distance and a cognitive distance of 2 will here be conceived as the most optimal cognitive distance.

However, only 40% of the organizations in the sample owned one (or more) patents. This automatically is the cause for the fact that a lot of collaborations are classified as a 0 when the patent classes are considered. Of the relationships in which both organizations own one (or more) patents only 17 were indicated having a cognitive distance of 1 or 2. A total of 263 relationships had a cognitive distance of 0.

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	0	263	93,9	93,9	93,9
	1	7	2,5	2,5	96,4
	2	10	3,6	3,6	100,0
	Total	280	100,0	100,0	

Table 7. Frequency table of the patent classes

This again produces too little feasible data to perform a sound analysis. However, these two results from the data collection do raise some questions about the use of patents by the organizations within life sciences industry for the protection of unique resources and the acquisition of venture capital (Niosi, 2003; Baum & Silverman, 2004). This will be discussed later in section 7.2.

6 Results organizational level analysis

In this section of the study the organization level analysis results will be described. In 6.1 the descriptive statistics of the research population will be given. Then in 6.2 the network dynamics of the Dutch life sciences industry will be investigated. After that the effects of knowledge complementarity on the volatility of the relationships in the network will be tested. Then a link will be made between the discovered partnering behavior and the population in section 6.3. In this study data for different years are used. In order to see whether there are significant differences between the data of these years, t-tests of successive regression coefficients will be presented in 6.4.

6.1 Descriptive statistics

The research population of this study are the organizations which participated in the BioPartner programme between 2002 and 2005. The units of analysis are thus the organizations themselves. From the three surveys 119 organizations have been identified which were active within the Dutch life sciences industry. For these 119 organizations some general characteristics can be displayed.

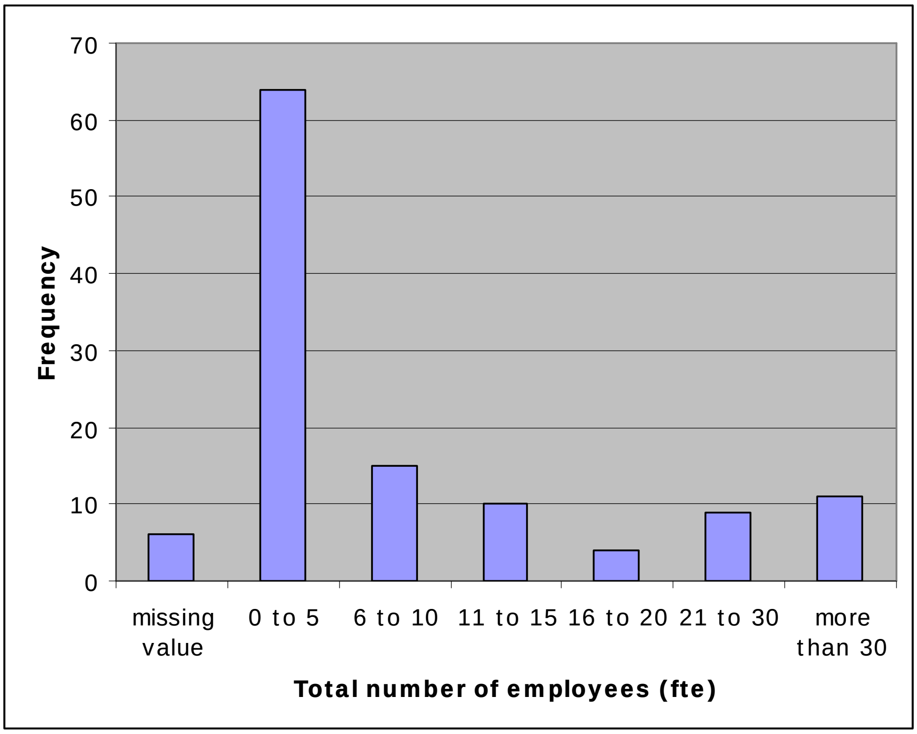

Figure 10. Frequency distribution of the size of the organizations (N=119)

Figure 11. Frequency distribution of the age of the organizations (N=119)

As can be seen from the two figures above the population of start-ups in the Dutch life sciences industry is very young and small in size. This needs to be kept in mind when the results of the analysis will be interpreted, because for small and young organizations it is harder to acquire patents. The acquisition of patents and legal patent enforcement involve high costs, which is harder to afford for these small and young organizations (Lemarié et al., 2000). It could also be that these young organizations do not yet have patentable knowledge, because they did not have enough time to fully develop this knowledge.

6.2 Analysis organizational level

6.2.1 Network dynamics

In this part of the chapter the underlying network dynamics of the life sciences industry in the Netherlands will be investigated. Already in sections 2.2 and 4.2, models and equations are derived and these will be tested here.

In the following table the estimates of the regression coefficients, their t-values and the R^2 values of the equations are given (see for the acronyms Table 5).

Dependent variables	Equation	$NoREL_{2002}$	$NoREL_{2004}$	AR_{2004}	NR_{2004}	R^2
AR_{2004}	(b)	0,907 (23,397)				0,823
NR_{2004}	(c)	-0,498 (-6,231)				0,248
AR_{2005}	(d)		0,897 (22,042)			0,805
NR_{2005}	(e)		-0,112 (-1,221)			0,013
AR_{2005}	(f)		0,647 (7,763)	0,104 (2,497)	0,332 (3,768)	0,830
NR_{2005}	(g)		-0,727 (-3,828)	-0,060 (-0,630)	0,668 (3,436)	0,116

Table 8. Estimation of the parameters

The critical absolute t-value for a two-tailed test with a 90% confidence interval of the estimated regression coefficients is $t_{0,10}$ = 1,66 (N=120) (Wonnacott & Wonnacott, 1990).

The results show that there are only two coefficients which are insignificant; these are the negative effect from the number of relations in 2004 on the number of new relations in 2005 and the negative effect from the aborted relations in 2004 on the newly established relations in 2005. The other (significant) effects give insight into the network dynamics of the Dutch life sciences industry.

The assumption that if an organization has more relations then they are able to abort more relationships, seems true from this analysis. The number of relationships in 2002 has a significant positive effect on the amount of aborted relationships in 2004 and the number of relationships in 2004 also has a significant positive effect on the amount of aborted relationships in 2005. Both equations represent a good prediction of the number of aborted relationships; the R^2 values are 0,823 and 0,805. The number of relationships in 2002 also has a significant effect on the number of newly founded relationships in 2004, however here it is a negative one and the R^2 value is much lower (0,248). When the same relationship is considered in the time period thereafter, the same, negative, effect is not significant and also the R^2 value is extremely low (0,013). Nevertheless, both negative effects imply that when an organization has fewer relationships it will form new ones. So, it seems that when an organization has less relationships, this is an incentive to form new ones.

After that, the equations (f) and (g) are considered in order to see whether there exists cohesion between the abortive and formative behavior over time. It turns out that the number of relations in 2004, the amount of aborted relations in 2004 and the number of newly founded relations in 2004 all have a significant positive effect on the amount of aborted relations in 2005. Here, again, the R^2 value is excellent (0,830). So, it seems that this model gives a correct prediction of the number of aborted relations in 2005. Consequently, the abortive behavior in 2005 is both a continuation of that behavior in 2004 and instigated by the formation of new collaborations in 2004. When the newly founded relations in 2005 are considered the number of relations in 2004 has a significant negative effect and the amount of newly founded relations in 2004 has a significant positive effect. However, the amount of aborted relations in 2004 has a non-significant negative effect.

This non-significant effect implies that the formation behavior in 2005 does not depend on the abortion behavior in 2004. Also the R^2 value is very low; 0,116. So, it seems as if the models which were constructed to predict the number of aborted relationships perform well. However, the models which were constructed to predict the number of newly founded relationships perform less and the predicting effects even deteriorate over time to be seen in the declining R^2 values (0,248 and 0,013).

In Figure 12 the significant relations are visualized.

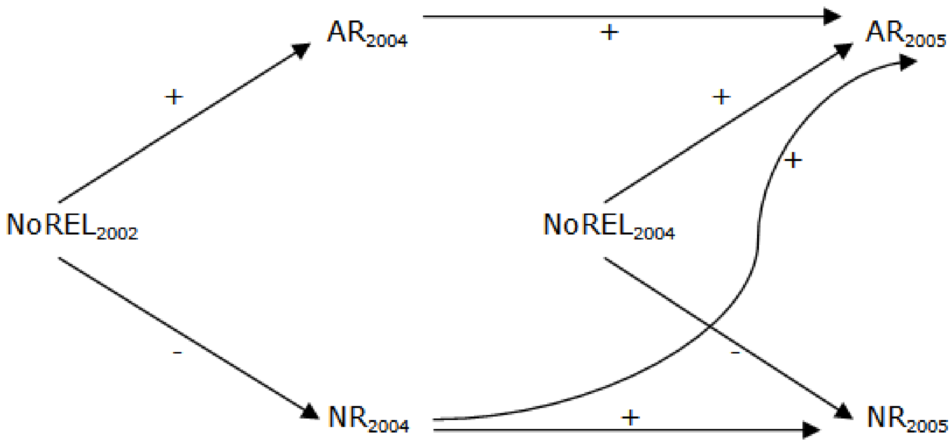

Figure 12. Estimated model of the network dynamics

The results on the network dynamics can be interpreted as follows. The more relationships an organization has in 2002, the more relations will be aborted in 2004 and fewer relations will be newly founded in 2004. However, when an organization has a lot of relations in 2004 the same will happen, more relations are aborted in 2005 and fewer relations are newly founded in 2005. Also, when an organization has aborted a lot of relations in 2004 it is likely that this organization will continue this abortive behavior and aborts also relations in 2005. However, in contradiction to this is the relation between the amount of newly founded relations in 2004 and 2005, this is also a positive relationship. So it seems that an organization which has established a lot of new relationships in 2004 will establish even more relations in 2005. Moreover, when an organization has established a lot of new relations in 2004, it is also likely to abort more relations in 2005.

From this analysis the constructed model from Figure 3 seems only partly confirmed. There is a two wave influence of the total number of relationships on the number of aborted relationships and the number of newly formed relationships and these influences are continued over time. The partnering behavior of an organization thus depends on the number of relationships an organization already has. The relationship between the total number of relationships and the number of aborted relationships is positive. So, it seems that when an organization has many relationships in 2002 it will abort the less beneficial relationships and this effect has been found for the next time period also. When an organization already has aborted the less beneficial relationships in 2004, it will continue selecting among its relationships in 2005. However, the expected positive relationship between the number of relationships and the number of newly formed relationships has not been found. An even contradicting negative relationship has been discovered. This would imply that when an organization has no or a few relationships in 2002 this is an incentive to form new relationships. When these new relationships are formed another selection takes place and the less beneficial relationships will be aborted. However, there will also again be formation of new relationships. So, it seems that the organizations with fewer relationships first form new ones, then again form new ones and abort the less beneficial previously formed relationships. From this model it can be derived that once an organization has aborted relationships there is no incentive to form new ones. The partnering behavior of an organization thus also depends on the previous partnering behavior of that organization. The continued influence of the number of relationships on the number of aborted and the number of newly formed relationships does, however, deteriorate over time. So, there seems to be a weakening of these processes over time (this can be seen from the t-values). This weakening is very strong for the influences on the number of newly formed relationships and it is weak for the influences on the number of aborted relationships. This weakening of effects over time is also shown by the deterioration of the R^2 values over time in equations (a) and (c) and equations (b) and (d), respectively.

6.2.2 Network dynamics and the Resource Based View

In this part of the analysis the volatility of the collaborations in the network will be explained with the help of a more extended Resource Based View perspective. In section 4.2 already the equations were derived in order to perform a multiple regression analysis.

In the following tables the estimates of the regression coefficients, their t-values and the R^2 values of the equations are given (see for the acronyms Table 5).

Dependent variables	$PATP_{2002}$	$ACPAT_{2002}$	VC_{2002}	AGE_{2002}	$SIZE_{2002}$	RDI_{2002}	$TYPE_{2002}$	$NoREL_{2002}$	R^2
AR_{2004}	-0,175 (-3,702)	-0,042 (-1,212)	-0,002 (-0,028)	0,066 (1,506)	-0,009 (-0,156)	-0,014 (-0,316)	0,043 (1,007)	0,958 (22,546)	0,862
NR_{2004}	0,330 (3,402)	0,085 (1,186)	0,292 (2,594)	0,267 (2,970)	0,027 (0,236)	-0,182 (-1,981)	0,250 (2,866)	-0,759 (-8,699)	0,418

Table 9. Estimation of the parameters; (h) and (i)

Dependent variables	$PATP_{2004}$	$ACPAT_{2004}$	VC_{2004}	AGE_{2004}	$SIZE_{2004}$	RDI_{2004}	$TYPE_{2004}$	$NoREL_{2004}$	R^2
AR_{2005}	0,298 (6,739)	0,150 (4,817)	-0,195 (-4,982)	-0,103 (-2,898)	0,061 (1,846)	-0,299 (-6,888)	0,079 (2,076)	0,907 (27,602)	0,894
NR_{2005}	0,124 (0,987)	0,016 (0,176)	-0,100 (-0,901)	0,107 (1,056)	0,087 (0,928)	0,225 (1,821)	-0,236 (-2,177)	-0,108 (-1,152)	0,142

Table 10. Estimation of the parameters; (j) and (k)

As already said before, the critical absolute t-value for a two-tailed test with a 90% confidence interval of the estimated regression coefficients is $t_{0,10} = 1,66$ (N=120) (Wonnacott & Wonnacott, 1990). This means that the effects of some independent variables are insignificant and will not be considered in the discussion.

From the resulting equations it can be concluded that the volatility of the collaborations in the network, seen from an organizational perspective, depends on many different factors. The number of newly formed relations in 2004 for instance depends on the patents in property, the amount of acquired venture capital, the age of the organization, the R&D intensity, the type of the organization and the number of relationships. The number of aborted relationships in 2004 depends only on the patents in property and the number of relationships. The number of patents in property and the number of total relations are thus important variables here as they appear in both equations. However, they do not have the same sign in every equation. When the R^2 values are considered again the number of aborted relationships is best predicted with these models. The other model for the number of newly formed relationships has a much smaller R^2 value.

When the same equations are considered for the next time period, other patterns can be seen. Here the volatility of the relationships in the network depends on the number of patents which an organization has access to, the amount of acquired venture capital, the age, the size, the R&D intensity, the type and the number of relationships. Here again the differentiation between the amount of aborted relations and the amount of new relations can be made. The amount of aborted relationships is influenced by the amount of patents to which an organization has access to, the amount of acquired venture capital, the age, the size, R&D intensity, the type and the total number of relationships. The amount of new relationships only depends on the R&D intensity and the type of the organization. In these two models the amount of R&D intensity and the type of the organization are included in both the equations. However, the signs differ. In this time period it also seems that the model for the number of aborted relationships predicts the outcome best. The other model for the newly formed relationships has a much lower R^2 value.

Some interesting things are found when the influences of the independent variables on the dependent variables are categorized according to the following categories: independent variables which have the same influence over time, independent variables which have a switching influence, independent variables which only have an influence once and independent variables which have no influence at all. This is summarized in the following tables.

	PATP	ACPAT	VC	AGE	SIZE	RDI	TYPE	NoREL
AR								(+)
NR								

Table 11. Independent variables which have the same influence over time

	PATP	ACPAT	VC	AGE	SIZE	RDI	TYPE	NoREL
AR								
NR			(+) → (-)			(-) → (+)	(+) → (-)	

Table 12. Independent variables which have a switching influence

	PATP	ACPAT	VC	AGE	SIZE	RDI	TYPE	NoREL
AR	(-)	(+)	(-)	(-)	(+)	(-)	(+)	
NR	(+)			(+)				(-)

Table 13. Independent variables which only have an influence once

	PATP	ACPAT	VC	AGE	SIZE	RDI	TYPE	NoREL
AR								
NR		X			X			

Table 14. Independent variables which have no influence at all

In Table 11 can be seen that the total number of relationships has a continued positive influence on the number of aborted relationships. From the conceptual model both signs could be expected. It seems that, as already mentioned before, organizations which have more relationships abort the less beneficial ones and select the most beneficial ones out of their total set of relationships. So, the total number of relationships has a positive influence on the number of aborted relationships and thus also on the volatility of the relationships in the network.

Table 12 shows the independent variables which have a switching influence over time. All these variables are drawn from the equation which predicts the number of newly formed relationships. The amount of acquired venture capital has a switching influence, from positive towards negative. This is in line with what was expected in the conceptual model, since there were two competing hypotheses distinguished. One possible explanation for this is that when an organization has much venture capital it can develop much in-house R&D and thus can become attractive to collaborate with for other partners within the industry and form an opportunity (Ahuja, 2000). Due to this the organization will be able to form more new relationships. When the organization has enough new relationships and it still has enough venture capital the necessity to establish new relationships and the inducement for external resource need is likely to decline (Ahuja, 2000), which explains the negative influence. For the type of organization almost the same holds. In the conceptual model both influences were expected. When an organization is a spin-off it is likely to form new relations with partners in the network of the mother organization. However, once these relationships are established the need to establish more new relationships will decline and there will be less inducement for external resource need (Ahuja, 2000). So here the switching influence (from positive towards negative) could also be explained. R&D intensity also has a switching influence. However, here the influence switches from negative to positive. When an organization has a low R&D intensity and does not perform much R&D in-house, they have to acquire knowledge from external sources, which indicates an inducement for external resource need (Ahuja, 2000), and will thus establish more new relationships as was already expected in the conceptual model. However, when they have formed these new relationships and have access to this knowledge as reflected in larger R&D intensity, they are apparently attractive for other organizations within the network to collaborate with (Ahuja, 2000).

In Table 13 the variables are presented which only have an influence once. As can be seen there are quite a lot of variables which only once have an influence. The number of patents an organization has in property has a positive influence on the number of newly formed relationships and a negative influence on the number of aborted relationships. However, in the conceptual model knowledge complementarity was expected to have a negative influence on the volatility of the relations in the network. So, knowledge complementarity based on the number of patents in property seems to have both a positive and negative influence on the number of aborted and newly formed relationships and thus on the volatility of the relationships in the network. However, when the patents to which an organization has access to are considered only a positive relationship can be found, so here the expected negative influence from knowledge complementarity on the volatility of the relationships in the network cannot be found. This entails a partly rejection of the central hypothesis of this study. Maybe within this industry there is a lot of 'knowledge leaking' which could explain this unexpected influence or it turned out that the expected knowledge complementarities between two organizations were not there (see 3.2.3). When the control variable venture capital is considered it seems that it has an exclusively negative influence on the number of aborted relationships, which partly corresponds to the expected influence from the conceptual model (in the conceptual model both influences were expected). So, it seems that the effect from inducements (Ahuja, 2000) predominates here. When the age of an organization is considered it seems that it both has a negative and a positive influence on the number of aborted relationships and the number of newly formed relationships, respectively. Within the conceptual model both influences were expected. From the analysis it shows that the size of an organization has a positive influence on the volatility of the relationships in the network. However, in the conceptual model a positive and a negative influence were expected. When the results from the analysis before (the network dynamics) are taken into account this could be explained. A larger organization, which is likely to have more relationships (see Appendix 1. Correlation matrices), will abort the less beneficial relationships and only continues the more beneficial relationships. The effect of opportunities (Ahuja, 2000) seems to predominate here. R&D intensity has an exclusively negative influence on the number of aborted relationships. This partly corresponds with the expectations from the conceptual model since both influences were expected there. So, it seems here that the effect of inducements (Ahuja, 2000) predominates. Also the type of organization has an exclusively influence on the number of aborted relationships, however here it is a positive one. This was also already predicted in the conceptual model. The last control variable, the total number of relationships, has a negative influence on the number of newly formed relationships. This also coincides with the expectations from the conceptual model and indicates a predomination of the effect from the inducements (Ahuja, 2000).

Table 14 presents the variables which have no influence at all. These are only a few variables. The variables access to patents and size have no influence on the number of newly established relationships. However, these same variables do have an influence on the number of aborted relationships so they still have an influence on the volatility of the relationships in the network.

In sum it turned out that the effects of the explanatory variables are very time dependent, which can be seen from Table 12 and Table 13. Also there seems to be a large difference between the explanatory variables of organizations with a lot of relationships and organizations with fewer relationships and between the explanatory effects of the number of aborted relationships and the number of newly established relationships. From the previous analysis (the network dynamics) it already turned out that organizations with a low number of relationships first will form new relationships and then will abort the least beneficial ones. This could be explained by the fact that some of the control variables have a switching influence over time. It seems that the resources of these organizations change over time and accordingly their partnering behavior.

6.3 Population of the Dutch life sciences industry and its partnering behavior

When the results of the above analyses are combined with the data in Table 1 some more expectations can be stated with respect to the population of the Dutch life sciences industry. A difference can be made within this population between organizations already in the network in the year 2002 and organizations which enter the network in the years 2004 and 2005. From the data it turned out that organizations which are already in the industry have more relationships within the network because they are already embedded within the network than organizations which enter the network in 2004 or 2005. The organizations which enter the network later on have fewer relationships within the network because they are not embedded in the network yet.

The established organizations with a lot of relationships tend to select their relationships and abort the least beneficial ones. This behavior continues over time and there is no incentive to form new ones. So, over time the number of relationships of these organizations will decline. When this behavior proceeds it is possible that all of the relationships become aborted and that the established organizations will eventually extinct or leave the network, because organizations within the life sciences need their relationships in order to survive as an organization within the industry (Powell et al., 2005). This already can be seen in the short time period from Table 1. In 2002 64 organizations were connected with other organizations or partner organizations in the network, these were already established organizations within the network. From these 64 established organizations 26 became disconnected in 2004. Later on, in 2005, 10 organizations from these 26 left the network.

The entering organizations in the network with fewer relationships will, according to the analyses done, first form new relationships. Then there are two options; they can either be successful in their new relationships or not. The new organizations which are not successful in their relationships are expected to extinct, since unconnected organizations in the life sciences industry cannot survive as an organization within the industry (Powell et al., 2005). The newly entered organizations which did establish successful relationships are now expected to abort the less beneficial ones and to again form new relationships. However, the influence on the abortion of relationships then is weaker than the influence on the formation of new relationships. So, it is likely that the newly entered organizations which are successful in their relationships will again form new ones. From Table 1 it can be concluded that none of the entering organizations in 2004 left the network in 2005 and that none of the disconnected organizations in 2002 left the network in 2004 or 2005.

6.4 Differences between time periods

In this part of the chapter some t-tests will be done in order to test whether the differences between the different time periods are significant or not. The following sets of equations from the above will be considered here:

(b) $AR_{2004} = \beta_1\ NoREL_{2002}$

(d) $AR_{2005} = \beta_1\ NoREL_{2004}$

(c) $NR_{2004} = \beta_1\ NoREL_{2002}$

(e) $NR_{2005} = \beta_1\ NoREL_{2004}$

(i) $AR_{2004} = \beta_1\ PATP_{2002} + \beta_2\ ACPAT_{2002} + \beta_3\ VC_{2002} + \beta_4\ AGE_{2002} + \beta_5\ SIZE_{2002} + \beta_6\ RDI_{2002} + \beta_7\ TYPE_{2002} + \beta_8\ NoREL_{2002}$

(l) $AR_{2005} = \beta_1\ PATP_{2004} + \beta_2\ ACPAT_{2004} + \beta_3\ VC_{2004} + \beta_4\ AGE_{2004} + \beta_5\ SIZE_{2004} + \beta_6\ RDI_{2004} + \beta_7\ TYPE_{2004} + \beta_8\ NoREL_{2004}$

(j) $NR_{2004} = \beta_1\ PATP_{2002} + \beta_2\ ACPAT_{2002} + \beta_3\ VC_{2002} + \beta_4\ AGE_{2002} + \beta_5\ SIZE_{2002} + \beta_6\ RDI_{2002} + \beta_7\ TYPE_{2002} + \beta_8\ NoREL_{2002}$

(m) $NR_{2005} = \beta_1\ PATP_{2004} + \beta_2\ ACPAT_{2004} + \beta_3\ VC_{2004} + \beta_4\ AGE_{2004} + \beta_5\ SIZE_{2004} + \beta_6\ RDI_{2004} + \beta_7\ TYPE_{2004} + \beta_8\ NoREL_{2004}$

The regression coefficients and errors of the different variables will be used in order to estimate the t-value:

$$t = \frac{\beta 1t\text{-}1 - \beta 1t}{\surd((((SE(\beta 1t\text{-}1))^2)/Nt\text{-}1)+(((SE(\beta 1t))^2)/Nt))}$$

Equations		PATP 2002-2004	ACPAT 2002-2004	VC 2002-2004	AGE 2002-2004	SIZE 2002-2004	RDI 2002-2004	TYPE 2002-2004	NoREL 2002-2004
(b) + (d)	$AR_{2004-2005}$								1,941
(c) + (e)	$NR_{2004-2005}$								-34,610
(i) + (l)	$AR_{2004-2005}$	-79,712	-44,956	25,849	32,673	-11,485	50,124	-6,866	10,357
(j) + (m)	$NR_{2004-2005}$	14,158	6,502	27,051	12,885	-4,425	-28,836	38,102	-55,451

Table 15. T-values

As can be seen from Table 15 all t-values are larger than the critical absolute t-value for a two-tailed test with a 90% confidence interval; $t_{0,10}$ = 1,66 (N=120) (Wonnacott & Wonnacott, 1990). This means that all estimates of successive effects are significantly different from each other. The effects of the sets of variables differ over time from one another.

7 Conclusion & discussion

In this chapter all the previous findings will be combined in order to give an answer to the research question. First the conclusion will be given, then in the second part the results obtained and the research carried out will be discussed. After that some suggestions for policy recommendations and further research will be given.

7.1 Conclusion

7.1.1 Answer to the research question

Organizations within the life sciences industry need to collaborate with other organizations in order to survive as an organization within the industry (Powell et al., 2005). They indicate that these collaborations are mainly based on knowledge complementarities (Hu & Mosmuller, 2008). Because products within this industry take quite some time to develop (Moors & Faber, 2007) it is expected that these collaborations also last for a sufficient long time. However, the volatility of relationships within this industry in the Netherlands is very high (van der Valk, 2007). From this paradox the following research question has been derived:

To what extent does knowledge complementarity influence the volatility of relationships in the Dutch life sciences industry network from 2002-2005 from both a relational and organizational perspective?

From this research question two sub questions were derived (one on the relational and one on the organizational level):

- *To what extent is knowledge complementarity a prerequisite for enduring inter-organizational collaboration between organizations in the Dutch life sciences industry?*
- *To what extent is knowledge complementarity an organizational resource affecting inter-organizational collaborative behavior in the Dutch life sciences industry?*

The first sub question induces research focused on the relational level. The second sub question induces research focused on the organizational level. On a relational level knowledge complementarity was operationalized as patent citations and, later on, as patent classes. However it turned out that there were nearly no patent citations and also on patent class similarities not enough data was available for a decent analysis. So, patent citations and patent classes are not good indicators of knowledge complementarity at the relational level within this particular industry. As a result, no answer can be given on the first sub question.

The second sub question addresses knowledge complementarity at the organizational level. Seen from a Resource Based View perspective knowledge complementarity still should be measured with patents as they represent an organization's unique resources. The number of patents is taken here as the independent variable and a differentiation is made between the patents which an organization owns and the patents of partner organizations to which it has access. Also some control variables are included: the amount of acquired venture capital, the age of the organization, the size of the organization, the R&D intensity of an organization, the type of the organization and the total number of relationships of the organization. After performing a regression analysis, it can be concluded that a lot of variables had an influence on the volatility of the relationships in the network. However, there was only one variable which had an enduring constant influence over time. This was the total number of relationships an organization has. Dutch dedicated life sciences firms with many collaborative relations selected the most beneficial ones by aborting many non-beneficial relations. Dutch dedicated life sciences firms with little collaborative relations were much more focused on forming new collaborative relations. The number of patents in property had a negative influence on the volatility of the collaborations in the network, as was already expected. However, it turned out that the number of patents in property and the number of patents which an organization has access to also has a positive influence on the volatility of the relationships in the network. This could be an effect of 'knowledge leaking'. When one of the two partners also has relationships with other organizations, this knowledge leaking could happen. Knowledge can then leak towards third parties through a common node. This can lead to network effects like shorter collaborations despite the fact that the organizations have a high rate of knowledge complementarity (Stuart, 1998). Another explanation could be that the expected knowledge complementarities at forehand did not turn out to be real knowledge complementarities. It could also be that organizations which have access to a lot of patents of others are attractive for other organizations within the industry to partner with, because then they provide opportunities to collaborate with (Ahuja, 2000). This may result into the formation of new relationships or the abortion of relationships and thus a higher volatility of relationships within the network.

Because of the stranded attempts to give an answer to the first sub question, now only a partial answer to the main research question can be given which almost is the same as the answer to the second sub question. Knowledge complementarity seems to have an influence on the volatility of the relationships in the network from an organizational perspective because from the regression analysis of the second sub question it resulted that the number of patents in property and the number of patents to which an organization has access to both have an influence on the volatility of the relationships in the network. Partly the influence was as expected, negatively, but partly the influence was also positively, which could be attributed to knowledge leaking or the attractiveness of the organizations for others.

7.1.2 Implications of this research

However, next to this answer to the main question, some other interesting things were discovered. For instance the R^2 values of the different models. The models for the newly established relationships have a less predicting value as those for the aborted relationships. It seems like the Resource Based View approach used in this study suits the motives for the abortion of relationships better than for the formation of new relationships. It could for instance be that the formation of new relationships is more based on trial and error searching based on reputation by organizations and that the abortion of relationships is based on the lack of knowledge complementarity. This would confirm the different phases of collaborative behavior derived from Powell et al. (2005) and Gulati and Gargiulo (1999) as stated in section 3.1.3.

Also it can be concluded that organizations with a lot of relationships select their relationships and abort the less beneficial ones, this behavior continues over time. However, organizations with fewer relationships will form new relationships and then will form new relationships again but also abort the least beneficial ones. These effects of the total number of relationships on the partnering behavior, however, deteriorate over time. From this it can be derived that when an organization has fewer relationships, this is an incentive to form new ones. Also it seems that when an organization has aborted many relationships there is little incentive to form new relationships.

The change of partnering behavior of organizations with fewer relationships could be due to the fact that their own resources are developing and changing over time. Accordingly, the estimated effects of the explanatory variables are also volatile over time. Also the effects of explanatory variables are highly time dependent. An explanation could be that the resource needs of organizations within the industry change over time.

Some influences of explanatory variables did not have one particular sign exclusively, but often had a negative as well as a positive influence. This could be attributed to the inducement and opportunity aspects of resources (Ahuja, 2000). When an organization already has enough resources of its own, it could be expected that it would not contribute to the volatility of the relationships in the network, it would have no inducement to form relationships. However, this study found that these organizations also contribute to the volatility of the relationships in the network. This effect could be attributed to the fact that these organizations, which already possess the important resources in-house, are more attractive for other organizations in the network (i.e. an attractive opportunity for collaboration) and thus will form new relationships. However, these relationships are expected not to be initiated by the organization already possessing more resources but by the partner organizations which need (access to) these resources.

7.2 Discussion

7.2.1 Dataset

There are some limitations of the dataset which should be kept in mind when reading the conclusions. The dataset is not a complete overview but just provides an indication. The period was too short (2002-2005) in order to get a better insight into the network dynamics and to monitor collaborations which last longer. Also the fact that data for the year 2003 is lacking should be kept in mind. Next to the time period covered by the data, there are also some other limitations. For instance the limitation of the questions from the survey. The organizations were only able to fill in five other partner organizations. Luckily they were also asked to name the total number of organizations with which they had collaborations. So, from these numbers it can be concluded that the dyadic data on the collaborations has enough mass for performing the analyses. However, it still represents a loss of valuable data. Also the set of organizations that has filled in the survey's every year changed over time. Of course there are a lot of organizations which filled in the survey every year, but there were also organizations which did not answer the questions every year (and that was not always because they did not exist at that moment or they ceased to exist). Because of all these reasons the dataset does not provide a complete overview but merely an indication.

7.2.2 Operationalization

When Dutch dedicated life sciences firms are asked what the motives are for their collaborations they answer that knowledge complementarity is one of the two most important motives in order to collaborate with a certain partner organization (Hu & Mosmuller, 2008). However, when this concept is measured as patent citations this seems not possible within this industry although patented knowledge is one of the most important resources within the Dutch life sciences industry (Powell et al., 2005; Gersten, 2005). It remains unclear from this research whether this occurs only in the young Dutch life sciences industry. When the same research is conducted in another older and more mature industry like, for instance, the semiconductor industry, this question can be answered. Stuart (1998) has performed a patent citation analysis in the semiconductor industry but only with the purpose to measure the influence of technological (knowledge) complementarities on the formation of relationships. So, it seems that patent citation analyses are possible but not as a measure for knowledge complementarity within the young Dutch life sciences industry.

7.2.3 Validity and reliability

From the analysis it turned out that there were nearly no patent citations between the patents from the organizations in the sample and only 40% of these organizations owned patents. This could be a threat towards the construct validity of this study. However, due to the unique role of patents in the life sciences industry, this result was quite remarkably and unexpected. In the next section the role of patenting in the life sciences industry will be elaborated further upon.

There were no changes with respect to the internal validity. The inclusion of the control variable was a right decision because some of these control variables also had an influence on the dependent variable, the volatility of the relationships within the network.

With respect to the external validity some remarks could be made. In section 4.3.3 it was already mentioned that the results of this study could not be generalized towards other industries. However, the possibility to generalize these results to life sciences industries in other countries was stated there. After the study was performed this generalizability is also questionable, since only 40% of the organizations in the Dutch life sciences industry own one or more patents. In the next section this point is also addressed and it should be investigated whether these percentages also hold in life sciences industries in other countries before it is clear whether or not the results of this study are generalizable towards life sciences industries in other countries.

No other threats to the reliability were discovered during the research and it still is as it was already described in section 4.3.4.

7.2.4 The role of patenting in the life sciences industry?

As was already mentioned in chapter 5.2.2 after the data collection for the first sub question some questions were raised about the use of patents within the life sciences industry. What is the role of patenting within developing and emerging industries, and more particular, within the young Dutch life sciences industry?

Within the life sciences industry patents fulfill some different roles. Amongst others, they are considered as an indicator of the quality of the underlying knowledge (Stuart et al., 1999; Niosi, 2003). In this way, the acquisition of a patent can have a positive contribution to the reputation and visibility of the organization within the network and thus also contributes to the partnering opportunities of the organization within the network, which are essential for the survival of an organization within the life sciences industry (Sakakibara, 2002; Baum & Silverman, 2004; Thumm, 2004; Ahuja, 2000). Next to this role of enhancing partnering opportunities, the acquisition of a patent has also another very important role. It is also essential in order to acquire venture capital. Venture capitalists are not always able to correctly evaluate the value of an organization's technology portfolio. The acquisition of patents can help them with the evaluation of the value of this portfolio (Niosi, 2003; Baum & Silverman, 2004).

However, for young and small organizations (especially within developing and emerging industries) it is very hard to acquire patents because of the high costs involved and the difficulties encountered when the patent needs to be protected (Lemarié et al., 2000). But in the life sciences industry, many organizations are spin-offs which can make use of the already patented knowledge from their mother organizations (van der Valk, 2007).

So, it seems that some essential advantages of acquiring a patent and also some disadvantages of patenting can be identified. However, how can it be that, when the acquirement of a patent is so necessary for the survival of the organization, only 40% of the organizations in the sample own one or more patents? It seems as if the disadvantages of the acquirement of a patent are too large for the young and small organizations in the Dutch life sciences industry. To make sure this is the case because of the youngness and smallness of this industry and not because it has to do with the life sciences industry, this also needs to be investigated in other countries were the life sciences industry is older, further developed and larger.

7.2.5 Theoretical issues

Next to the already explained points of discussion some theoretical remarks can be made.

Relational/organizational

Knowledge complementarity is a relational concept since there are two actors needed in order to determine whether or not certain knowledge is complementary. This gives some questions for the second sub question. The transformation of a relational concept into an organizational variable with the help of the Resource Based View should be viewed with some caution and should be kept in mind when considering and interpreting the results. When an organization has more patents in its property or has access to more patents of other organizations it is more likely that it has a higher propensity to be knowledge complementair to other knowledge than when it has less patents in its portfolio. So, it does give an indication of knowledge complementarity, but it does not measure knowledge complementarity itself. This could have an effect on the results of this study.

Bounded rationality

A possible explanation for the fact that the relationships investigated here do not last that long and are based on knowledge complementarities can be found in the concept of bounded rationality (Simon, 1991). It seems that knowledge complementarities are presumed and expected when relationships are formed, because organizations themselves indicate this as one of the most important motives to partner (Hu & Mosmuller, 2008). However, according to the concept of bounded rationality it is impossible to have all the information and thus not all information is available for the organizations before the relationship is established. So, knowledge complementarities are presumed and expected, but at that point of the formation of the relationship it is not clear whether these expected knowledge complementarities really exist. When these knowledge complementarities are found it is likely that the relationship lasts longer. When these knowledge complementarities are not found it is likely that the relationship will be aborted. This is also in line with the phases constructed from Powell et al. (2005) and Gulati and Gargiulo (1999) in section 3.1.3.

Resource Based View

In this study the Resource Based View is used in order to develop the conceptual model. However, it turned out that this conceptual model is not a good model of the partnering behavior of Dutch dedicated life sciences firms because the effects of the explanatory variables specified change over time. In the next section this deficiency will be elaborated further upon and some suggestions will be given.

7.3 Implications for other research

The results of this study have some implications for other research, which will be specified below.

7.3.1 A more dynamic RBV model

This research showed that the effects of variables derived from the Resource Based View are time dependent and volatile over time. Apparently there seems to be no good fixed or structural Resource Based View explanation for the influences investigated in this report. With the results of this study in mind, the results from other studies based on the Resource Based View which only consider a single point in time cannot be generalized to other time periods. Also the relationships derived in these studies cannot generally be taken as 'variable X has either a positive or negative influence on variable Y', but the moment for which these relationships are found should be explicitly taken into account, because from this research it turns out that these relationships only hold for a certain moment in time. An example of a study within the life sciences which also has used the Resource Based View for developing a structural model is van der Valk (2007; chapter 4 and 5). Other studies which used a structural Resource Based View in their analysis are for instance; Eisenhardt and Bird Schoonhoven (1996), Ahuja (2000), Sakakibara (2002) and Baum and Silverman (2004). The results of this study ask for a more dynamic model and explanation. A suggestion for such a more dynamic model would be to include for each preceding year the same explanatory variables:

$AR_{2005} = f(PATP_{2004}, PATP_{2003}, PATP_{2002}, PATP_{2001}, PATP_{2000}, ACPAT_{2004}, ACPAT_{2003}, ACPAT_{2002}, ACPAT_{2001}, ACPAT_{2000}, VC_{2004}, VC_{2003}, VC_{2002}, VC_{2001}, VC_{2000}, AGE_{2004}, AGE_{2003}, AGE_{2002}, AGE_{2001}, AGE_{2000}, SIZE_{2004}, SIZE_{2003}, SIZE_{2002}, SIZE_{2001}, SIZE_{2000}, RDI_{2004}, RDI_{2003}, RDI_{2002}, RDI_{2001}, RDI_{2000}, TYPE_{2004}, TYPE_{2003}, TYPE_{2002}, TYPE_{2001}, TYPE_{2000}, NoREL_{2004}, NoREL_{2003}, NoREL_{2002}, NoREL_{2001}, NoREL_{2000})$

No explicit influences (either positive or negative) can be hypothesized here, because of the fact that it is likely that they will be different for successive years.

Furthermore, it would be wise to link this more dynamic model and the explanation it provides to the development phase in which the network or the industry is at a certain moment. This could have an influence because of the distinct characteristics of, for example, a new and emerging industry or network with respect to the partnering behavior of the organizations involved. Also the model and explanation of it would be improved if not only the phase of the network is included but also the phase of product development in which the organizations in the network are at that particular moment, because then other kinds of collaborations are needed for the organizations and thus the partnering behavior of the organizations will also change. In this study it is shown that the needs of organizations shift over time and this could very well have to do with (next to the already included phase in which the organization is itself, i.e. age) the phase of product development and the phase of industry/network development, because of the different kinds of collaborations needed in different phases of the product development and industry or network development. For example, when the development of a product is in one of its early phases, collaborations will mostly be focused on R&D. However, these R&D-collaborations could very well be based on incremental and modular new R&D for the product to develop which could result in different needs within this R&D phase and thus also different collaboration partners. Later on, as the product itself has already been developed further, the collaborations are likely to be more focused on the commercialization of the product.

7.3.2 Dynamic capabilities versus opportunities and inducements

From this study it turned out that the opportunities and inducements of organizations develop and change over time. This implies that these organizations have changing needs and that their resources will change over time. This puts some pressure on the use of dynamic capabilities (Teece et al., 1997). These dynamic capabilities are defined as, according to Teece et al. (1997: 516) "*the firm's ability to integrate, build, and reconfigure internal and external competences to address rapidly changing environments*". From this study it resulted that not only the environment of the organizations changes rapidly, but also the resources and the needs of the organizations themselves and thereby also the internal competences. So, in order to be able for these dynamic capabilities to be of any use, organizations within the Dutch life sciences industry also have to take into account their own changing resources and changing resource needs. These organizations have to keep an eye not only on their environment, which is likely to change rapidly, but they also have to pay attention to the changes in their own organization, specifically the changing resources and their changing resource needs.

7.4 Policy recommendations

The life sciences industry is considered to be a very important industry in order to stimulate future economic development (Ministry of Economic Affairs, 2004). In this industry collaborations are essential because of the rapid pace of technological developments and changes and the fact that organizations in this industry have all developed their own specialties (Powell et al., 2005). In order to let this industry grow and flourish these collaborations should be in order and optimal benefits should be reaped from them. This collaboration process within the life sciences industry should be better monitored and stimulated, certainly because of the shifting needs of organizations. When the monitoring is better it is easier to grant organizations more targeted subsidies.

In this industry there seems to be a high volatility of relationships in the network (van der Valk, 2007). This high volatility could be the cause of relatively high transaction costs because of the many changes in relationships. When these changes in relationships are diminished, the transaction costs are also likely to decline and the money saved could be used for other more beneficial purposes.

Also more insight needs to be gained in the needs of the organizations within this industry. It seems that these needs develop and change quickly over time. In order to stimulate this industry these needs have to be fulfilled at the right moments. The government should play a more active role here to make sure they are able to fulfill these needs when possible.

7.5 Further research

From this study some suggestions for further research can be derived. As already said in the first paragraph of this chapter this research shows that there is a difference in the explanations of the abortion and formation of collaborative relationships. The abortion of relationships can be explained quite well by the models developed in this study. However, the formation of relationships is not very well explained by these models. Further research should dedicate itself to finding causes which could explain the formation of relationships from another perspective. A suggestion for this would be to take another perspective instead of the Resource Based View, in which the reputation effect is included.

Already the problems with the quantitative operationalization of the concept knowledge complementarity have been discussed. A suggestion for further research would be to develop a better method to quantify the concept of knowledge complementarity from a relational perspective with respect to the young Dutch life sciences industry. For example, measure the concept knowledge complementarity on citations of publications instead of citations of patents. Publications should then be taken that are written by the employees from the partnering organizations and the citations between them.

One of the largest limitations of this study is the limitation of the dataset used. There are several limitations and due to these limitations the results of this study can only be considered as tentative. A suggestion for further research would be to do the same study on a better and more complete dataset. In order to acquire this dataset a couple of years are needed because of the dynamics which are also under investigation here.

Another suggestion for further research would be to investigate the presumed knowledge complementarities further. How is it possible that the organizations in the Dutch life sciences industry indicate knowledge complementarities as one of the most important incentives to partner (Hu & Mosmuller, 2008), but yet their collaborations are so short? Further research should dedicate itself towards the question whether this could have to do with the (wrong) presumption of knowledge complementarities before the establishment of new relationships. A suggestion would be to investigate organizations which intend to form a new relationships with a partner, the motives of the organizations for the formation of this relationship, their presumed knowledge complementarities and the real knowledge complementarities between the two organizations.

Already in 7.3 some suggestions for the development of a more dynamic model were given. Because of the time dependency and volatility of the explanatory variables a more dynamic model over time would give a more just explanation. Also the inclusion of the phase of product development and the phase of industry/network development would contribute to this. These suggestions should be addressed in further research.

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Appendix 1. Correlation matrices

2002-2004

Correlation Matrix

	PATP	ACPAT	VC	AGE	SIZE
PATP	1.000				
ACPAT	0.121	1.000			
VC	0.010	-0.056	1.000		
AGE	-0.019	0.024	-0.058	1.000	
SIZE	0.012	-0.048	0.712	0.205	1.000
RDI	0.522	0.067	0.104	-0.200	-0.094
TYPE	-0.073	0.110	-0.059	-0.483	-0.237
AR	0.158	0.043	0.122	0.217	0.071
NR	-0.052	0.049	0.152	0.034	0.187
NoREL	0.365	0.105	0.143	0.175	0.080

Correlation Matrix

	RDI	TYPE	AR	NR	NoREL
RDI	1.000				
TYPE	-0.006	1.000			
AR	-0.156	0.155	1.000		
NR	-0.004	-0.022	-0.405	1.000	
NoREL	-0.036	0.140	0.907	-0.498	1.000

Means

PATP	ACPAT	VC	AGE	SIZE
0.000	0.000	0.763	4.326	17.469

Means

RDI	TYPE	AR	NR	NoREL
0.376	0.000	0.000	0.000	0.000

Standard Deviations

PATP	ACPAT	VC	AGE	SIZE
1.000	1.000	7.059	4.995	28.430

Standard Deviations

RDI	TYPE	AR	NR	NoREL
0.317	1.000	1.000	1.000	1.000

2004-2005

Correlation Matrix

	PATP	ACPAT	VC	AGE	SIZE
PATP	1.000				
ACPAT	0.134	1.000			
VC	0.531	0.088	1.000		
AGE	-0.001	0.062	-0.040	1.000	
SIZE	0.068	0.016	-0.033	0.304	1.000
RDI	0.430	0.020	0.064	-0.404	-0.194
TYPE	-0.044	-0.129	-0.006	-0.448	-0.292
AR4	0.079	0.119	-0.172	0.249	0.137
NR4	-0.059	0.086	0.281	-0.158	-0.043
AR5	0.179	0.326	0.216	-0.032	0.194
NR5	0.175	0.046	-0.055	0.159	0.145
NoREL4	0.102	0.192	0.284	-0.054	0.111

Correlation Matrix

	RDI	TYPE	AR4	NR4	AR5	NR5
RDI	1.000					
TYPE	0.470	1.000				
AR4	-0.328	0.157	1.000			
NR4	0.067	0.048	-0.405	1.000		
AR5	-0.015	0.011	-0.255	0.856	1.000	
NR5	0.090	-0.219	-0.073	0.045	-0.007	1.000
NoREL4	0.109	0.083	-0.353	0.890	0.897	-0.112

Correlation Matrix

	NoREL4
NoREL4	1.000

Means

PATP	ACPAT	VC	AGE	SIZE
0.000	0.000	0.000	4.820	14.367

Means

RDI	TYPE	AR4	NR4	AR5	NR5
0.359	0.000	0.000	0.000	0.000	0.000

Means

NoREL4
0.000

Standard Deviations

PATP	ACPAT	VC	AGE	SIZE
1.000	1.000	1.000	5.083	29.029

Standard Deviations

RDI	TYPE	AR4	NR4	AR5	NR5
0.298	1.000	1.000	1.000	1.000	1.000

Standard Deviations

NoREL4
1.000