MASTER

Knowledge sharing and protection in R&D collaborations
exploring the tension field

Bogers, M.L.A.M.

Award date:
2004

CHALMERS

TU/e technische universiteit eindhoven

Knowledge Sharing and Protection in R&D Collaborations: Exploring the Tension Field

MARCEL BOGERS

Technology and Innovation Policy – Advanced Economies
Department of Technology Management
EINDHOVEN UNIVERSITY OF TECHNOLOGY
Eindhoven, the Netherlands

Department of Industrial Management and Economics
School of Technology Management and Economics
CHALMERS UNIVERSITY OF TECHNOLOGY
Göteborg, Sweden 2004

Knowledge Sharing and Protection in R&D Collaborations

Exploring the Tension Field

Marcel Bogers

Knowledge Sharing and Protection in R&D Collaborations: Exploring the Tension Field

Marcel Bogers

Eindhoven: Eindhoven University of Technology
Gothenburg: Chalmers University of Technology

Thesis for the degree of *Master of Science* in the field of:
'Technology and Society, Technology and Innovation Policy – Advanced Economies'

Supervisors:

Rudi Bekkers, Ph.D.
Department of Technology Management
Eindhoven University of Technology

Ove Granstrand, Ph.D., Professor
Department of Industrial Management and Economics
Chalmers University of Technology

Charmianne Lemmens, Ph.D.
Department of Technology Management
Eindhoven University of Technology

M.L.A.M. Bogers

Technology and Innovation Policy
Technology and Society
Department of Technology Management
Eindhoven University of Technology
Eindhoven, the Netherlands

December, 2004

Abstract

This study addresses the tension field that arises when firms participate in R&D collaborations and have to – at the same time – share *and* protect their knowledge. A literature survey of the theoretical perspectives on collaborative knowledge sharing and the possibilities for firms to protect their knowledge gives a model of the tension field that arises, which is backed up by a series of case studies. This model reveals the main dimensions that comprise the tension field and their relations. These dimensions are the 'knowledge characteristics', the 'knowledge embodiment', the 'relational dimension', the 'collaboration dimension' and the 'environmental dimension'. Because the main focus of this study is on (pre-competitive) R&D collaborations, the central dimension appears to be the characteristics of the knowledge. The embodiment of the knowledge gives the possibilities and constraints of how knowledge can be shared and protected. The relational dimension has an important role in how the tension between the sharing and protection of knowledge can be resolved, with trust as a main element. The collaboration itself (and the characteristics of the partners that are active in it) and the environment influence the condition of the tension field on a higher level by affecting the more central dimensions.

Furthermore, this study proposes four main strategies that firms can adopt in R&D collaborations, based on a certain condition of the dimensions in the tension field. These four strategies are a 'public open exchange strategy', a 'private open exchange strategy', a 'layered exchange strategy' and a 'closed exchange strategy'. Propositions are developed that link the conditions in the tension field to the probability of the adoption of a certain strategy. In order to explore these possible coping strategies (theoretically and empirically) a framework is developed that can be used to explain knowledge transfer and the governance hereof. Licensing is an important issue in this as well.

The case studies show the adoption of two strategies, namely (a) the 'private open exchange strategy' in case of the existence of new and specific knowledge, the presence of small firms and no university involvement, and (b) the 'layered exchange strategy', in case of a large number of partners, a wide variety of partners and university involvement. In general the R&D collaborations are characterized by an explorative nature, highly complex knowledge and a high importance of tacit knowledge. Because of this, the closed model did not occur on the practitioners' level, although the strategic management level might put more emphasis on the protection of knowledge. The open strategy can moreover be characterized as a royalty-free cross-licensing strategy with grant-back provision and the layered strategy as the implementation of 'sub-collaborations' which perform different (sub) tasks. In addition to these specific governance mechanisms, the role of trust takes a central place in reducing the tension between sharing and protecting knowledge in R&D collaborations.

Keywords:
knowledge governance, appropriation, embodiment, trust, licensing, open exchange, layered collaboration scheme

Preface

I strongly adhere to the significance of 'path dependency' and the 'human factor', which are relevant for many aspects of our lives. Among other things, this means that this piece of work is the result of the path I traveled during my life and the people that have been involved in this. This brings me to the gratitude I would like to express to my acquaintances, friends, relatives and family, for being part of my life and making it enjoyable. In particular I would like to thank my parents who have raised me in such a way that I was able do reach this point in life, with much gratitude. I am fortunate enough to have friends with various backgrounds from all over the world, most of which I have (more-or-less subsequently) met when I was growing up in 'my' village Lepelstraat; when I went to school in Bergen op Zoom, both my primary school 'Montessori school' and secondary school 'Gymnasium Juvenaat'; in Eindhoven while I was studying at the 'Eindhoven University of Technology'; when I went abroad for one semester to study at the 'University of California at Berkeley' in the United States; and finally during the time I spent in Gothenburg, Sweden to write this thesis at the 'Chalmers University of Technology'. Without specifically addressing anybody – which would be rather impossible – I would like to take this opportunity to thank my friends for the joyful, interesting, instructive and relaxing times I spent with them. I think they know themselves with which of these (if not all) categories I refer to them.

Of course there are many people who have either directly or indirectly contributed to my thesis. First of all I am grateful for the education I had in Eindhoven and would like to thank all the people (from the university, my department and my program) that have been contributing to this. More specifically, I would like to thank Martijn Bakker, Emilia van Egmond, Wil Kuijpers, Paul Lapperre, Henny Romein, Bert Sadowski, Bart Verspagen, Marc de Vries, as well as Tineke Duyzer and Els Wijers from the Course Administration department.

Secondly, regarding the more direct input to this thesis, I would like to express my gratitude to the people (and institutions) who in some way gave input to the thesis. Therefore I acknowledge the assistance from the department of Technology Management at Eindhoven and the department of Industrial Management and Economics at Chalmers for giving me the opportunity to write my thesis in the way I did, which proved to be very valuable. Furthermore, some people who I would like to thank are Alan Burford, Jacomien Drent, Bo Heiden, Marcus Holgersson, Sven Lindmark, Judy Senior, Olof Winberg, the students of the courses 'Economics and Management of Technology' and 'Innovation Economics' for which I was the course-assistant, the participants of the Symposium on 'The Entrepreneurial University' organized by the Center for Intellectual Property Studies at Chalmers (1-3 June, 2004), the participants of the Meeting on 'EU funding from a Licensing Perspective' organized by the Licensing Executives Society Benelux in Brussels (16 June, 2004), the participants of the Workshop on 'Performance Assessment of Public Research, Technology and Development Programmes' organized by the European Commission in co-operation with Washington Evaluation Network in Brussels (17-18 June, 2004), and finally the interviewees (both for my interviews at the early stage of this study as well as those during my case studies) for giving me the opportunity to get more detailed insight in various issues. I particularly owe great gratitude to Torbjörn Jacobsson, Frank Tietze and Arne Ziegert for their insightful comments, good discussions on various issues, and their friendships.

I moreover want to express my grateful acknowledgements to three persons in particular, namely the supervisors for my thesis. Although I have learned a great deal from them on various fields, I would like to focus on one issue that I especially learned about from each of them. Charmianne Lemmens has mostly contributed to my ability to identify the 'red thread' while writing a thesis like this. Although one sometimes have to get of the track in order to see where it is, it is very good to have someone like Charmianne to get the writing on its right place. Ove Granstrand has contributed very much to my understanding of how one could and/or should do research. He gave me important insights which methods to use (in different occasions) and how to use them, caveats one has to look out for, which (personality) traits are common for some researchers and people from industry, and various other related issues. Because he also often took the role of the devil's advocate – which is in fact something I appreciate very much – he triggered me to keep paying attention on several issues, both within and outside my research, and to see things in perspective. Rudi Bekkers has largely contributed to my insights in the field of innovation in general as well as R&D collaborations in particular. Our discussions were very supportive for me to get a clear general picture and also to visualize and formulate more detailed concepts. Therefore, Charmianne, Ove and Rudi, thank you very much for making this experience a very valuable one for me! Furthermore, I want to thank Eva Burford for assisting me in various issues and making sure I had the proper conditions to write this thesis.

With regard to my thesis, I would like to note that I am very glad to have chosen this topic. It greatly increased my understanding of the 'world of collaboration' and the process of innovation in general. Finding the right path towards the final topic proved to be quite challenging. That is to say, when I (finally) found a topic which would be very insightful for me and highly relevant in general, it appeared to be 'too hot'. Fortunately, I was able to find an equally interesting topic which in the end was not so far from my original plan. In any case, this thesis can be considered the 'crown' on my years of study, all the more because the main 'pillars' of my program are technology, innovation, economics, sociology and law. I hope this work can increase your insights like it did for me.

Briefly about my future path, I acknowledge the valuable advice of Rudi Bekkers, Michiel van Dijk, Geert Duysters, Dominique Foray, Ove Granstrand, William Ibbs, Henny Romijn, and Bart Verspagen, which helped me to realize that this way of contributing to the world is something I want to continue doing in the coming years and therefore want to pursue my studies in doing a Ph.D.

And last, but not by far least, I am very grateful for having Hanneke who supported and guided me through this phase of my life even though this sometimes (in fact quite often) had to be done over quite a distance. So, Hanneke, thank you for your love, support, compassion and patience, and I look forward taking the next step in life together with you by my side.

Marcel Bogers, Gothenburg 2004

Content

List of Figures[1]

[1] Unless otherwise stated, the figures in this study are own figures develop by the author.

x

List of Tables[2]

[2] Unless otherwise stated, the table in this study is tables develop by the author.

1 Introduction to the Study

1.1 INTRODUCTION

Increasingly firms go into collaborative agreements with other organizations entailing various modes of collaboration. This trend relates to several developments in the world economy (which will be discussed in the next section), and the way firms cope with and stay ahead in these developments. One of the main driving forces for collaborations is the increased need to share and combine knowledge, vis-à-vis 'go-it-alone' strategies. This is related to the increased cost of R&D (research and development) and shortening market lead times. It is acknowledged that collaborative efforts are becoming of increasing importance for a firm's competitive advantage. A very delicate, though crucial, issue in these collaborations relates to how firms on the one hand share their knowledge in order to contribute to the collaboration and on the other hand – although at the same time – protect this knowledge they put into the collaboration. In other words, there exists a tension between the sharing and protection of knowledge, which is exactly the issue that is going to be addressed in this report. Although there have been investigations that try to reveal this tension field in some way (e.g. Henkel, 2004; Oxley and Sampson, 2004), it is acknowledged that it still needs significant investigation (McEvily, Eisenhardt and Prescott, 2004).

This tension field becomes apparent on many occasions. In the telecommunication industry, for example, it is crucial for firms to create certain standards (e.g. in the subsequent generations of the mobile telephony). In order to achieve this, the firms will have to collaborate with their competitors, among others, and share their knowledge. Despite this need for sharing, it is obvious that firms want to limit the (unwanted) appropriation of knowledge. Thus, the need for knowledge protection, or protection of (unwanted or unnecessary) knowledge transfer, is clear as well, both in particular collaborations and for firm competitiveness in general.

To give an example from another sector, the developments in the chemical industry are traditionally triggered by research and development on new applications and by customer needs. In order to keep up with these developments, it is logical to go into collaborations with these customers to address their needs. Furthermore, collaboration with (potential) competitors also takes place because chemical firms are often not able to achieve certain goals on their own. This is reinforced by the traditionally strong patent portfolios many of the firms have in the chemical industry. Because of this, and among other things such as the importance of trade secrets, firms will have a strong need to protect their knowledge when they collaborate with others. Thus again, the tension between knowledge sharing and protection becomes apparent.

This chapter will first describe the background with the developments that have given rise to this tension. Also specific reference will be made to the importance of knowledge sharing in collaborations as well as knowledge protection. Additionally, section 1.3 will give an overview of the possible modes of collaboration. Furthermore, the value chain in which a firm's activities can be identified and delineated, i.e. in relation to the development of knowledge, is briefly revisited in order to clarify on which levels firms operate and can collaborate. After the background and the mapping of the field have given the broad framework and some of the main considerations, the relevance of this study is specified by going into its main contributions. Furthermore, the research problem will give the exact goal that is going to be addressed in this study, and what the consequent research question is that needs to be answered. The subsequent delineation will make clear what some of the boundaries of this study are. The methodology and report outline will finally introduce the scheme and structure of this research and report.

1.2 BACKGROUND

1.2.1 Main Global Developments

Many of the developments that have characterized some of the recent changes in our economy have had significant impact on how firms act in, and beyond, their industry limits. The sharing and (continuous) development of knowledge, i.e. with other organizations, is one of these developments. This section addresses the most relevant developments that have lead to the importance of this sharing. It is obviously impossible to give a fully comprehensive overview of all developments in the scope of this study, although the most relevant ones will be described. It has to be noted that these developments have not all developed independently and that certain interdependencies do exist.

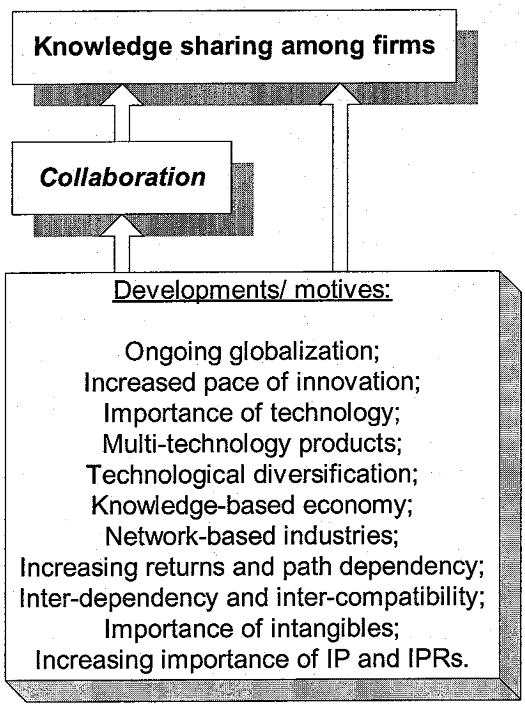


Figure 1. Main global developments

In a more and more globalized world, the pace of innovation increases rapidly. Furthermore, technology has become to play a crucial role in the present economy (Das and Teng, 2000). Moreover, products have become more complex with a multi-technology character (Granstrand and Sjölander, 1990; Granstrand, 2004c); products and firms have become technologically more diversified (Granstrand, Patel and Pavitt, 1997; Cantwell, Gambardella and Granstrand, 2004). This again is related to the establishment of collaborations for firms to access external competencies (Giuri, Hagedoorn and Mariani, 2004). Another development is the increasing importance of network-based industries in which issues such as network externalities and inter-compatibility come to play a role (see e.g. Katz and Shapiro, 1985). This in turn has a clear relation with the rise of the present knowledge-based economy with increasing returns and path dependency (see e.g. Arthur, 1994) and the importance of intangibles (see e.g. Edvinsson and Malone, 1997), knowledge and information (Roos, Roos, Edvinsson and Dragonetti, 1997), and the need for firms to reach the critical mass (see e.g. Rogers, 1995) although this need has changed due to the rise of the network-based industry and the importance of value networks (see e.g. Christensen and Rosenbloom, 1995). Due to these developments, the economy has gone through a shift toward more knowledge-intensive activities (Foray, 2004). This is also reflected in knowledge sharing and collaboration because firms are dependent on each other to create value and stay competitive in this knowledge-intensive economy. Therefore, they have to collaborate in some way, which is in turn affected by their portfolio of (intangible) assets as well as by their ability to collaborate. Furthermore, intellectual property (IP) plays an important role in the 'new economy'. Sometimes this role was even an essential one, meaning intellectual property issues directly determined the development and outcome of certain (collaborative) ventures, for example in the development of the GSM technology (Bekkers, 2001). Furthermore, it is acknowledged that intellectual property rights (IPRs) play a crucial role in the world economy and, therefore, are an important issue for policy makers, academics and business firms (Verspagen, 2003).

These developments show an increased need for firms to share knowledge among them. For example, the critical role of technology has led to contention that firms have to co-operatively create their competitive strength, which can be done by the establishment of inter-firm collaborations (Das and Teng, 2000). Furthermore, in a knowledge-based and network-based economy with increasing returns on adoption, it is fruitful for firms to share and combine their knowledge with others. This development gives rise to inter-dependency and inter-operability issues, which in turn means that firms have to share knowledge in order to make their technologies and services function in practice.

As will be discussed in the next section, there are several means for firms to get access and profit from each other's knowledge. The logical way to try to establish this sharing is through collaboration (see Figure 1), in contrast to an arm's-length transaction, for example. Some developments, e.g. the diversification of technologies, ask more directly for collaboratively sharing knowledge. And regardless of the exact motives, a significant increase of the establishment and importance of inter-firm (or inter-organizational) collaborations has been shown by a broad range of studies (Mowery, 1988; e.g. Contractor and Lorange, 1988a; Hagedoorn and Schakenraad, 1990; Bleeke and Ernst, 1993; Dodgson, 1993; Hagedoorn and Schakenraad, 1994; Gomes-Casseres, 1996; Doz and Hamel, 1998; Hagedoorn, Link and Vonortas, 2000; Bamford and Ernst, 2002; Narula and Duysters, 2004). From the time this trend started to arise, academics were still puzzled by it (Hladik, 1985). Today much more is known about the relevant processes and mechanisms although some issues still have to be resolved, which is also due to the changing environment of collaborations.

As will be shown in Section 1.3.2 , firms can collaborate on different activities. As an illustrative example, Figure 2 shows the increase of the number of collaborations in research and development (R&D) from 1960 until 1998. Although the figure shows two clear drops at the early and late 1990s, the general trend is clear[3]. This general trend in the establishment of collaborations is expected to continue in the near future giving an increasing importance to R&D collaboration. This is also visible in the value of firms' collaborations; for example, the consultancy firm Booz-Allen Hamilton predicts that within a couple of years the value of alliances will be in between $30 and $50 trillion (Verspagen and Duysters, 2004).

[3] Some main factors creating these drops are the increased interest in mergers and acquisitions, and the downturn in the economic situation in general as well as in the information technology sector in particular.

In sum, there are several developments that give rise to the (collaborative) sharing of knowledge, which in turn has significant implications for how firms operate in the present economy.

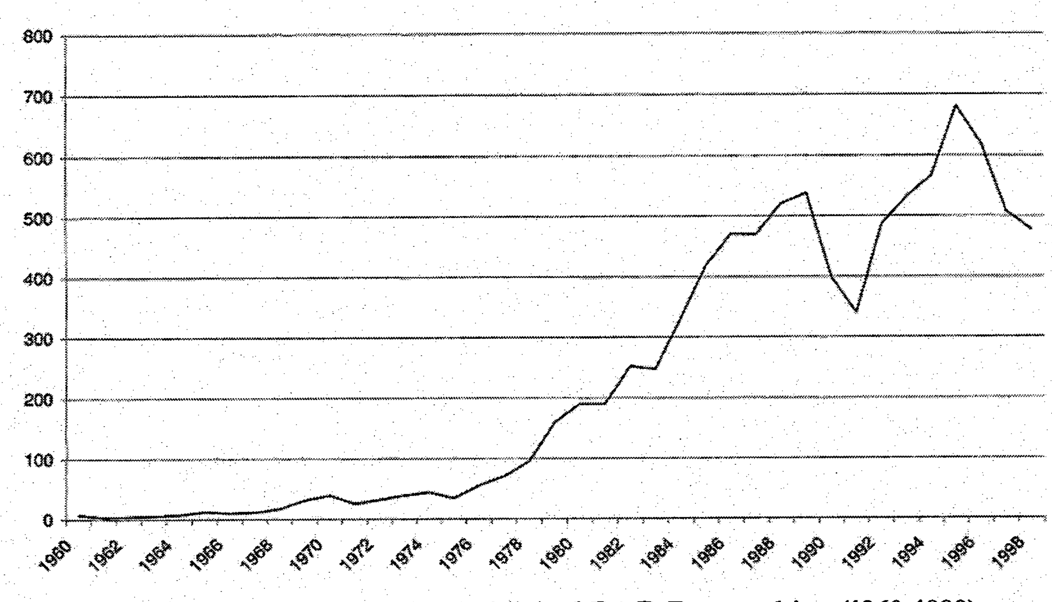


Figure 2. Growth of newly established R&D Partnerships (1960-1998)

Source: Hagedoorn (2002)

1.2.2 Developments in Knowledge Sharing and Protection

The developments that are discussed above differ across sectors. The above-mentioned developments mostly relate to knowledge-intensive sectors. For example, the link between globalization and the growth of collaborative (international) agreements has been most apparent in capital-intensive and knowledge-intensive industries due to the importance of innovation and technological development (Narula and Duysters, 2004). In order to keep up with the increased pace of innovation, firms have get access to other organizations and share their own resources with them.

The different organizations involved put in a certain amount of their knowledge in order to create a common goal, i.e. knowledge output. In the scope of the rise of the knowledge-based economy, this gives firms a good means to stay ahead of other in their pursuit for competitive advantage. Especially in high-technology industries the importance of knowledge becomes apparent because it is used as a medium of sharing and exchange as well as a tool for competition. Moreover, the literature is still challenged by the 'hybrid' or 'intermediate' (see e.g. Table 1) organizational mode of inter-firm collaborations, and a need has arisen to look beyond the existing literature – both economic organization as well as strategic management – and investigate which concepts can be developed for the new specific kinds of collaborations. The role of knowledge in the economic development as a whole is very important as well. Considering the rise of this knowledge-based economy, both scholars and people from industry have acknowledged the importance of knowledge management to foster the creation, sharing and utilization of knowledge. Aadne, Krogh and Roos (1996) argue that in the present world of fast technological changes, more competitive environments, strategic behavior among firms, vanishing industry boundaries and increased inter-firm competition, both researchers and managers realize that knowledge is the most important capital resource for sustaining high performance. This is also exactly the view that is adopted by some of the theoretical approaches that will be discussed in Chapter 2. A firm's knowledge base is thus clearly becoming one of its main competitive assets.

But if this is the case, a firm most definitely wants to protect this competitive asset, i.e. its knowledge. With the increasing participation in collaborative agreements, this protection has become a more subtle issue. A firm's knowledge represents a certain value although this is quite hard to determine[4]. The characteristics of knowledge can be put on different scales, e.g. low complexity vs. high complexity or codified vs. tacit. All of this makes that there is not on clear-cut management tool available for firms to protect their knowledge. One important characteristic of knowledge is its public good nature property. This property can lead to the failure of markets for information and other kinds of knowledge (Arrow, 1962). The two main characteristics of (knowledge as) a public good are non-rivalry and non-excludability. Non-rivalry means that several actors can use or consume the same good without diminishing its value, whereas non-excludability means that an actor cannot be prevented from using or consuming the good. The problem with explicit knowledge is the non-exclusivity in use and the difficulty of concluding contracts without first revealing the involved knowledge, the so-called 'disclosure dilemma' or 'information paradox' (Arrow, 1962). This is due to the information asymmetry that exist between the two parties that share or transfer knowledge and the difficulty to protect this knowledge. Because of this the party with the knowledge will be hesitant to show its (valuable) knowledge before the transfer or transaction but on the other hand the (potential) knowledge receiver wants to know the content of this knowledge (or 'merchandise') in order to (e)valuate it. This can in turn be taken care of by the some sort of secrecy agreement before revealing the knowledge. The non-rivalrous characteristic makes it hard to protect, especially in collaborations because knowledge can just disperse very easily, so to say. Though, and this highly relates to working around the non-excludability characteristic of knowledge, firms are able to reap the advantages of the knowledge they 'own'; in other words, they can appropriate it. Especially for knowledge put into a collaboration, the need to protect it will be high, which makes it necessary to reconsider the mechanisms that are used to protect knowledge and possibly to develop new ones that go beyond the traditional modes of knowledge protection. The most traditional means of protecting knowledge, especially related to technology, is the use of a patent. But certain knowledge can also be kept secret in order to protect it, or a certain lead-time can be created to create a 'head start' and achieve a certain market share and recover R&D costs.

Because of the increasing importance of R&D collaborations, the protection of knowledge has to be reconsidered, as noted above. So, the appropriate protection of knowledge is crucial for a firm that participates in R&D collaborations. But the main determinant for the success of such a collaborative effort *is* the sharing of the individual participants' knowledge, as also described above. These elements seem to be (to a certain extent) two different and therefore opposite sides of the same coin. The challenge, which will be addressed in this report, is to gain insight in the aspects that underlie this tension between knowledge sharing and protection. From a firm perspective it will be fruitful to identify how it can cope with this tension in order to maximize the 'collaborative outcome' as well as the benefits for the individual firm.

[4] This is exactly what some of the intellectual capital approaches that are referred to in section 2.2.5 try to establish (e.g. Sullivan, 2000).

1.3 Mapping the Field

1.3.1 Modes of Collaboration

As indicated above, firms can co-operate in several ways, one of which is inter-organizational collaboration. The sharing of knowledge – in whatever form – is at the heart of this kind of co-operation. Before going into the several possible forms of collaboration, this more general range of possible co-operation is briefly discussed. In this context the term co-operation mainly refers to the coordination and integration of knowledge.

Table 1. Three main forms of co-operation

Market transaction	Inter-organizational arrangement	Hierarchy
Transaction through the market place that is short-term and involves minimal co-operation	Co-operation between organizations (e.g. firms) with a long-term commitment	Long-term intra-firm co-operation
◄──────────────	──────────────►	
	Non-equity based collaboration / Equity based collaboration	

Co-operation can generally take place in three more-or-less distinct forms, as shown in Table 1. The form that involves the least amount of co-operation, if any, is the market transaction. In this case the co-operation (and the time it takes) is limited to the actual exchange. The second form of co-operation, which is the focus of this study, consists of the arrangements that exist between organizations (or firms in particular). In this a high degree of co-operation is required and the term of this co-operation exceeds the time of some actual arm's-length transaction. This form of co-operation includes several modes of inter-organizational collaborations, which will be discussed in the remaining part of this sub section. The exact degree and term of co-operation depends on the exact mode of collaboration. The final form of co-operation that can be distinguished is the hierarchy. This entails an intra-firm co-operative arrangement in which certain transactions are internalized within one firm (or unit). In this case the co-operation only exists *within* the firm and no inter-firm co-operation is principally involved. Obviously, the next step for a firm is to go into (co-operative) market transactions or inter-firm co-operation, or both. The arrow in Table 1 indicates that in reality, this distinction should be replaced by gradual scale and the potential fuzziness of the boundaries should be considered. The table furthermore shows where to place two main modes of collaboration, i.e. non-equity and equity based collaboration. These are two main modes of collaboration that either lean more towards a market transaction or a hierarchy, which will be discussed in more detail at the end of this sub section.

Within the inter-organizational arrangements, as shown in Table 1, there are several possible modes of these co-operative arrangements. Before going into these possible modes, an issue that needs to be addressed is the definition of a collaboration, and the related terms. Principally, all co-operative inter-organizational arrangement can de denoted as collaborations. In this sense, the broad concept of collaboration is also referred to as, among others, 'alliance' (e.g. Bleeke and Ernst, 1993; Doz and Hamel, 1998; Narula and Hagedoorn, 1999; Kale, Singh and Perlmutter, 2000; Oxley and Sampson, 2004), 'co-operative agreement' or 'partnership' (Pisano, Russo and Teece, 1988; e.g. Contractor and Lorange, 1988a; Hagedoorn and Schakenraad, 1990; Aadne, *et al.*, 1996; Dyer and Singh, 1998; Hagedoorn, *et al.*, 2000; Hagedoorn, 2002), or 'network' (e.g. Osborn and Hagedoorn, 1997) although to a minor extent, that can be either bilateral or multi-lateral. In this study therefore collaboration is defined as 'an inter-organizational co-operative arrangement in which separate organizations pool their resources collaboratively in order to reach a mutually beneficial goal.' This collaborative arrangement can principally be bilateral with two collaborating partners or multi-lateral with more partners that collaborate, and embrace different time spans. And in this sense, inter-firm collaboration refers to the case in which only firms are involved.

When identifying different modes of collaboration, a useful dimension to create a range of modes is *organizational interdependence*. Relating this dimension to the main forms of co-operation in Table 1, it can be said that in a market transaction the transacting organizations remain totally independent whereas in the hierarchical form of co-operation a complete interdependence exists. In between, i.e. in inter-organizational arrangements, there is a certain degree of organizational interdependence. A dimension that, in this case, is parallel to organizational interdependence is the degree of internalization. Within the inter-firm arrangement, two broad groups of agreements can be distinguished in which one represents a higher degree of internalization (and interdependence) than the other (Narula and Hagedoorn, 1999). These two groups are equity and non-equity based agreements, respectively. A main representative of an equity agreement (which received considerable scholarly attention) is a joint venture, in which two or more organizations – typically firms –establish a new venture with shared ownership and input of resources. The non-equity agreements consist of, with increasing organizational interdependence:

- unilateral technology flows, e.g. patent licensing and know-how licensing (licensing in and out),
- bilateral technology flows, e.g. cross-licensing agreement,
- customer-supplier relations, e.g. R&D contract and co-production contract, and
- joint R&D agreements, e.g. research partnership and joint development agreement (Contractor and Lorange, 1988b; Mowery, Oxley and Silverman, 1998; Narula and Hagedoorn, 1999).

In addition to increasing interdependence and internalization, there are some other characteristics that increase with these agreements, e.g. duration, breath of contracts, intensity of interaction and contract incompleteness (Contractor and Ra, 2002).

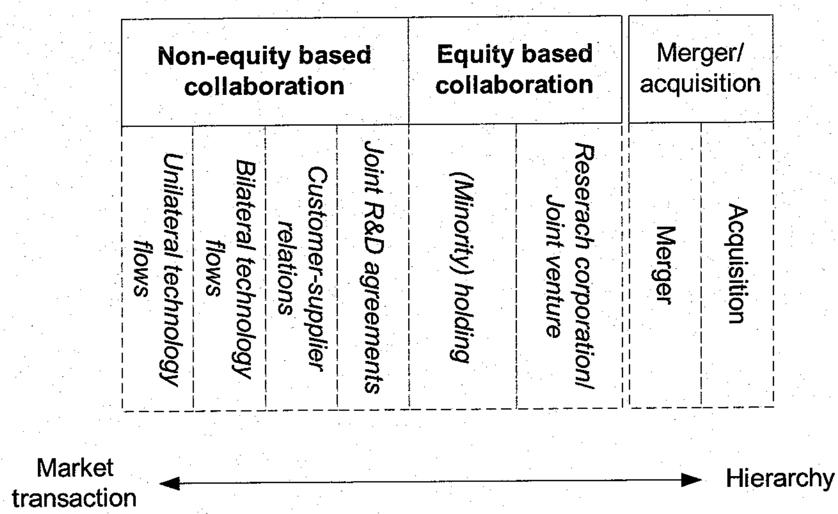


Figure 3. Modes of collaboration[5]

[5] Adapted from Contractor and Lorange (1988b), Mowery, Oxley and Silverman (1998), and Narula and Hagedoorn (1999).

Figure 3 shows an overview of the different modes of inter-firm collaboration. On the extreme right of the figure 'merger and acquisition' is given as a mode of collaboration. This mode involves the highest level of interdependence and internalization. Moreover, once the merger of acquisition has taken place, one could speak about a fully internalized entity, e.g. a wholly owned subsidiary. Although this is, in its pure form, not a form of collaboration, it is still taken into account in this figure because (a) the process of merging or acquiring entails a lot of collaboration and (b) it is an important alternative to the other forms of collaboration. On the other side of the spectrum, i.e. on the extreme left, non-equity agreements such as licensing are given. Although this is very close to a 'normal' market transaction, it can still be considered as an important mode of collaboration because it involves a significant amount of collaborative agreement and it requires a longer-term commitment. This is to a large extent due to the specific economic properties of knowledge, which is in the end the object of the license. In any case, the boundaries between different modes of collaboration – both at the extremes of the spectrum as well as in the middle – can be fuzzy.

An important issue in defining different forms of collaboration is its nature. An important distinction that can be made in this context is whether the nature of a collaboration is vertical or horizontal. This relates to the relation the different collaborating firms have towards each other. A vertical collaboration involves two or more partners that are in subsequent phases of their value chains whereas a horizontal collaboration involves partners that are active in the same phase, e.g. direct competitors. Put in the extreme case, in these two cases the partners' resources are either complementary or substitutive to each other, respectively. In order to see which possible collaborations could exist, the next sub section will elaborate on the value chain of firm and therefore on the potential relationship between possibly collaborating partners.

1.3.2 Value Chain of Firm Activities

Whereas the previous sub section discussed the different possible modes of collaboration, it is also important to consider on which level a collaboration – in whatever form – can take place. For this, the value chain of firm activities has to be examined.

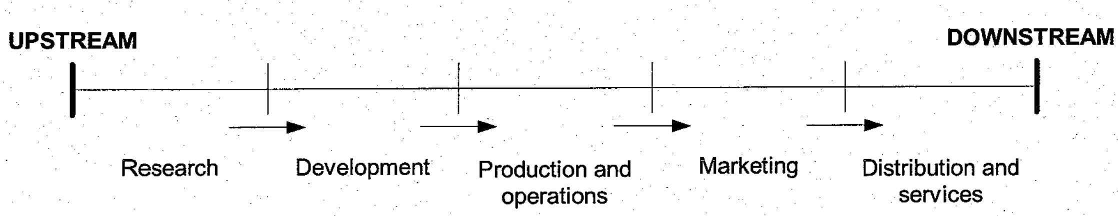


Figure 4. Value chain of firm activities

As shown in Figure 4, the activities that a firm conducts can be characterized by a flow from upstream to downstream activities. A single firm does not necessarily have to be involved in all activities and, moreover, a firm can conduct a certain phase together with another organization. In inter-firm collaboration, different possibilities relating to the activities in which firms collaborate are thinkable.

Firms could thus decide to collaborate at a certain point of the value chain. As said before, an important distinction that has to be made is whether the collaboration is horizontal or vertical.

The latter refers, for example, to the case in which a chemical firm wants to commercialize a new product they develop in collaboration with one of its customers. An example of the former is that several telecommunication firms (that can each other's competitors) collaboratively try to develop a new standard for mobile telephony.

This also relates to the life-cycle of a business that affects the propensity of a firm to go into a collaboration for every stage in the value chain. Figure 5 shows the changing objective of a firm's collaborations along the life-cycle of a business and shows the relation to the cash flow.

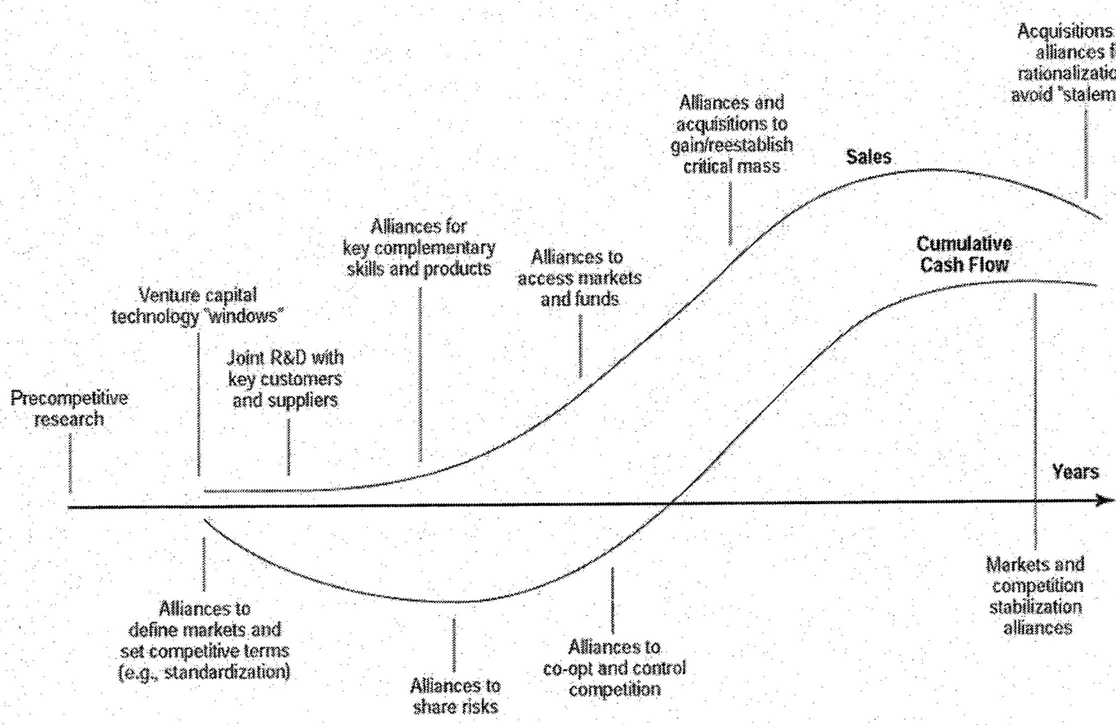


Figure 5. Typical partnership objectives along the life cycle of a business

Doz and Hamel (1998: 115)

Because of the importance to share knowledge in the present economy (see Section 1.2), which is also the focus of this study, this chain of firm activities can be translated into a 'knowledge development value chain'. In this value chain the downstream processes mainly consist of marketing and commercializing the knowledge. The upstream processes, i.e. research and development, are more related to exploration and exploitation of knowledge.

The terms and concepts of research and development have received (and still receive) a considerable amount of scholarly attention. It still remains to be a controversial issue to a certain extent. The fact that research and development usually is referred to with the term 'R&D' indicates that these two have a certain relationship. Although some scholars argue that research and development are part of a linear model in which research always precedes development, this view is strongly contested[6]. Some authors also emphasize the conceptual continuum between research

[6] In relation to this, the issues overlap those of the discussions about the relation between science and technology (see e.g. Rosenberg, 1994). Research is, for example, to a certain extant used connotated with science. The distinction between basic science (often seen as public knowledge), applied science (often seen in relation to technology and

and development (see Nelson, 1959). Furthermore, firms and scholars alike tend to see R&D as one concept, which can be derived from the terminology used by many managers and scholars. Therefore, this study will use the term R&D in a broad sense, with research as a systematic and methodical search for knowledge, and development as the application of knowledge and ideas to new industrial products and processes. However, in the industrial situation R&D mainly refers to the development part of it. And moreover, although managers and scholars often refer to the concept research and development as a whole, i.e. R&D, there is increasing recognition that a more detailed definition and use of the terms in necessary. One important implication is the distinction between the exploration and exploitation of knowledge, for example in relation to learning (e.g. March, 1991). In this sense, "exploration includes things captured by terms such as search, variation, risk taking, experimentation, play, flexibility, discovery, innovation" (March, 1991: 71) and "exploitation includes such things as refinement, choice, production, efficiency, selection, implementation, execution" (March, 1991: 71).

Exploration is said to have a high variety and to be distant from the firm existing knowledge base whereas exploitation has a limited variety and to be close to the firm's existing knowledge base (Schildt, Maula and Keil, 2003). Translating this to R&D collaborations, it means it has to be investigated to which extent the collaboration is focusing on research as a search for new knowledge in an explorative manner or on the application of this knowledge in order to exploit it. This study thus, to a large extent, relates research to exploration and development to exploitation. One important implication of this distinction is the relation to the technological distance between collaborating partners, e.g. firms. Because new knowledge is often created through the combination of existing knowledge items (Kogut and Zander, 1992), the knowledge bases should not be too distant in order to efficiently learn form each other and collaboratively create new knowledge. Therefore, the relationship between the collaboration parties will have to be taken into consideration, as well as the motives for the collaboration (i.e. explorative research or exploitative development). Furthermore, prior experience with a partner and/or their relationship could influence the outcomes for exploration or exploitation differently because of the importance if the (non-) redundancy of the collaboration (Vanhaverbeke, Beerkens and Duysters, 2003).

1.4 Research Problem

1.4.1 Relevance

On the one hand, there is a vast brand of literature developing on the collaborative sharing of knowledge. On the other hand, there is an established legal framework on how firms can protect their knowledge although there are still some major developments going on in this field (as will be discussed in Chapter 3). But, despite the present state of knowledge on these two separate fields, there is still significant work to be done to see how these fields can be combined. A recent academic contribution that acknowledges this, is McEvily, Eisenhardt and Prescott (2004), who state that "[s]ignificantly, less attention has been given to how firms can protect their technological competencies at the same time they collaborate with other organizations" (McEvily, *et al.*, 2004: 715). Combining these fields could increase the insight in how firms can cope with the tension field between the sharing and protection of knowledge in R&D collaborations. This, in turn, will lead to a better overall understanding of how firms function in collaborative efforts and how these collaborations can be effectively managed.

conducted for commercial purposes) and (commercial) development and production becomes apparent (see e.g. Stokes, 1997; European Commission, 1999; Organisation for Economic Co-operation and Development, 2002).

Therefore, one of the main contributions of this study is that it can help firms to better 'manage' their collaborations. As indicated, collaborations are growing in number and importance, and they have become of crucial importance for the success and survival of firms and industries. This trend has changed the overall strategies of firms. Whereas collaborations were previously seen as a *second-best* option (compared to mergers and acquisitions), it is now recognized they represent a *first-best* option[7] (Narula and Duysters, 2004).

The second main contribution relates to the fact that public policy makers have recognized the importance of collaborations and that (collaborative) research produces long-term economic and social benefits. Therefore collaboration among organizations has been promoted and public funding initiatives that incentive firms to collaborate have been established. This study can increase the insight that policy makers need in order to set up regulations and (formal) programs for firms that want to share – and of course protect – their knowledge, in order to support innovation and economic growth.

The third main point of relevance of this study is its contribution to the 'state-of-the-art' academic understanding on the field of R&D collaborations. As said before, this research will most specifically develop the insights in the sharing and protection of knowledge in collaborations, and thereby reveal the tension field between the two aspects as well as the mechanisms that are active in it. Furthermore, it gives a framework to look at this tension field that will show which strategies firms can use when they collaborate with other organizations while at the same time sharing and protecting their knowledge.

1.4.2 Research Goal

The motivation for this research refers to the acknowledged need for firms and scholars to get more insights on the processes related to the sharing and protection of knowledge. The above-mentioned developments that lead to an increased necessity to share knowledge and to collaborate with other organizations have given rise to the need to know more about how this exactly can be established. One of the main challenges for firms is to find out how this sharing of knowledge through collaborating can be established effectively while at the same time protecting its knowledge base. As mentioned above, this issue has not been addressed in academic research that explicitly yet. The goal of this study therefore is to explore and describe the tension field of the sharing and protection of knowledge in R&D collaborations, and more precisely to identify which dimensions are active in this tension field and how these are related. The ultimate objective is to develop a model that can be used to investigate what the exact tension field looks like and how it is influenced. Hereby firms can develop a strategy how to cope with this tension field by exploring which factors lead to certain outcomes. Therefore, this study tries to develop a framework that can be used to identify how firms can cope with this tension field. Additionally, it will be valuable to explore possible strategies for firms to copy with this tension field.

[7] "The increasing similarity of technologies across countries and cross-fertilisation of technology between sectors, coupled with the increasing costs and risks associated with innovation has led firms to consider R&D alliances as a first-best option in many instances." (Narula and Duysters, 2004: 199)

1.4.3 Research Questions

The central research question that accompanies the above-mentioned goal is the following:

What is the tension field of knowledge sharing and protection in R&D collaborations, and how can firms cope with this tension field?

In order to identify what can be said about the tension field, the separate fields have to be considered. Hence, one element is to investigate what is known about the sharing of knowledge in collaborations and a second element is to identify how knowledge can be protected in these collaborative efforts. Therefore, the following four sub research questions are posed:

(A) Which dimensions comprise the tension field of knowledge sharing and protection in R&D collaborations?

(B) Which dimensions can be identified with regard to a firm's knowledge sharing in R&D collaborations?

(C) Which dimensions can be identified with regard to the way a firm can protect its knowledge in R&D collaborations?

(D) Which strategies exist for firms to cope with the tension field of knowledge sharing and protection in R&D collaborations?

These questions will be addressed by investigating these issues taking both *endogenous* and *exogenous* (e.g. environmental) factors into consideration. Subsequently, the third element is to combine these fields by investigating their relationship, both theoretically and empirically. The fourth and final step is to explicitly identify the dimensions that comprise this tension field. This can be done by developing a model that shows these dimensions and their relations in the tension field. This can moreover help firms to develop and consider different strategies to share and protect the knowledge they put into a collaboration, which is an issue that will also be addressed in this study.

1.4.4 Delineation

As shown in Figure 3, there are several possible modes of collaboration. The increase of the establishment of collaboration has been especially apparent in the non-equity based agreements as shown in Table 2, and therefore the focus will be on this mode of collaborations. Moreover, the increase has been most specific for joint R&D. The significance of the growth of newly established R&D partnerships is also clearly illustrated by Figure 2. Furthermore, the capital-intensive and knowledge-intensive industries are associated with an important role for innovation and technological development (see Section 1.2.2), which has a clear relation with research and development. Therefore, this study will focus on (non-equity) R&D collaborations that in some cases are referred to as (joint) R&D partnerships or agreements, or technology or technological collaborations if they aim more generally at technological innovation[8]. Furthermore, the focus will

[8] Due to the fuzziness of the boundaries between the different modes of collaboration, one could point out the unit of this analysis by stating it is located at the right side of the non-equity based collaborations in Figure 3, i.e. 'joint R&D agreements' and to a lesser extent 'customer-supplier agreements'.

be mainly pre-competitive R&D collaborations (cf. Figure 5) that are active upstream of the value chain in Figure 4. Within this type of collaboration this study will focus on the role for large firms that participate in the collaboration. Therefore, the study will take the firm perspective in analyzing the relevant issues. Moreover, the starting point will be bilateral, or dyadic, collaborations. This means the tension field between the sharing and protection of knowledge will principally be discussed by taking a bilateral collaboration as main point of reference, as well as for the development of the framework, although in some cases a direct reference is made to collaborations with more than two partner (e.g. joint licensing; see Chapter 3). This does not necessarily mean this research and its framework cannot be used for multi-partner collaboration although these can become increasingly complex. In fact, because the increasing number of partners in R&D collaborations is one of the important trends (see Chapter 2), the multi-partner case will be taken into explicit consideration when analyzing R&D collaborations.

Therefore, the empirical investigation will consist of both bilateral as well as multi-partner collaborations. These two different kinds of collaboration are more or less representative for the sectors in which they are investigated, namely the chemical sector and information and communication sector, respectively. Firms from both sectors will be investigated in Sweden and in the Netherlands. Because of mainly practical considerations, this research will to a large extent investigate publicly subsidized collaborations because of the possibility to find and access them. This will also increase the likelihood of finding the people responsible and sufficient (publicly available) information. For this reason, the publicly accessible database[9] of the 'Framework Programmes' of the European Commission will be one way of finding suitable projects. This is mainly the case for the information and communication sector for which the publicly subsidized R&D collaborations actually become to play an increasingly important role[10].

Table 2. Evolutionary changes in the organizational modes used in STP[11] activity

	1980–1984	1985–1989	1990–1994
Equity STP	*46.9*	*40.9*	*26.7*
Joint ventures	21.9	23.7	19.7
Other equity SA	25.0	17.2	7.0
Non-equity STP	*53.1*	*59.1*	*73.3*
Joint R&D	38.0	47.5	70.4
Customer–supplier	10.1	8.2	2.7
Two-way technology	5.0	3.3	0.2
	100.0	100.0	100.0

Source: Narula and Hagedoorn (1999)

1.5 METHODOLOGY

Because this research addresses an issue that has been rather under-investigated, this study takes an explorative approach. In order to answer the central research question, different methods will be used to improve the insights in the tension field of knowledge sharing and protection. This research consists of three main elements of activity, namely a series of semi-structured explora-

9 This database can be accessed through the website www.cordis.lu.

10 Despite this increasing importance, the interviews (see Section 1.5) showed that a minority (approximately 5-15%) of all of the collaborations of the firms of interest is (partly) publicly subsidized. Although these kinds of collaborations have a significant amount of similar characteristics as non-subsidized, this is obviously a bias in this research. Though, the collaborations of interest for this study, i.e. R&D collaboration, will account for a higher percentage, meaning that a higher percentage of this kind of collaboration received public subsidies.

11 In this research the authors use STP as an abbreviation for Strategic Technology Partnering.

tory interviews, an in-depth literature survey and a series of case studies. Because of the (recent) relevance and the exploratory nature of this study, eight semi-structures interviews were conducted at an early stage of the study in order to identify some of the main trends and relevant issues (see Appendix A for more details). Table 3 gives a short overview of the firms, the functions (in the firm) of the interviewees as well as their base countries. Because this study focuses on firms from the Netherlands and Sweden, firms from each country were chosen (i.e. three from the Netherlands and five from Sweden). The selection criteria for these interviewees were the kind of firm they work at, the experience of the firm in R&D collaborations, their role in this firm, and their role in the R&D collaborations (or related issues). The eight interviews together constitute a group of firms with various characteristics and backgrounds, also in relation to R&D collaborations.

Table 3. Semi-structured interviews

Firm	Country	Function of interviewee
ASML	Netherlands	Project leader some of the R&D collaborations
Lionix	Netherlands	Technical director and co-founder; project leader of R&D collaboration
Philips	Netherlands	Corporate alliance manager
ABB	Sweden	Project leader of some of the collaborations with universities
Acreo	Sweden	Senior scientist; project leader of R&D collaboration
Eka Chemicals	Sweden	Intellectual property manager
Ericsson	Sweden	Responsible for consortium agreements in FP6[12] and other collaborations at the licensing and patent development department
Volvo	Sweden	Research coordinator

In addition to these semi-structured interviews, the two main research methods of this study are an extensive literature study and the use of in-depth case studies. The literature survey takes place over the full length of the study, to different extents. An important goal of this literature study is to find out what the boundaries of the tension field are. Therefore, the literature survey gives the relevant and necessary background knowledge on this field. Hereby, the state-of-the-art academic knowledge is revealed, and the gap in the literature can be identified. Furthermore, it shows some of the major trends in R&D collaborations in relation to the sharing and protection of knowledge. This will be reinforced by discussion with experts in the field and people from the industry (i.e. (informal) discussions with experts and the semi-structured interviews).

Thus, the literature study will reveal the main elements of the tension field of knowledge sharing and protection, and will furthermore give indications of the possible dimensions that are active in it. This exploration is further developed by conducting a number of eight in-depth case studies. These case studies facilitate the more explicit identification of the tension field and the active dimensions. Although the case study methodology will be described in more detail in Chapter 5, a brief overview will be given here. For these case studies, eight firms have been identified that in some way are involved in R&D collaborations. Of the eight firms, four are based in the Netherlands and four in Sweden. Each firm was chosen on the basis of its representation (e.g. of the sector and/or kind of collaboration) and accessibility, and for each firm one collaboration was chosen to investigate for the same reason. Although it was not necessarily identified explicitly in the firms, the main selection criterion for these case studies was that (advanced) experience exists on how firms can go about some of the aspects relating to the tension between knowledge sharing and protection in R&D collaborations. Chapter 5 will deal with the more detailed meth-

[12] Sixth Framework Programme of the European Commission.

odology and indicate what the exact considerations were to choose a specific firm and collaboration, as well as the exact characteristics of the firms and their collaborations. Table 4 shows an overview of the firms that were investigated as well as the specific collaboration[13]. In each case study the tension field was investigated by taking the viewpoint of the single firm. While conducting and analyzing the case studies – which is done by interview and investigating the (publicly *and* privately) available information – the findings are compared and to compare this with the findings thus far. This can make clear the validity of the framework of the tension field and appropriate mechanisms and develop it in more detail.

Table 4. In-depth case studies

Firm	Country	Subject of collaboration
Akzo-Nobel	Netherlands	Development new CD-R technology
KPN[14] (TNO)	Netherlands	Analysis of UMTS system-behavior and development of UMTS planning tools
Lionix	Netherlands	Provide integrated optic technologies for easy assembly and packaging
Philips	Netherlands	Development and implementation of personalized services for digital television
Array	Sweden	Development of Toner Jet printing technology for color application
Eka Chemicals	Sweden	Speciality Colloidal Silica applications
Ericsson	Sweden	Creation of network solutions for mobile and wireless systems beyond 3G
Telia	Sweden	Increase understanding of automated spoken dialogue technologies

1.6 Report Outline

This chapter has given an introduction to this study by providing the background for it, by mapping the field, and by explaining and defining the research problem and methodology. The remainder of the report is structured as follows.

The next chapter will address one element of the tension field, namely the sharing in collaborations. It will therefore address and answer the first sub question as given in Section 1.4.3. It will give the theoretical perspectives that explain the existence of collaborations from which the relevant dimensions for the tension field can be identified. It will also give an overview of the main trends in knowledge sharing by collaboration that can be useful to identify the most relevant issues. It will furthermore elaborate on the limits that the competition law puts on collaborative knowledge sharing.

The third chapter of this report will address the second element of the tension field, which is the protection of knowledge in collaborations (i.e. the second sub question). It will go into the rationale for knowledge protection by investigating the specific properties of knowledge. It will also give a brief overview of what our society has thus far developed in order to address the need for knowledge protection. It will make clear that the embodiment of knowledge, as being an intellectual property, is an important aspect. In order to address this issue in more detail, an intellectual property framework is provided as well as possible intellectual property strategies. Because the protection of (shared) knowledge in R&D collaborations is subject to agreements, different licensing schemes are given. These can also be helpful in explaining how firms can cope with the tension field.

Chapter 4 subsequently identifies the tension field by integrating the findings from the previous two chapters. Consequently, the dimensions that are active in the tension field are identified,

[13] A more detailed overview of the case studies and the conducted interviews can be found in Chapter 5 and Appendix B.
[14] Due to changes in organizational structures the investigated collaboration was taken over from KPN Research by TNO Telecom.

and a model is given that shows these dimensions and their relations in the tension field. Finally, Chapter 4 elaborates on which strategies firms can use to cope with the tension field of knowledge sharing and protection and develops propositions for some main strategies. The fifth chapter gives an overview of the case studies that were used to identify the exact tension field and coping strategies. It will give the case study methodology and the findings for every separate case. Furthermore, it will compare the findings of the different case studies and moreover the findings will be discussed by reconsidering the literature. The conclusions finally revisit the main research question. Furthermore, it discusses the main findings and gives indications for further research.

2 Sharing Knowledge in Collaborations

2.1 Introduction

As the previous chapter already describes, the sharing of knowledge through collaboration plays an (increasingly) important role in the present knowledge-based economy. Furthermore, it has attracted a significant amount of attention of scholars that try to identify the rationales, critical issues, outcomes, and so forth. The issue of collaboration also became an explicit part of the more traditional theories. Among other things and to different extents, these theories describe why firms exist, how they achieve competitive advantage, and what their resource bases entail. The main theoretical perspectives are surveyed in this chapter in order to find out which dimensions (of the tension field of knowledge sharing and protection) can be identified with regard to a firm's knowledge sharing in collaborations. This chapter furthermore provides a general framework for investigating collaborations because it gives more insight in the rationales, elements and implications for collaborations. Additionally, this chapter reveals some of the main trends that are related to knowledge sharing in collaborations. This helps to identify relevant aspects that need more detailed investigation and gives an even better idea of why this research is of importance. More specifically this means that these trends have to be taken into consideration in the design of the case studies (see Chapter 5). After the theoretical perspectives are given, the main dimensions with regard to collaborative knowledge sharing that can be derives from these theories are identified. These are used to identify the dimensions that comprise the tension field in relation to a firm's knowledge sharing. Additionally, this chapter indicates some of the limits to knowledge sharing by collaborating in relation to competition law considerations. Finally, by taking all the above issues into consideration, the second sub research question (question B in Section 1.4.3) is answered by giving an overview of which dimensions can be identified with regard to a firm's knowledge sharing in collaborations (and R&D collaboration in particular) and by discussing these outcomes and the implications for the remainder of the study.

2.2 Trends

Whereas some of the major trends in our economy were already discussed in Section 1.2, this section focuses on the specific trends that are apparent in collaborations in general and the knowledge sharing aspect of it in particular. As stated before the main (global) developments gave rise to an increasing importance for firms to share knowledge among each other. An important way in which this can be established is by setting up collaborations of some sort (see Section 1.3.1). Therefore, one of the main trends clearly is the increasing number of collaborations itself. Some studies that pointed out this trend are mentioned in Section 1.2.1. Especially the growth of non-equity agreements and joint R&D collaborations has been significant (e.g. Narula and Hagedoorn, 1999; Hagedoorn, 2002); Figure 2 and Table 2 give clear illustrations of this. It has even been indicated that we have entered an era of 'alliance capitalism' (e.g. Gerlach, 1992; Narula and Duysters, 2004).

Within these more general trends of collaborative activity, some important trends can furthermore be recognized. Gulati and Singh (1998) for example note that the growth of inter-firm collaborations has been characterized by increasing diversity of the collaborations, in relation to the nationalities of the partners, their motives and goals and the formal structures that they use in the collaborations. It is clear that the present economy is highly globalized and globalizing, also reflected in R&D collaborations that are becoming increasingly international. On the one hand, this is due to the diversification of firms that set up businesses and new business units in an increasing number of countries. Multi-national firms in fact own a large part of the world's technology. On the other hand, R&D is internationalizing, thus creating the need for firms to collaborate across borders. Moreover, because of the increasing complexity of knowledge, more partners and different kinds of partners are often necessary to achieve a certain (research and/or development) goal. Therefore, another trend is the increasing number of partners participating in an R&D collaboration. Furthermore, firms have to collaborate with a broad range of different partners, causing an increasing trend in cross-sector collaboration, university (and public research organizations) involvement, as well as collaborations with competitors. It is even getting more common that these different kinds of partners are all part of one (large) collaboration. This is among others reflected in the public funding initiatives that increase both in number and in importance. In addition to several national subsidizing programs, the European Commission set up several generations of 'Framework Programmes'[15]. These programs were set up to promote industrial competitiveness and to strengthen Europe's science and technology base, with a traditional strong focus on the information technology industry. On a more general level, the interest in R&D collaborations from a public policy point of view increased, which is again related to the increasing importance of the network-based society.

2.3 THEORETICAL PERSPECTIVES

2.3.1 Introduction

For several decades scholars have acknowledged the increasing importance of collaborative efforts among firms. Explanations on different levels, e.g. motives, formation processes or outcomes, are still being developed. Different streams of literature have given collaborations a significant position in their views, although from a different perspective. The traditional approach that analyses the boundaries between the market and the firm, and hereby sees collaboration as an 'intermediate' or 'hybrid' organization form, is transaction cost economics[16]. Other approaches, which investigate the firm by examining the tasks of motivation and coordination, e.g. of a firm's resources, are more oriented towards strategic management. Dependent on their exact focus, these approaches consider the coordination and integration of a firm's physical and/or intangible assets.

Although several streams of literature investigate collaborative efforts, two main streams of literature have traditionally been used to explain the existence of collaborations, namely the *transaction cost theory* and the *resource-based view*. These two theories are the basis for many investigations on collaborative efforts (e.g. Kogut, 1988; Das and Teng, 2000; Hagedoorn, *et al.*, 2000; Tsang, 2000) and respectively represent the economic organizational theories and the strategic management theories, to a certain extent.

[15] The roots of these Framework Programmes' (FPs) go back to the 1980s with the establishment of the First Framework Programme (FP1) in 1983, following the successful program ESPRIT in 1983. ESPRIT stands for European Strategic Programme for Research and Information Technology. The Framework Programmes that followed on ESPRIT were successively FP1 (1984-1987), FP2 (1987-1991), FP3 (1990-1994), FP4 (1994-1998), FP5 (1998-2002), and FP6 (2002-2006).

[16] To give a more complete picture, there is the brand of organizational behavior theory that, in contrast to transaction cost economics which is an organizational economic theory, focuses on features of human behavior and interaction of people in organizations (Foss, Husted, Michailova and Pedersen, 2003). Because this behavioral approach sees the ways people behave in organizations and the impact organizations have on people's behavior as two sides of organizational behavior, it is less relevant for this analysis.

In addition to the resource-based view, some related views have been developed. These latter views can be considered as highly relevant to explain the phenomenon of R&D collaboration (as becomes clear in the remainder of this section), although this relation received only marginal attention in the literature. Though, a remark should be made that these related views, by nature, *do* take the existence of collaborations into account. One of the main views that applies the resource-based logic to explain firm activities is the *dynamic capabilities approach* – which is an attempt to make the resource-based view more dynamic, i.e. evolutionary and capability-based. This means it investigates firm dynamics, i.e. the relevant processes in a changing environment.

Two other distinctive approaches that use the resource-based logic are the *knowledge-based view* and the *technology-based view*, in which the technology-based view can be seen as a specific kind of knowledge-based view. These two approaches can be grouped under the heading *intellectual capital approach*. The knowledge-based view, on the one hand, considers knowledge as being the main (intellectual) asset that defines a firm. It sees the coordination and integration of individuals' knowledge – or human capital that is part of a firm's intellectual capital – as the main process that creates value within the firm. In addition, it can be used to explain the existence of R&D collaborations, as a means to integrate external and internal knowledge in order to establish a knowledge creating process. On the other hand, the technology-based view is more specific and sees the technology-based firm as a particular kind of firm, which relies on its intellectual capital based resources. These intellectual (or immaterial) resources have specific characteristics in contrast to other resources, i.e. physical and financial resources. A firm can adopt different strategies to acquire and exploit its technology base, as well as its entire resource base. R&D collaboration is one of these strategies. Figure 6 gives an overview of these different kinds of theories, which in some way deal with collaborations, as well as their (general) relations.

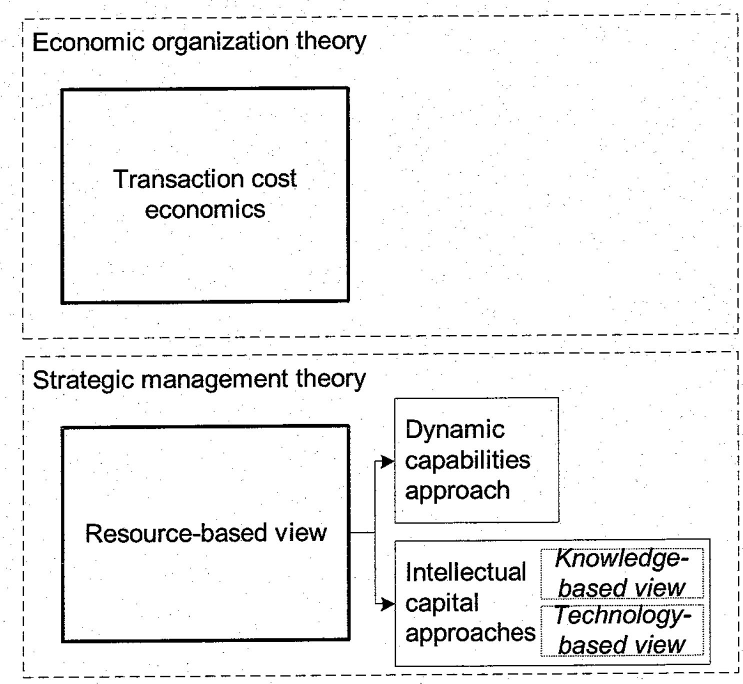


Figure 6. Selected theories on collaboration

The following part of this section subsequently deals with the different theoretical streams of literature. In each of these sub sections, first a reference is made to the origin of the approach, also placing it in a broader perspective. Then some of the basic elements of the theories are explained, and finally their explanations for collaborations among firms (or organizations in general) are given. A summary of these elements is given in Section 2.3.6 in Table 5. As indicated by the literature (e.g. Kogut, 1988; Hagedoorn, *et al.*, 2000) the different existing views are related to a certain extent. Therefore, the subsequent part of this chapter (in Section 2.4) revisits the different theories and it identifies which dimensions in the field of knowledge sharing that can be identified put forward. Hereby, a comprehensive explanation of firms' knowledge sharing in collaborations can be given. Therefore, one of the main contributions of this study is that it considers the different theories and partly integrates them to investigate how they contribute to the insights in R&D collaborations, which in turn contributes to the 'theory of collaborations'.

2.3.2 Transaction Cost Economics

The transaction cost theory, of which the roots go back to Coase (1937) and Williamson (1975b; 1985), is part of the New Institutional Economics that expands neo-classical economic theories by incorporating property rights and transaction costs into neo-classical economics to explain economic behavior. It tries to explain why firms organize their activities in a certain way. The main concepts – also of the New Institutional Economics in general – involve a focus on the economic effects of institutions, with rational decision-making that is not complete and based on non-costless available information, and with actors that can act opportunistically.

The basic thought of the transaction cost theory is that firms decide how to transact by trying to minimize the sum of production and transaction costs. Transaction costs consist of costs for searching, negotiation, monitoring and enforcement. Transaction costs are, on the one hand, influenced by human factors and by environmental factors, on the other hand. As noted above, actors' decision-making is not complete. Therefore, although actors act intentionally rational, decisions are made on the basis of limited rational capabilities. Consequently, information will be incompletely gathered, processed and transferred. This concept is called 'bounded rationality' and can be described as follows: "the capacity of the human mind for formulating and solving complex problems is very small compared with the size of the problems whose solution is required for objectively rational behavior in the real world" (Williamson, 1975b: 9). Bounded rationality is only relevant if the capacity of the human mind does not match the complexity or uncertainty of the situation. The main kind of uncertainty[17] is 'behavioral uncertainty' that relates to the deliberate misleading actions of economic actors (Williamson, 1985). In increasingly insecure and complex settings, the role of bounded rationality becomes more apparent.

Another human factor, attributable to behavioral uncertainty, is 'opportunism', which can be described as "seeking self-interest with guile" (Williamson, 1975b: 26). Economic actors can – they do not necessarily do so – provide incomplete or wrong information, or give false promises in order to realize a certain individual advantage. The degree of opportunism – if present at all – is not known ex ante, creating a possible need for more complete contracts that deal with potential opportunistic behavior. This is obviously directly related to increasing transaction costs. Op-

[17] In addition to behavioral uncertainty, one can distinct 'primary' and 'secondary' uncertainty, as described by Koopmans (1957) with primary uncertainty arising from random acts of nature and unpredictable changes in concurrent preferences and secondary uncertainty arising from a lack of communication between decision makers and others on whose plans and decisions he bases his decision (Teece, 2000). Williamson's behavioral uncertainty most specifically relates to the concept of secondary uncertainty.

portunism is especially relevant in the case of 'small numbers', which relates to the situation in which a firm can only transact with of small number of others. If this is not the case, opportunism will not have any effect because firms can choose a variety of others to transact with.

The basic dichotomy given by transaction cost economics was the one of transacting through hierarchy or through the market (Williamson, 1975b). In other words, in this dichotomy, firms will expand up to the point where the costs of an additional transaction though the hierarchy equal the costs of that transaction carried out through the market mechanism. However, instead of this dichotomy of firms and markets, transaction cost economists started to consider a continuum of mechanisms to govern transactions, with the market and the organization on each end of the spectrum. Relational contracting is one of the possible mechanisms in between the two ends and is seen as an important economic institution, which is a more efficient governance structure when transactions are costly, complex and difficult to specify (Williamson, 1985). Therefore, cooperation among firms has become an important alternative form of organizing or governing transactions (Williamson, 1996). The choice for a certain governance structure will be determined by asset specificity, frequency and uncertainty. For example, if a firm more frequently transact with another firm, collaboration can create more efficient transactions.

An appropriate governance mechanism will economize on bounded rationality and safeguard transactions against the hazards of opportunism (Williamson, 1991b). Technology collaborations can cope with a high degree of asset specificity that can cause high switching costs and, more importantly, they can create a lower uncertainty over specifying and monitoring the performance of the other partner (Kogut, 1988). Collaboration can therefore make firms more flexible and better able to control their transactions. Because of the closer relation that firms have with the collaborating partner, they are able to build better, more suitable contracts with the possibility to monitor each other. Though, contracts are often still incomplete, due to the difficulty to fully specify the contribution of each partner and to specify intangible assets, e.g. technical knowledge (Das and Teng, 2000; Hagedoorn, *et al.*, 2000). Furthermore, if firms transact with a small numbers of others, this can create a situation in which firms are locked-in. And in this case, when they can only choose from a limited number of others, collaborative strategies can be beneficial to cope with restraints that arise from this locked-in situation. More specifically, in this case, collaboration prevents opportunistic behavior.

Taking all of this into account, the commitment of resources can make the collaboration mutually beneficial (Hagedoorn, *et al.*, 2000). The mutual contribution of efforts and assets can even create a *mutual hostage situation*[18] (e.g. Kogut, 1988), which can balance out the contributions and lower opportunistic behavior. Furthermore, technological knowledge is subject to positive externalities and spillovers[19] (Kogut, 1988; Granstrand and Lindmark, 2002). The hybrid organization form of collaboration could internalize these externalities or spillovers. This is especially the case for R&D investments because the above-mentioned externalities have a negative influence on the incentive for individual firms to invest in R&D which will lead to market failure (Granstrand and Lindmark, 2002). Therefore, R&D collaborations can be seen as a possible means to prevent market failure, i.e. in the case of R&D investments.

---

[18] By a mutual hostage situation, Kogut (1988) refers to the situation in which the collaborating partners both gain or lose by the performance of the collaboration.

[19] Granstrand and Lindmark (2002) distinguish pecuniary (market) externalities, knowledge spillovers and network externalities.

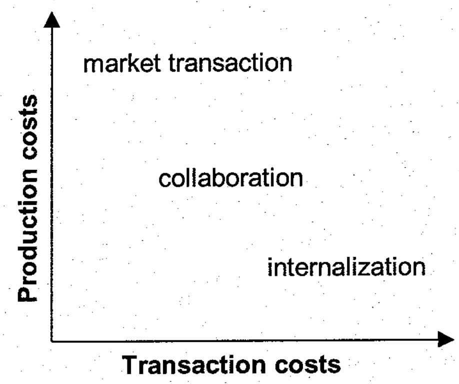


Figure 7. Most appropriate governance mechanism

In sum, a firm will minimize the sum of production and transaction costs. In this, production costs mainly consist of coordination costs. Transaction costs are determined by asset specificity, uncertainty, frequency, and costs for controlling opportunistic behavior. These costs will determine which governance mechanism an economic actor will choose, as shown in Figure 7. Internalization (e.g. internal development, or mergers and acquisitions) can effectively control the costs of economic exchange, i.e. writing and enforcing contracts. Therefore, this will be the preferred governance mechanism in the case of high transaction costs. A transaction through the market, on the other hand, will involve significant costs to control the economic exchange, i.e. high transaction costs. But because no internal development, and therefore coordination, is necessary, production costs can be avoided. Therefore, in the case of high production costs and low transaction costs a market transaction will be the preferred governance mechanism. A third form of governance mechanism is a collaboration of some sort, which lies in between the market transaction and full internalization, and is often referred to as a 'hybrid' or 'intermediate' governance mechanism. One could say that collaboration partly internalizes the economic exchange and that contracts are still used to control the exchange, although a certain degree of joint coordination remains needed because the contracts are often incomplete. Therefore, collaboration can be the preferred governance mechanism in the case of intermediate transaction and production costs.

Concluding, the transaction cost view gives a good insight if one wants to give collaborative organization forms a place in the 'market-hierarchy spectrum' with the obvious determinant of transaction (and production) cost minimizing as main rationale to collaborate, among the other possible governance modes. Though, it is argued that it explains little about the motives for collaboration related to capability building and learning (Dodgson, 1993).

2.3.3 Resource-Based View

In contrast to the transaction cost theory, of which the roots appear to be rather well identifiable with Williamson (1975a; 1975b; 1981; 1985; 1991b; 1996; 1999) rediscovering Coase's (1937) work, the development of the resource-based view seems to be more complicated. One important reason for this is the fact that the resource-based view offers a logic that gave rise to several related streams of literature. This section therefore first deals with the origin and development of the resource-based view and consequently, in the following sub sections, discusses the important views it gave rise to. All of this is done by starting from a more general point of view and then focusing on the relevance for collaborations.

The basis for the resource-based view can be clearly identified with Penrose (1959) who sees a firm as a administrative organization with a collection of productive resources that ultimately determine the growth of the firm. She conceptualizes firms as bundles of resources and services, of which the organization and application causes firms to be heterogeneous. The growth of the firm is related to diversification and is path-dependency. The resource-based view, which builds on Penrose's work, further develops the idea that firms diversify and try to outperform other firms. It has been growing in popularity and emerged in the mid-1980s with the work of Rumelt (1984), Wernerfelt (1984) and Barney (1986). The key ideas are that firms are essentially heterogeneous in terms of underlying resources, that these resources can be anything that could create an advantage for a firm, and that the resource differences – that are relatively stable – cause performance differences.

Two key contributors to the resource-based view are Barney (1991) and Peteraf (1993), who analyze how sustained competitive advantage can be obtained. According to Barney (1991) this is the case when a firm is able to implement a value creating strategy other than its competitors who are also not able to duplicate the benefits of this strategy. For this, the underlying resources have to be (a) valuable, (b) rare and (c) imperfectly imitable, and (d) there should not be strategically equivalent substitutes. According to Peteraf (1993) the conditions that underlie a sustained competitive advantage are (a) efficiency differences that create superior resources (i.e. heterogeneity within an industry), (b) difficulties in imitating these resource-bundles (i.e. ex post limits to competition), (c) mobility of resources that is imperfect, and (d) limited competition for the potential superior position.

Continuing on the resource-based logic, a firm has to develop its resource base in order to obtain sustained competitive advantage. Access to external complementary resources can be necessary to achieve this sustained competitive advantage (Teece, 1986). Therefore, collaboration takes a natural and important place in a firm's exploitation and development of resources.

The resource-based view can be used for insights in the motives for collaboration and in partner selection. For the latter, absorptive capacity (Dyer and Singh, 1998; Mowery, *et al.*, 1998) and bridging the gap between existing and desired capabilities in a short time frame (Kogut, 1988) seem to be essential. Regarding motives to collaborate, the main ones seem to be to exploit economies of scale, to gain low cost entry into new markets, to learn from competitors, to strategically manage uncertainty, to manage costs and risks, and to facilitate tacit collusion (Barney and Hesterly, 1996).

The primary economic incentive for collaboration is said to be exploiting resource complementarities (Barney and Hesterly, 1996). This again relates to Penrose (1959) who assumed that firms tend to expand whenever profitable opportunities exist. In this context the exploitation of ones resource base to achieve competitive advantage takes place by accessing and transferring knowledge from one firm to another, in this case through R&D collaboration. This point is emphasized by Das and Teng (2000: 37) who state that "the overall rationale for entering into a strategic alliance [according to the resource-based view] is fairly simple. It is to aggregate, share, or exchange valuable resources with other firms when these resources cannot be efficiently obtained through exchanges or mergers/acquisitions."

As noted above, the resource-based view gave rise to several other views. If one, for example, takes the point of view that a firm has to manage its resources rationally, the development of a firm's resources can be a main reason for collaboration. Taking this viewpoint, a rather distinct view has been developed that goes beyond the traditional resource-based view, namely the 'core competences' approach (Prahalad and Hamel, 1990). This approach considers which resources a firm should acquire and which ones it should dispose in order to create an optimal resource portfolio. In this approach, collaboration takes a similar place as in the resource-based view although more emphasis is put at the actual core competences.

Another distinctive approach, which has received considerable attention and created an entire view on its own, is the 'dynamic capabilities' approach. Because of its importance and relevance, this view will be discussed in the next section.

2.3.4 Dynamic Capabilities Approach

The dynamic capabilities approach has its foundations in (and thereby tries to integrate) the resource-based view and evolutionary economics[20]. Therefore, it attempts to give a more dynamic view on a firm's resources. This view focuses on how firms can accumulate and deploy both internal and external resources in their changing environment. The main representatives of this view are Teece and Pisano (1994), Teece, Pisano and Shuen (1997), and some have further developed or reconceptualized (some elements of) the view, e.g. Eisenhardt and Martin (2000), Zollo and Winter (2002) and Winter (2003).

Dynamic capabilities are defined as "the firm's ability to integrate, build and reconfigure internal and external competences to address rapidly changing environments" (Teece, *et al.*, 1997: 516). Although the external link essentially refers to possible imitation by other firms, collaboration takes a natural place in this approach. Due to the complex and tacit nature (see Section 2.4 and also Chapter 4) of a firm's competences and capabilities, replication by other is impossible, which creates a source of competitive advantage. The three classes of factors that jointly form and shape a firm's competences and dynamic capabilities are *positions*, *processes* and *paths* (Teece, *et al.*, 1997). The positions consist of a variety of assets (cf. resources in resource-based view); the processes entail static, dynamic and transformational concepts; and finally, a firm's current position is a function of the path it traveled. This path dependency has important implications in industries with increasing returns to adoption (Teece, *et al.*, 1997). This means that firms are dependent on the path that lies behind them and that they have to act in a world with positive feedback (Arthur, 1994). This refers, for example, to the case in which different technologies are competing for dominance. In this case it is important to allocate dynamic capabilities in such a way that a firm is able to take part in the development of this technology. On a more general level, increasing returns imply that a firm's (or industry's) decisions will determine the opportunities and constraints in the future. This all means that firms have to choose such a strategy that enables them to achieve a competitive advantage.

Thus, the firm-specific asset positions and evolutionary paths shape the firm's managerial and organization processes, i.e. dynamic capabilities, that determine its competitive advantage (Teece, *et al.*, 1997). A firm has to develop its capabilities in a changing environment by exploiting external firm-specific competences, among others. It can access these competences from other firms that are all heterogeneous. Therefore, (R&D) collaboration can develop a firm competences and capabilities and thus enhance its competitive advantage.

[20] The evolutionary economists (e.g. Cyert and March, 1963; e.g. Nelson and Winter, 1982), following Schumpeter (1934), consider economic development as being an evolutionary process, in contrast to economists that use equilibrium models.

2.3.5 Intellectual Capital / Knowledge-Based Approaches

Intellectual Capital

In relation to the above-discussed views, some other distinct approaches have been developed. As shown in the previous part of this section, the view that sees the firm as resource-based caused development of its own and other approaches. This can be considered logical because a firm's resources can entail a wide variety of different kinds of assets. Moreover, approaches can differ widely when looking at the same set of resources. The development of the dynamic capabilities approach is perhaps the most illustrative example. But in addition, some other views that were developed consider just a part of a firm's resource. Or maybe better, these views consider just a specific type of firms, with specific characteristics, i.e. with a specific kind of resources. This sub section discusses two approaches that use this logic, namely the knowledge-based view – with a main representative being Grant (1996) – and the technology-based view – with a main representative being Granstrand (2000). Because these views acknowledge the importance of intellectual capital and therefore derive from this, these can be put under the heading of *intellectual capital approaches*. Intellectual capital received increasingly more attention from both the Academia and industry, and furthermore became a more important concept in our economy. This concept is also highly relevant in the case of high-technology industries and is therefore applicable to the setting of R&D or technological collaborations in this study. Without going into too many details on what intellectual capital exactly entails[21], it is clear that it comprises intangible or immaterial resources, such as knowledge, skills, relationships and intellectual property. It exists in addition to physical and financial capital, and consists of (a) human capital, (b) (internal and external) relational capital, and (c) capital embedded in organizational structures.

The literature on intellectual capital emerged at the beginning of the 1990s, with some of its pioneering research being by Edvinsson (1997), Edvinsson and Malone (1997) and Sveiby (1997a; 1997b). The literature on knowledge management and intellectual capital suggests that competitive advantage flows from the creation, ownership, protection and use of certain intangible or knowledge-based organizational resources. Two fields that are therefore close to intellectual capital are knowledge management (see e.g. Nonaka and Takeuchi, 1995) and organizational learning (see e.g. Levitt and March, 1988; Huber, 1991). Learning can be considered as the dynamic concept of the above-mentioned 'processes' (see dynamic capabilities approach in Section 2.3.4) and is again related to the view that acquisition, sharing and transfer of knowledge is at the heart of a firm's business (Dodgson, 1991; Kogut and Zander, 1992; Grant, 1996) and that learning plays an important role in this, also in collaborations in particular (Kogut, 1988; Hamel, Doz and Prahalad, 1989; Hamel, 1991).

Knowledge-based view

The emergence of the knowledge-based economy had different consequences, such as digitalization, virtualization, and the role of networks and services. In relation to the knowledge-based view of the firm, it is important that the focus shifted from tangibles to intangibles (cf. intellectual capital) and that knowledge became a significant factor of production (Grant, 2002).

When discussing the fundaments of the knowledge-based view, Grant (2002: 135-136) gives the following assumptions and observations concerning the nature of knowledge and its part in production. (a) Knowledge is the overwhelmingly important productive resource (Machlup, 1980;

[21] See, for example, Roos *et al.* (1997), Granstrand (2000), Sullivan (2000), and Choo and Bontis (2002) for a more comprehensive overview of the concept of intellectual capital.

Grant, 1996). (b) Different types of knowledge vary in their transferability. Explicit knowledge can be articulated and easily communicated between individuals and organizations. Tacit knowledge (skills, know-how, and contextual knowledge) is manifest only in its application – transferring it from one individual to another is costly and slow (Kogut and Zander, 1992; Nonaka, 1994). (c) Knowledge is subject to economies of scale and scope. A characteristic of all knowledge is that its initial creation is more costly than its subsequent replication. This, together with the complementarity of different types of knowledge, implies increasing returns in knowledge-intensive industries. Non-specific knowledge furthermore leads to economies of scope. The economies of scale and scope are especially great for explicit knowledge, information in particular (Shapiro and Varian, 1999). (d) Knowledge is created by human beings, and to efficiently create and store knowledge, individuals need to specialize (Simon, 1991). (e) Producing a good or service typically requires the application of different types of knowledge (Kogut and Zander, 1992). Subsequently, Grant (2002) acknowledges that these assumptions lead to the distinction between activities that are concerned with increasing the stock of knowledge, i.e. 'exploration' (March, 1991), and those that deploy knowledge in order to produce goods and services, i.e. 'exploitation' (March, 1991). More particularly, as explained in Section 1.2.2, this distinction also has important implications for R&D collaborations (between knowledge-based firms), e.g. for the relation between the collaborating partners.

In any case, taking knowledge as the main competitive resource or asset has important implications. By definition, firms are superior in the integration of knowledge. As discussed before, the exchange of knowledge through the market mechanism is involved with transaction costs. Furthermore, the 'disclosure dilemma', which relates to the difficulty of concluding contracts without first revealing the involved knowledge (see section 1.2.2), gives problems in market transactions for explicit knowledge. The exchange of tacit knowledge, on the other hand, also has problems because is cannot be readily transferred and integrated. R&D collaborations take an intermediate position. Trust between the collaborating partners can give the solution to the disclosure dilemma by limiting opportunism. Furthermore, collaborations can establish certain routines that facilitate knowledge integration and the transfer of tacit knowledge, although firms (i.e. hierarchies) are generally more efficient in this. Inter-organizational collaboration can be superior to the hierarchical firm especially as the range and diversity of knowledge increases (Grant, 2002).

Technology-based view

The technology-based view puts more focus on the technology base as a part of a firm's resource base. Intellectual capital is part of this resource base and the technology base is an even more specific part of it. Granstrand (2000) subdivides intellectual capital in (a) embodied capital, i.e. human competences, (b) relational capital, which includes organizational embedded structures, and (c) disembodied intellectual capital, i.e. intellectual property. A firm acquires, combines and exploits its resource base in general as well as its specific technology base. This technology base represents a firm's technological competence and the firm develops acquisition and exploitation strategies for it (Granstrand, 2004c). The technology-based view is highly relevant in high-technology industries, in which R&D collaborations are increasingly important. In this perspective it can also be explained why firms, to deal with market uncertainties, have to externalize their technology sourcing (Granstrand and Sjölander, 1990), giving R&D collaborations a logical place in a firm's strategy. And because the technology base of companies became more diversified in recent years there is an increased need for external sourcing and partnerships (Granstrand and Lindmark, 2002).

The technology-based view considers technology as being a special kind of knowledge, with the following attributes: technology has a link to (physical) artifacts and to science, it has a relatively high degree of explicitness (although tacit knowledge remains an important asset), it has a 'practical purpose' with possible performance measures, and it is embedded in a global system of operationalization and assessment (Granstrand, 2000). Furthermore, coming back to the disembodied intellectual property, it is possible to protect technology by patents. Because of this approach – i.e. the acknowledgement of the special characteristics of technology as a specific kind of knowledge, and of R&D collaborations as part of a (technology-based) firm's acquisition and exploitation strategies – is can be highly relevant to use its reflections as a specific element of the considerations that have to be made if firms share (and protect) their knowledge when they participate in R&D collaborations.

2.3.6 Overview

Table 5 gives an overview of the contribution of the different theoretical perspectives that have been discussed in the sub sections above. Starting with the transaction cost theory, it is clear that this approach takes the perspective of the transaction that takes the form of a contractual agreement. This transaction involves costs and accordingly firms, as economic actors, will choose an appropriate governance mechanism to organize their activities and go into transactions, either internally or externally. One of these governance modes is collaboration. When focusing on the collaboration itself, the concept of transaction costs is a relevant one to monitor the agreements that are made in this collaboration. The aspects asset specificity, uncertainty, frequency, bounded rationality and opportunistic behavior are therefore important ones to keep in mind when setting up collaborative knowledge sharing.

The other approaches could be summarized under the heading of strategic management. This field is concerned with understanding the forces and causes that explain performance differences between organizations. The discussed approaches to a large extent focus on internal resources and capabilities as sources of sustained competitive advantage. This mainly applies to the resource-based view and dynamic capabilities approach. The knowledge-based and technology-based views (under the mutual heading of intellectual capital approaches), on the other hand, consider the firm as a repository of respectively knowledge-based and technology-based resources and capabilities. These resources can give a sustained competitive advantage because they are unique, rare and difficult-to-imitate. All in all, these strategic management approaches present the firm as a bundle of resources and/or capabilities and, in general, they consider R&D collaboration as a means of acquiring and exploiting those.

Table 5. Overview of the contribution of theoretical perspectives

Theoretical perspective	Origin of the theory, i.e. main question	Basic element(s), i.e. main answer(s)	Main explanations/ implications for collaboration
Transaction cost economics (TCE)	How can firms organize their activities?	The preferred governance mechanism is determined by the minimization of production and transaction costs, which depend on asset specificity, uncertainty, frequency and costs for controlling opportunistic behavior.	Collaboration is the preferred governance mechanism in the case of medium production and transaction costs.
Resource-based view (RBV)	Why do some firms outperform others?	A firm's difficult-to-imitate resources determine its competitive advantage.	Collaboration can be used to exploit resource complementarities.
Synamic capabilities approach (DCA)	How and why do firms build and sustain competitive advantage in dynamic markets?	A firm's difficult-to-imitate position, processes and paths determine its competitive advantage.	Collaborations are established to develop a firm's dynamic capabilities and thus enhance its competitive advantage.
Knowledge-based view (KBV)	How does knowledge, being the overwhelmingly important productive resource, create sustained competitive advantage?	The difficult-to-imitate resources of a firm are knowledge-based, of which the characteristics explicitly affect the possibilities to transfer and appropriate of this knowledge.	R&D collaboration is a means to benefit from complementarities among firms, and the characteristics of knowledge should be taken into explicit account for its transfer.
Technology-based view (TBV)	How can technology-based firms achieve sustained competitive advantage?	A firm tries to optimally acquire and exploit its technology base, which has specific (resource) characteristics.	Collaboration is one strategy for acquiring and exploiting a firm's technology base.

Revisiting the explanations these approaches provide for collaborative knowledge sharing, it can be identified that the different approaches each have their own way of explaining the existence of R&D collaboration. From the different theories one can derive that the transaction cost economics mainly explains the existence of collaborations in the first place and it puts emphasis on the environmental and relational dimension and to a minor extent on the characteristics of the collaboration. The resource-based view, and the views that are related to this, more explicitly analyze the exact sharing of resources, i.e. knowledge, and put the emphasis on the characteristics of these resources. Furthermore, the intellectual capital approaches take the nature of the collaboration in more explicit consideration. This will be elaborated on in more detail in the next section. The differed approaches also vary according to how closely related they are to this knowledge sharing. The following section revisits these theoretical perspectives that explain collaborative knowledge sharing and thereby identify which relevant dimensions (for the tension field of knowledge sharing and protection) can be derived from these theories.

2.4 Main Dimensions of Collaborative Knowledge Sharing

The discussions of the transaction cost and resource-based view – and the other related approaches – show (fundamentally) different approaches with regard to collaboration between firms. The transaction cost theory takes the transaction as a starting point by focusing on its costs for contracts, whereas the resource-based theory and the other views put the firm's resources central by looking at its value-creation benefits. Thus, the two theories have different starting points and deal with different concepts. But as stated by Tsang (2000), in his attempt to integrate the transaction cost and resource-based theories into a more comprehensive perspective to explain joint ventures, the two theories (i.e. transaction cost economics and resource-based view) are to some extent complementary to each other. What is more, Osborn and Hagedoorn (1997) expect to see more attempts that integrate both transaction cost and non-transaction cost arguments to more comprehensively explore the perspectives of the theories for inter-organization alliances and networks. This section goes into these issues by partly integrating the insight from the several relevant approaches in order to get a comprehensive view on the sharing of knowledge in R&D collaborations. To be sure, this research does not intend to fully integrate all these theories (which would be at least rather questionable) but it wants to 'reap the benefits' from the insights given by the different views in order to comprehensively give an overview of the dimensions that appear to be relevant for knowledge sharing within R&D collaborations.

As explained in Section 2.3, transaction cost economics can especially be used to determine when a firm chooses the (hybrid) collaborative governance mechanism. This occurs in the case of intermediate transaction costs that are determined by asset specificity, uncertainty, frequency and costs for controlling opportunistic behavior.

In addition to opportunistic behavior, the concept of bounded rationality can be an important one with regard to knowledge sharing in R&D collaborations. The existence of this bounded rationality could imply a limited capability in constructing contracts that cover all relevant aspects to the full extent. Of course, experience shows that failure does appear in practice. Therefore, the outcomes of collaborative agreements also depend on the effectiveness of the governance structure, of which the feasibility and efficacy is directly related bounded rationality and opportunism. Consequently, Williamson (1996) states that all complex contracts are unavoidably incomplete due to bounded rationality. The mutual contribution of efforts and assets, as discussed above, can deal with certain threats in a collaboration. Therefore, mutual commitment and trust are two relational characteristics influencing the outcome of the collaboration.

All in all, it is important – assuming firms want to minimize transaction costs – to consider how uncertain the *environment* is in which a collaboration takes place, and moreover what the *relation* to the collaboration partner is (e.g. trust, commitment, and geographical, cultural and technological distance). Additionally, in relation to this, the *nature* of the collaboration is important to consider, i.e. if it is explorative or exploitative.

The resource-based (related) views give more insight in how the characteristics of the shared resources influence the coordination and integration, i.e. appropriation, of them. According to the resource-based view, firms have resources that are unique and hard to imitate. Collaborations can be established to profit from each other's resource *complementarities*. Because profiting from each other's resource complementarities is one of the main purposes of R&D collaboration, the exact complementarities between the resources of the collaborating partners are important. The complementarity vs. substitutiveness of the different firms' resources is therefore a dimension that is relevant to consider knowledge is shared. This is also related to the relation to the core competences of the collaborating firms and consequently it has to be considered, in addition to the complementarity of the different resource bases, if the nature of the collaboration is either explorative or exploitative. An additional characteristic of importance with respect to the uniqueness of a firm's resources is the *specificity* of knowledge. This specificity can also determine to which extent the knowledge complementarities can be combined.

But despite the goal of profiting from resource complementarities, an important characteristic of resources is that they are related to a certain difficulty to imitate them. Therefore, *imitability* is an important dimension for knowledge that has to be shared. The resource-based view and, even more specifically, the dynamic capabilities approach give some explanations for the problem of imitability, which also gives some indications for how this can be resolved. Imitability has in fact an important relationship with appropriability (Teece, 2000) which, as will be shown later, has important implications for the tension field of knowledge sharing and protection. The characteristics of a firm, e.g. its path dependent processes, cause its resources to have a certain degree of *tacitness*. This is indeed one of the traditional important characteristics of knowledge that has been distinguished (e.g. Nonaka and Takeuchi, 1995; Cowan, David and Foray, 2000; Teece, 2000; Nonaka and Teece, 2001a). This goes back to, among others, Winter (1987) who made the following distinctions for knowledge characteristics: tacitness vs. explicitness, system-quality vs. stand-alone, teachability vs. non-teachability, and complexity vs. non-complexity. Two related counterparts of *tacit* knowledge used in literature are (a) *explicit* and (b) *codified* knowledge. While codifibility refers to the exact body (and the 'language' used) of knowledge or knowledge transfer, explicitness relates more to the general embodiment of knowledge which determines the extent to which it can shown or revealed (i.e. made explicit). This concept of embodiment is also related to the *systematic* (vs. autonomous) *nature* of knowledge. It determines the knowledge sharing in R&D collaborations to a certain extent because it influences, again, the appropriability (Teece, 2000). Although this issue will be elaborated on later in the report, this study in principle refers to the pair tacit and explicit as each other's counterparts because this is more at the core of the concept. *Codifibility* is considered to be a separate characteristic that is of relevance as part of this dimension. In relation to learning in collaborations, *teachability* and *complexity* are important knowledge characteristics. Collaboration helps to access skills and to transfer complex and tacit knowledge, with an important role for appropriability and protection of intellectual property (Dodgson, 1993). The protection of intellectual property is discussed in Chapter 3 and the role of effectively sharing it, i.e. appropriation, in Chapter 4.

Also taking the intellectual capital approaches (the knowledge-based view and the technology-based view) into consideration, the influence of the resource characteristics, i.e. knowledge characteristics (cf. Winter, 1987), indeed becomes even more apparent. Clearly, this is highly relevant for the R&D collaborations which are the focus of this study. It goes without saying that the knowledge-based view considers knowledge as the main productive resource of a firm. The transferability of knowledge depends on its exact type; and indeed, tacitness and the other distinguished types of knowledge are important characteristics of this resource. Furthermore, to benefit from increasing returns, explicitness is an important characteristic of knowledge due to the interdependencies and cumulativeness of knowledge. As also mentioned above, the exact nature (or goal or focus) of the collaboration is important, i.e. if the research that is undertaken is of explorative or exploitative nature.

Taking the perspective of the technology-based view, some important characteristics of a firm's resources can be derived from its definition of intellectual capital. Intellectual capital namely consists of (a) human competences, (b) relational capital, and (c) intellectual property. The first two types of intellectual capital are greatly related to the 'tacitness' characteristic, as described above. The third form of intellectual capital, i.e. intellectual property, has important implications for R&D collaborations as well. Intellectual property can be highly tacit when it is embedded in the human mind but it can also be codified when it is embedded in intellectual property rights. The protection of knowledge with intellectual property rights will be discussed in the next chapter and again revisited in Chapter 4. The characteristics given by the technology-based view are especially relevant for R&D (or technology-based) collaborations because it considers technology as being a special kind of knowledge (see Section 2.3.5). In this context, especially the degree of codifibility and the importance of intellectual property are important. Additionally, R&D collaborations are by definition involved with the creation of new knowledge. But because of the high pace of innovation the knowledge that is put into the collaboration can be highly new – in other words, recently developed – and therefore the *newness* of the knowledge has to be considered as well.

Table 6. Dimensions of collaborative knowledge sharing

Environmental dimension	Relational dimension	Knowledge characteristics	Collaboration characteristics
Uncertainty	Commitment	Complementarity	Nature of collaboration (e.g. explorative or exploitative)
Sector	Trust	Tacitness	Number of partners
	Geographical distance	Codifibility	Experience of and with partners
	Cultural distance	Imitability	Partner size
	Technological distance	Systematic nature of knowledge	University involvement
		Teachability	Duration
		Complexity	
		Newness	
		Specificity	

Table 6 gives an overview of the relevant dimensions that become apparent when considering all the theoretical perspectives on (R&D) collaboration. This table already includes some of the dimension that will appear to be relevant in the remainder of this chapter. In Chapter 4 these dimension will serve as an input to identify, formulate and develop relevant aspects and mechanisms in the tension field of knowledge sharing and protection in R&D collaborations. The next section will now go into some of the limits to collaborative knowledge sharing.

2.5 Limits to Collaborative Knowledge Sharing

As briefly described in Section 1.3.2, research and development are in a certain way considered to be drivers for (technical) innovation. In order to foster this to a larger extent – because apparently the market forces give too few incentives to ensure sufficient research and development – the European Commission (as an important example) promotes collaborative R&D. In order to reach this goal, i.e. achieve increased innovation, it is acknowledged that competition (or antitrust) legislation has to be modified in order to give enough room for the organization to actually conduct efficient R&D (see e.g. Jorde and Teece, 1990). The European competition policy principally aims at ensuring effective competition. Agreements that restrict competition are prohibited, which is covered by Article 81 of the EC Treaty (ex Article 85), given in Table 7. Article 82 of the EC Treaty (Ex Article 86), given in Table 8, in addition tries to ensure that firms in a dominant position do not abuse that position. The latter article may relate to the outcomes of a collaboration that could give a certain firm a dominant position of the market. Article 81 of the EC treaty in principle prohibits any anti-competitive (or anti-trust) outcomes of collaborative undertakings and therefore R&D collaborations would be subject to this Article. However, R&D collaborations are often of a pre-competitive nature and therefore foster innovation and growth. Hence, R&D collaborations are relieved by the Block Exemptions as given in Article 81(3) of the EC Treaty.

This Block Exemption can be applied (given certain conditions) to vertical agreements, licensing agreements for the transfer of technology, and horizontal co-operation agreements. For these issues the European Commission has published several interpretations. The Block Exemption for horizontal agreements, for example, acknowledges the fact that these agreements can lead, on the one hand, to competition problems but also to substantial economic benefits, on the other hand. Co-operation (i.e. between firms on the same level in the market) is necessary in the changing (increasingly competitive and globalizing) market place. For many small and medium-sized enterprises it is even considered to be an essential activity for their survival. In general, it can be stated that (horizontal) agreements are relieved by the Block Exemption if they are carried out between non-competitors, if the competing firms cannot independently carry out the project, or if the collaboration does not influence the relevant parameters of competition. Pre-competitive R&D collaboration, which is the main subject of this study, is therefore generally not subject to Article 81(1). Although this kind of collaboration is considered to be pro-competitive in nature in general, Article 81 remains an issue of interest for collaborating firms (European Commission, 2001a).

The Block Exemption for technology transfer agreements, which is also important in relation to R&D collaborations, is concerned with licensing of technology. This exemption[22] acknowledges that these kinds of agreements are usually pro-competitive and improve economic efficiency. This can be explained by the fact that the licensing of technology can incentivize R&D and reduce duplication of it, and it facilitates diffusion and generates product market competition. In order to attain this, the technology transfer agreement (or license) should satisfy the conditions of Article 81(3) with sufficient certainty (European Commission, 2004).

[22] The latest (change in) regulation of this exemption was published on 27 April 2004l, to indicate the ongoing changes (also in regulation).

Table 7. Article 81 of the EC Treaty (ex Article 85)

1	The following shall be prohibited as incompatible with the common market: all agreements between undertakings, decisions by associations of undertakings and concerted practices which may affect trade between Member States and which have as their object or effect the prevention, restriction or distortion of competition within the common market, and in particular those which: (a) directly or indirectly fix purchase or selling prices or any other trading conditions; (b) limit or control production, markets, technical development, or investment; (c) share markets or sources of supply; (d) apply dissimilar conditions to equivalent transactions with other trading parties, thereby placing them at a competitive disadvantage; (e) make the conclusion of contracts subject to acceptance by the other parties of supplementary obligations which, by their nature or according to commercial usage, have no connection with the subject of such contracts.
2	Any agreements or decisions prohibited pursuant to this Article shall be automatically void.
3	The provisions of paragraph 1 may, however, be declared inapplicable in the case of: - any agreement or category of agreements between undertakings; - any decision or category of decisions by associations of undertakings; - any concerted practice or category of concerted practices, which contributes to improving the production or distribution of goods or to promoting technical or economic progress, while allowing consumers a fair share of the resulting benefit, and which does not: (a) impose on the undertakings concerned restrictions which are not indispensable to the attainment of these objectives; (b) afford such undertakings the possibility of eliminating competition in respect of a substantial part of the products in question.

Source: EC Treaty (http://europa.eu.int, 2004)

Table 8. Article 82 of the EC Treaty (ex Article 86)

Any abuse by one or more undertakings of a dominant position within the common market or in a substantial part of it shall be prohibited as incompatible with the common market insofar as it may affect trade between Member States. Such abuse may, in particular, consist in:	
(a)	directly or indirectly imposing unfair purchase or selling prices or other unfair trading conditions;
(b)	limiting production, markets or technical development to the prejudice of consumers;
(c)	applying dissimilar conditions to equivalent transactions with other trading parties, thereby placing them at a competitive disadvantage;
(d)	making the conclusion of contracts subject to acceptance by the other parties of supplementary obligations which, by their nature or according to commercial usage, have no connection with the subject of such contracts.

Source: EC Treaty (http://europa.eu.int, 2004)

Concluding, pre-competitive R&D collaboration is generally considered not to hamper innovation. On the contrary, it is believed to have substantial economic benefits. Therefore, despite the existing competition rules, it is not subject to the regulation given by anti-competition law, through the Block Exemptions as described above. These limitations to collaborative knowledge sharing through R&D collaborations are also related to the way firms (and other organizations) go about the protection of their knowledge, e.g. by the use of licenses, both from the firm perspective as well as for the collaboration in general. Therefore, the Chapter 3 will address the issue how firms can protect their knowledge in collaborations.

2.6 Discussion and Conclusions

The considerations that are described above, in relation to the (potential) limits of collaborative knowledge sharing clearly show that, although collaboration in general can hamper innovation and growth on the long term, (pre-competitive) R&D collaborations can positively contribute to innovation and economic growth. In relation to the ongoing globalization by which the present economy is characterized, as becomes clear from Section 2.2, this means that R&D collaborations are becoming more international (in relation with the diversification efforts of firms). Moreover, because of the increasing complexity of knowledge, more and different kinds of partners are involved in order to be able to achieve the goal of the collaboration. Two apparent outcomes of this are cross-sector collaborations and the involvement of non-firm entities. This is all also reflected in the increasing public subsidy programs that are set up to promote competitiveness and foster innovation and growth.

Thus, R&D collaborations are becoming more complex, which is in turn reflected in the increasing interest from scholars, public policy makers and people from industry. Because of this, another important trend is the increasing importance to protect the knowledge that one puts into the collaboration as well as the knowledge that is created in the collaboration, with the appropriation of this as an important related issue. This issue is explicitly addressed in the next chapter. What is important in relation to the 'sharing concept' of R&D collaborations is, among other things, the distinction that is being made between different kinds of knowledge in an (R&D) collaboration. Two main kinds of knowledge that are identified are background knowledge, i.e. knowledge put into the collaboration, and foreground knowledge, i.e. knowledge created as an outcome of the collaboration (e.g. European Commission, 2002). But furthermore the importance of (a) sideground knowledge, i.e. knowledge developed simultaneously (in-house) by the firm with a direct relation to the collaboration subject *during* but *outside* (i.e. in parallel with) the collaboration, and (b) postground knowledge, i.e. knowledge developed (in-house) by the firm with a direct relation to the collaboration subject *after* the collaboration is finished[23] (European Commission, 2001b).

Partly in relation to these kinds of developments, the regulation is subject to important changes. While the policy makers, e.g. the European Commission, on the one hand want to encourage (pre-competitive) knowledge sharing though R&D collaborations to foster innovation and growth, they on the other hand want to limit the unwanted anti-competitive agreements. Especially due to the internationalization of R&D collaboration and the involvement of universities, the (international) legislation has to adjust to address these changes.

From this it becomes clear that the environment that surrounds a collaboration, as well as the characteristics of the collaboration itself, are important dimensions regarding the sharing of knowledge. And as already pointed out in Section 2.4 (see Table 6), these dimension consist of (a) uncertainty and industry setting for the environmental dimension and (b) the nature of the collaboration, number of partners, experience of and with partners, partner size, university involvement and duration for the collaboration dimension.

The environmental dimension became already clear from the theoretical perspectives in Section 2.3, in which especially the transaction cost economists try to explain the existence of collaborations (as a hybrid governance mechanism) by considering the environment. A

[23] European Commission (2001b) states that the terms sideground and postground knowledge are not commonly accepted but suggests them in relation to Internet collaborations. This report also uses the terms to explain different kinds of knowledge transfer (see Chapter 4).

laborations (as a hybrid governance mechanism) by considering the environment. A collaboration can in certain conditions lower transaction costs in uncertain situations. The exact nature of the collaboration, which is again part of the collaboration dimension, relates to the conditions in which collaboration can be the preferred governance system. Whereas the nature of the collaboration is directly related to the motives and goal of the collaboration (again in relation to the environment), the other elements of the collaboration dimension are more closely related to the actual collaboration itself.

By taking the resource-based view into account it becomes clear that the characteristics of the resources that are being shared in a collaboration are of essential importance to understand the actual sharing. These resources are being combined and integrated in some way that facilitates the appropriation of it for each partner. Because the present economy has become more knowledge based, the explicit role of knowledge has to be considered. This is obviously one of the main reasons for the development of the knowledge-based view. The same can be said about the importance of technology (as a special form of knowledge) and the development of the technology-based view. From this it becomes clear that the characteristics of knowledge, which is the most important resource in an R&D collaboration, are extremely important to explain the process of knowledge sharing. Because the appropriation of knowledge (as foreground knowledge) is important for the firms, the knowledge characteristics can take a central role in explaining the protection of knowledge as well. The main reason for collaborating is to profit from each other by benefiting from the pooling of each other's resources, i.e. knowledge. Therefore, the resource complementarities are essential to explain collaborative knowledge sharing.

Closely related to this (and especially the dynamic capabilities approach helps to explain this) is imitability of the knowledge. The imitability of (shared) knowledge namely has a strong relationship with the appropriability of it. The concept of imitability relates to both the *ease* as well as the *difficulty* to imitate it. In relation to the 'information paradox', this means that a firm on the one hand will be hesitant to share its knowledge, which is its competitive asset, and therefore tries to hamper an easy imitation of it. It is in fact the difficulty to imitate a firm's knowledge that distinguishes it from others, and can give it a competitive advantage. On the other hand, collaborating firms should be able to understand and imitate each other's knowledge easily in order to profit from each other's complementarities. Therefore, the ease to imitate should be low. In this sense, imitability could also be called teachability. In any case, there appears to be a (natural) tension between the ease and difficulty to imitate knowledge in collaborative efforts. It will therefore be interesting to investigate the role of this tension in the general tension field between knowledge sharing and protection.

A characteristic of knowledge that makes the issue of imitability even more apparent is the tacitness of knowledge. Tacitness has important implications for collaborative knowledge sharing but, as will be shown later, this process mostly takes place through the way the knowledge can be protected. Another characteristic of importance in R&D collaboration is the complexity of knowledge, as well as the newness of it. Because R&D collaborations are highly knowledge-based and pre-competitive these concept will highly matter with regard to the sharing of knowledge. In addition, the systematic (vs. stand-alone) nature of knowledge can be an important characteristic because it can determine to which extent knowledge can be shared and appropriated.

In order to appropriate the collaborative knowledge, it is important to consider that it has to be transferred from one partner (i.e. the transferor) to another (i.e. the transferee). Assuming the rationale for collaboration is to lower transaction costs and to profit from each other's resource complementarities, the relationship between the two (or more) partners should facilitate an appropriate transfer of knowledge. This can both facilitate a good sharing of knowledge and at the same time be a means to deal with the protection of it (as will be shown later). Therefore, the relational dimension will be of importance to consider in the tension field of knowledge sharing and protection. In this relationship, the concepts commitment and trust take a central place in the sharing of knowledge. Some issues that are related to these are in turn the distance between the partners (both technologically and geographically).

All in all, the considerations above give an answer to the second sub research question that asked which dimensions can be identified with regard to a firm's knowledge sharing in R&D collaborations (see question B in Section 1.4.3). Thereby, research question A is also partly answered. Section 2.4 (especially Table 6) already gave an elaboration on which dimensions could be identified by considering the theoretical perspectives that discuss collaboration. Therefore, in short the answer to the question is that the 'environmental', 'collaboration', 'knowledge' and 'relational' dimensions can be identified with respect to a firm's knowledge sharing and these dimensions will therefore comprise the tension field of knowledge sharing and protection as well.

In R&D collaborations the knowledge dimension takes a central role because of the importance of the characteristics of the knowledge that is shared. Furthermore, the appropriate sharing of knowledge can be facilitated (or hampered) by this relational dimension. The collaboration dimension is more a meta-dimension that influences the collaboration in general and the tension field in particular as a whole on a higher level. The environmental dimension finally influences the above dimensions on an even higher level.

3 Protecting Knowledge in Collaborations

3.1 Introduction

As it became clear in the previous chapters, the collaborative sharing of knowledge is increasing both in number and in importance. It gave rise to several issues of importance with regard to the environment of the collaboration, the relationship between the partners and the characteristics of the collaboration itself, as well as the characteristics of the knowledge that is being shared in the collaboration. This chapter, on the other hand, takes the sharing of knowledge 'for granted' and investigates which possibilities a firm has in order to protect the knowledge (that it 'owns') that it puts into the collaboration, i.e. when the sharing of knowledge is a fact. Different kinds of knowledge that are shared in relation to a collaboration are background, sideground, foreground and postground knowledge as briefly discussed in Section 2.6. Of course the protection of knowledge is (most typically at least) already considered before the actual sharing or transfer takes place. As also described before, the protection of knowledge is becoming of crucial importance for a firm that wants to protect its knowledge base, which is in turn considered to be its main competitive asset. Some of the main trends in relation to this will be discussed in the next section.

This chapter investigates how the 'knowledge protection field' can be characterized by investigating which dimensions can be identified with regard to the way a firm can protect its knowledge in R&D collaborations. Hereby the research question C as given in Section 1.4.3 (i.e. which dimensions can be identified with regard to the way a firm can protect its knowledge in R&D collaborations?) is answered. This is done by first giving some of the main trends in this field. Subsequently, the theoretical perspectives are discussed by addressing the rationale for knowledge protection and by focusing on the explicit role of knowledge (and its characteristics) in this. The next step is to go into more detail by characterizing knowledge as a form of intellectual property and to describe the framework in which intellectual property is embedded as well as which strategies a firm can adopt in relation to this. These issues are relevant for R&D collaborations because they address the specific properties of knowledge and the existing need for firms to protect it because knowledge is the main 'asset' in the collaboration as well. In order to protect this knowledge it is made clear that the use of agreements (of various sorts) is an important means to go about it and therefore different licensing schemes are discussed. From these considerations, the subsequent step is to identify which dimensions of knowledge protection are important to take into account. Furthermore, licensing strategies are discussed that a firm adopts to deal with some knowledge protection issues in particular as well as to exploits its intellectual property in general. Finally, a discussion and conclusion is given that explicitly answers and goes into research question C. After this chapter, Chapter 4 will combine the findings from this and the previous chapter in order to identify which exact tension exists between the sharing and protection of knowledge in R&D collaborations.

3.2 Trends

As already described, the sharing of knowledge has become essential for many of today's industries. Moreover (in parallel) the protection of knowledge became to play an essential role. The role of intellectual property and intellectual property rights (as a body of intellectual property) consequently increased in importance. The role of intellectual property in our economy became of increasing significance. From the 1980s this gave rise the 'pro-IP era' (especially in the United States) which mainly consisted of a 'pro-patent era' (Granstrand, 2000; Jaffe, 2000). Several studies show the increasing propensity for firms to file patents (e.g. Grindley and Teece, 1997). Patents (and intellectual property in general) are often considered as being a firm's 'crown jewels' among its assets, especially in high-technology industries (Coriat and Orsi, 2002, a.o.). The increasing importance of intellectual property and intellectual property rights clearly relates to the rise of intellectual capitalism (see e.g. Gerlach, 1992; Teece, 2000), of which some of the resulting views are described in Section 2.2.5. From this the increasing importance of 'intellectual property management' can be identified (Arora, Fosfuri and Gambardella, 2003).

As discussed later, the patent system was created to facilitate the diffusion of knowledge and to create exclusivity (which in turn gives incentives for innovative activity and commercialization of innovations). In relation to these two elements of patenting, i.e. diffusion and exclusivity, it can be questioned if the net value of the patent system is positive. The net value relates to the 'payment' by society by granting an exclusive right and the 'payment' by the inventor by making his invention public, i.e. the main rationale for the patent system (e.g. Ordover, 1991). There are indications that the societal costs of the patent system are increasing which creates the need to reconsider the present patenting and licensing approach (e.g. Mazzoleni and Nelson, 1998; Davis, 2004). Consequently, an open question that arises is if the economy (or some industries in particular) is (or are) moving from a pro-patent to an 'over-patent era' with an 'overshoot' of patenting. It is argued that the legal provisions in the current patent regime are to a large extent overprotective which may result in a slowdown in innovation, for example in software technologies (Harison, 2004) It can furthermore be argued that a 'patent thicket'[24] arises in some industries, which can have important anti-competitive (or anti-trust) implications and can hamper innovation (Shapiro, 2001; Beard and Kaserman, 2002). However, sometimes an inherent paradox arises if patents have to be pooled in order to ensure certain developments, e.g. in relation to certain standardization efforts.

In addition, the increasing uncertainty in relation to patenting becomes apparent (Bekkers, 2004). It is extremely difficult to estimate the value of a patent, or a patent portfolio. The uncertainty of the outcome of innovative activity differs over the different stages of the innovation process as does the (real) value of a patent. Consequently, the assessment of the value of a patent is extremely difficult and the value can therefore differ over the different stages of the knowledge development process (cf. the value chain in Figure 4, Section 1.3.2). Moreover, the value of a patent can generally only be assessed after it is infringed and found valid, or either invalid[25] (Sherry and Teece, 2004). In relation to this, the market value of a license generally rises (while the uncertainty decreases) over the different stages of the innovation process (Granstrand, 2000).

These trends make clear that, as said before, intellectual property rights are becoming of increasing importance and one could in fact state, as for example done by Andersen (2004), that intellectual property rights are not neutral but set the rules of the game for the firms to work with. In other words, the characteristics of intellectual property rights have to be taken into explicit consideration in determining firm activities and developing strategies.

[24] Shapiro (2001) defines a patent thicket as an overlapping set of patent rights requiring that those seeking to commercialize new technology obtain licenses from multiple patentees.

[25] In the latter case the value would in fact be zero.

All of this, among other things, gives rise to the emergence of new kinds of intellectual property rights as well as the trend towards 'enlarging' the patentable area (e.g. patents in bio-tech and software, which is a broadening of 'technical' requirement). Clearly, there is an ongoing discussion on breath and depth of intellectual property rights. In relation to the outcome of this discussion (which will probably be continuously ongoing, however) it is emphasized that the ideal design of the intellectual property right system depends on the ease with which right holders can enter into licensing and other contractual arrangements involving these rights (Gallini and Scotchmer, 2002). Furthermore, because firms increasingly encounter a patent thicket (as mentioned above) they more and more have to acquire multiple licenses if they do not want to risk litigation when they commercialize an innovation (Shapiro, 2001). Licensing is thus an important issue and it is moreover argued that our economy is entering pro-licensing era (Granstrand, 2004a), while licensing is considered to be an under-researched area (Hertzfeld, Link and Vonortas, 2001).

The trends described above influence and are influenced by policy changes. In relation to intellectual property rights, several changes in procedures and regulations can be identified. It is interesting to note that policy changes increasing patent protection tend to have a much stronger effect on inward patenting by foreigners than on domestic patenting (Lerner, 2000). Furthermore, the intellectual property right system (and the patent system in particular) is neither necessary nor sufficient to historically explain technical and economic progress (Granstrand, 2004b). The effect of policy making also depends on the sector. For example, Granstrand (2004b) argues that patents are most likely to support the growth of knowledge-intensive industries with low ratios of imitation to innovation costs, e.g. in chemicals in which large-scale R&D projects result in highly codified knowledge. Other industries might have strong 'first-mover advantages' however which reduce the importance of patents. In any case, the intellectual property right system has different effects dependent on various issues. The changes in the economy and in policies are important to consider for firms participating in R&D collaboration. One example is the exemption for pre-competitive R&D collaborations to pool and transfer their resources (e.g. intellectual property rights). Another important trend (in the United States, that is) is the establishment of the Bayh-Dole Act. This Act, adopted in 1980, forces universities to change their rules related to intellectual property rights and strongly encourages them to apply for patents on the results of this government-sponsored research, while earlier the norm was to place such results in the public domain (Eisenberg, 1996). Its effect are the subject of many discussions (Hersey, 2004) and in the ongoing debate on intellectual property rights its pros and especially cons are addressed Mazzoleni and Nelson (1998). In relation to the increasing involvement of universities in R&D collaborations this issue can have important implication on how the protection of knowledge has to be arranged. A final remark about the intellectual property right system relates to the increasing globalization of the economy. Internationalization has important implication for the knowledge protection field. Because collaborations are becoming more and more cross-border, problems arise such as the different national legal systems. For example, patentability requirement may vary across countries (and over time) although there is a trend towards some convergence through international co-operation and harmonization[26].

[26] To be sure, every country has its own intellectual property right laws, although a process of international harmonization is ongoing, not the least in Europe.

Because patents (and intellectual property rights in general) increasingly 'set the rules of the game', firms and innovativeness in general are to a large extent getting constrained by this legal framework. Because of this, some countertrends can be identified. There is an increasing interest in the open or collective innovation models, with the so-called Open Source Model as being one of the main representatives. This 'open innovation paradigm' is especially being developed in relation to the creation of knowledge as a public good, for which the market often fails to give enough incentives to innovate. This is thus in contrast with the closed or private investment model (see e.g. von Hippel and von Krogh, 2003). Another example of the more open or free exchange of knowledge in this context is the 'Creative Commons'. Creative Commons is an organization that offers licenses that define the extent to which others can use make use of a certain piece of work that would otherwise be protected by standard copyright (http://www.creativecommons.org, 2004). The Creative Commons licenses have four main attributes that one can combine to the desired extent. These attributes are (a) the attribution requirement, (b) non-commercial use, (c) no derivatives work, and (d) one can define requirement that others that build on your idea have to share it under the same conditions. After one defines the exact conditions others can 'freely' use your new idea or innovation as long as they respect the conditions.

The Open Source Model mainly refers to the software industry[27] in which the use of an open source code was the way to go about its development at the beginning of the industry's history. The roots of it can be traced back to the academia and government labs in the United States, in which open science with was the main paradigm to establish innovation, diffusion and recognition. When a shift in this paradigm occurred, it was MIT's Artificial Intelligence Laboratory that licensed the source code of a piece of software to a commercial firm, which in turn appropriated and protected the source code and thereby used it in a 'closed-source' manner. The employees at MIT, most specifically Richard Stallman, were afraid that this was the beginning of a 'closed-source' trend and the 'free source movement' was therefore founded in 1984. This free source movement preceded the Open Source movement (and now exists in parallel it), which takes a (philosophically) fundamentally different approach although they have essentially the same goals. Whereas the free source movement considers free software as a matter of freedom, the Open Source movement is more orientated towards the interest of firms and the diffusion of the open code. Therefore, Open Source software opened the possibility for firms to commercialize on open source software. The licensing practices of the two movements are very similar, however. Open Source can therefore be considered as a pragmatic approach that incorporates the benefits of efficiency, reliability and technological pace (Raymond, 2001). Although the mechanisms in Open Source are based on normative ideas to encourage collective efforts and contribution of improvements, legal mechanisms are being used that state how software should be used. The copyright law is namely being used to grant licenses on terms that would guarantee a number of rights to all future users (sometimes referred to as 'copyleft'). This idea is implemented in the General Public License, which is very strict in its requirement for asking developers to release the source code of derived work. There exists however a multitude of different licenses that to a varying degree allows the user to fit the code to their purposes and commercialization of follow-up inventions (Lerner and Tirole, 2002a).

---

[27] Some of the well-known examples of Open Source software that have many users the GNU/Linux computer operating system, Apache server software, and Perl programming language. To be sure, the number of users of Open Source software can range from a few to many millions, and in the same way the number of developers participating in an Open Source project can range from a few to many thousands.

The well known examples of 'open source-like' advances to a large extent refer to more global or broad developments and adaptations. In addition, a more 'local open source' can be of interest in which a smaller community applies the concept of open source to its local development. This moreover relates more significantly to the R&D collaborations of interest in this study, because these might also adopt a similar model within their (local) collaboration.

Furthermore, the role of users and communities takes an important role in the innovation process as well (von Hippel, 1988). In this sense, open innovation also takes place in an informal way, dependent on the exact interests of the developers. It is argued that users can benefit from freely revealing their newly developed knowledge (Harhoff, Henkel and von Hippel, 2003). Because the users *use* the innovation and do not *sell* it, they potentially benefit more from an open sharing of improvements than from (closed) developments that are in turn exploited privately (von Hippel, forthcoming). In some cases (e.g. commercial open source software) some kind of 'selective revealing' of developments is used, thereby adopting a strategy of profit-maximization in relation to a (selectively) free revealing of results (Henkel, 2004). Dependent on the openness (i.e. degree of disclosure), the optimal strategy in software development can change from entirely proprietary to some open-source development (Harison and Cowan, 2004).

Most importantly, the way in which organizations generate ideas and bring them to market is undergoing a fundamental change. In the old model of closed innovation, companies generated their own ideas, which they then would develop, manufacture, market, distribute and service themselves. In the new 'Open Innovation Model', the boundaries of the firm are permeable (e.g. Chesbrough, 2003a). In other words, firms (especially large ones) went from a highly internalized vertical (product) development chain to a more open development with possibilities of spinning in and out technologies. The Open Innovation Model or paradigm which is argued to be the new imperative for creating and profiting from technology in general (Chesbrough, 2003b) also becomes apparent when studying R&D collaborations to a certain extent, as well as the Open Source and Creative Commons-like models. This will be discussed in more detail in Section 4.3.3.

3.3 Theoretical Perspectives

3.3.1 Properties of Knowledge

As can be derived from the Chapter 2, knowledge can be seen as an asset that firms can acquire and exploit in a variety of ways. The characteristics of knowledge appear to be crucial to understand how firms can use it. One critical (general) characteristic of knowledge is its public good nature, as already noted by Arrow (1962). The two properties of knowledge as a public good are that it is (a) non-rivalrous and (b) non-excludable. Although these properties have important implications for how firms can acquire and use knowledge, they are not purely valid due to the possibility to appropriate knowledge. So, presently, industries do not only work with knowledge that no one *should* be excluded from (non-rivalry) and that no one *can* be excluded from (non-excludability). As a matter of fact, some knowledge can be made excludable. For example, a firm can choose to keep its knowledge secret in order to reap the benefits from it. To a certain extent this can be a fruitful strategy, especially if the knowledge is not shown when it is used. This can be the case if the knowledge is embedded in a process technology (e.g. a chemical process) for which competitors cannot reveal the exact knowledge (i.e. embodied in an end product) by analyzing its output[28]. But this way of secrecy can, and often will, prove to be quite an unsatisfactory strategy. Besides the fact that there is a risk of disclosure (both legal and illegal), the knowledge potentially has to be shown at a certain moment (e.g. if another firm wants to valuate its technology or knowledge in the case of a potential transaction). In general it can be said that excludability of knowledge is costly. Furthermore, as a public good, knowledge has high fixed costs in production and low costs in distribution. An additional property in relation to its production and distribution is that knowledge is cumulative and interactive. It also is impossible to reverse the process of knowledge transfer. In other words, dispossession is impossible.

Therefore, there is a clear need for knowledge protection in order to appropriate it and benefit from it. For this reason it is interesting to consider the origin of the 'formal' means of knowledge protection, which is presently still in use, namely the patent system. The concept of patenting has its roots in the 15th century Venice, which adopted a patent law in 1474 that granted inventors with a temporary monopoly. The patent system, as we presently know it, was developed in the two previous centuries with some major milestones being (a) the Paris Convention in 1883, (b) the signing of the Patent Cooperation Treaty (PCT) in 1970 and (c) the European Patent Convention (EPC) in 1973 (and 1995), (d) the establishment of the European Patent Office (EPO) in 1977, and (e) the agreement known as 'trade-related aspects of intellectual property' (TRIPs) in 1994.

The rationale behind the patent system is that it, on the one hand, grants an inventor a (temporary) monopoly to use and exploit his (or her, of course) invention exclusively for a limited period of time[29]. This exclusive right is seen as an incentive to innovate because it gives the possibility to cover the high (up-front) investments that are involved with innovation. Put differently, the patent holder is able to charge higher prices than the marginal costs so that he can compensate for the (fixed) investment costs. On the other hand, the innovation has to be made public which in turn stimulates technical progress, which again relates to the reason for setting up the Venice patent code. Patents are said to stimulate technical progress because they are a source of learning and experimenting, they trigger the search for possible alternative substitutes as well as for complementary technology, and after 20 years (when the patent expires) everybody is free to use it. A very important implication of this side of the 'patent-coin' therefore is that the innovation can diffuse which is beneficial to the society as a whole. In fact, the patent system can be seen as a deal (or transaction) between the inventor and the society. The society 'pays' for the invention by means of granting an exclusive right and the inventor 'pays', in addition to administrative costs, by disclosure of his innovation. It however remains an issue of debate to what extent the patent protection system actually provides incentives to innovate and how desirable the outcome is (e.g. the social costs of strategic patenting) from a public point of view (e.g. Mansfield, 1986; Mazzoleni and Nelson, 1998; Cohen, Goto, Nagata, *et al.*, 2003). And regardless of the outcomes of this debate, the impact of the patent system on our society remains substantial.

The next issue that deserves attention when investigating how knowledge can be protected in R&D collaborations is what this knowledge looks likes. Because the focus of this report is on collaborations involved with conducting R&D, the knowledge this study is concerned with is mainly *technical knowledge*. Some authors will in this case use the term technology as a particular kind of

28 This in contrast to a product technology, in which the technical knowledge is embedded in the product, and therefore can more easily be 'reverse engineered'.

29 A more thorough discussion about the rationale behind the patent system can be found in Scherer (1980) and Kaufer (1989), among others.

knowledge. Clearly, the two terms are closely related and in this sense could be used more or less inter-changeable. In principle (unless otherwise stated) the term 'knowledge' is used in this study to refer to 'technical knowledge'.

Considering the role of knowledge in R&D collaborations it goes without saying that the sharing of knowledge is the main activity, together with (jointly and thereby) creating new knowledge. Therefore, this knowledge has to be transferred in some way and hence has to have some form or body of transfer. The *embodiment of knowledge* is therefore a crucial issue to consider in R&D collaborations. It will also give the constraints and possibilities to protect it, e.g. when used in a collaboration. In this sense, there is one single characteristic of knowledge (as also discussed in Chapter 2) of interest, namely the tacitness of knowledge. Tacit knowledge, with explicit knowledge as its counterpart, refers to the degree of concreteness and the possibility to identify it. The concept of tacit knowledge was introduced by Polanyi (1958) and can be defined as knowledge that is highly personal and not easily made visible or expressible. Tacit knowledge refers to the fact that "we can know more than we can tell" (Polanyi, 1967: 4) and it is difficult to articulate and to valuate it. There is therefore an important relation between the degree of codification and the cost of its transfer. Therefore, Teece (2000) states that the more knowledge is codified, the more economically it can be transferred. Another characteristic of tacit knowledge, which highly relates to R&D collaborations, is that it usually requires joint, face-to-face communication to transfer it properly, which can make it slow and costly to transfer.

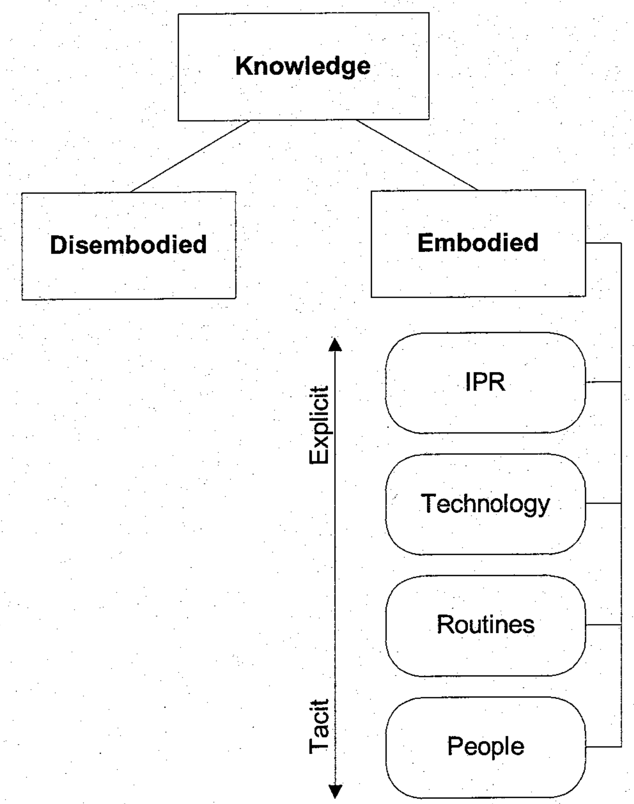


Figure 8. Disembodied and embodied forms of knowledge

Figure 8 shows that knowledge can be divided into disembodied and embodied knowledge, and it gives an overview of which kind of embodiments exist. First of all, *disembodied knowledge* is knowledge that is not embedded in any kind of form of some sort and it has an important relation to pure information. Though, one could argue that disembodied knowledge can also take a physical form, e.g. a formula or blueprint. But then the knowledge 'behind it' still has such a strong 'stand-alone' character that is remains a disembodied form of knowledge[30]. This kind of knowledge consequently needs not convey much meaning as such and a fuzzy boundary exists between disembodied and embodied knowledge. In some cases disembodied knowledge has the characteristics of a public good which gives it an important the role in global development (Stiglitz, 1999). Overall, the main point is that disembodied knowledge is rather pure and objective, meaning that it takes the form of pure information and in the extreme case it can referred to as the 'objective truth'.

Embodied knowledge, on the other hand, is embedded (or held) in some way, and this embodiment creates its usefulness or value. To be sure, whereas some authors only refer to embodied knowledge as tangible form of knowledge that potentially has been converted from embedded knowledge (e.g. Madhavan and Grover, 1996), this study refers to embodied knowledge as any kind of knowledge that gets its meaning and value through its embodiment and it can be both observable and unobservable. The embodiment of knowledge determines to a large extent how firms can go about the knowledge protection (and sharing, in fact).

This study distinguishes four different kinds of embodiment for knowledge that are important in relation to R&D collaboration an shown in Figure 8, namely (a) knowledge embedded in intellectual property rights, (b) knowledge embedded in a technology (i.e. products or processes, or even services and test results), (c) knowledge held in the minds of people (i.e. know-how), and (d) knowledge that is embedded in routines. Although all of them highly (and even mostly) refer to technical knowledge, especially the latter form of embodiment also comprises non-technical knowledge to a large extent, which is important to consider in relation to R&D collaborations. (This is the case for knowledge embodied in people as well, although to a minor extent.) As indicated in Figure 8, these types of embodiment can be categorized according to their degree of tacitness or their degree of explicitness, conversely. It is important to note that these different kinds of embodiments are not necessarily mutually exclusive, meaning that a certain piece of knowledge might as well be embedded in different embodiments, e.g. a product that is also patented or a routine explicitly known by people.

Intellectual property rights (and especially patent in particular) have become of major importance in the present economy and are discussed in more detail in next section. In short, an intellectual property right is a legal right granted to protect the creation of the human mind and it explicitly describes the technical knowledge that it comprises. In principle, an intellectual property right gives full freedom to act, meaning no limitations with regard to rules and conditions exist; there are regulations for exceptions, however. This study focuses on intellectual property rights in relation the creation and transfer of technical knowledge. To be sure, one of the main characteristics that distinguishes technical knowledge (as meant in this study) from non-technical knowledge is it patentability.

Knowledge embedded in a *technology* is the kind of knowledge that is often referred to as a product or process, or hardware or software (to give two characterizations that are often used). It has to be clear that this study considers 'technology' as one sort of (technical) knowledge. It can also include the application of knowledge or a technology, such as test results.

30 Some authors also refer to this kind of knowledge as 'codified stand-alone knowledge' (e.g. Teece, 1981).

The following type of knowledge is the archetype of tacit knowledge as described in more detail above. Knowledge embedded in the minds of *people* is indeed tacit and can entail important and even essential (technical) knowledge. Often this knowledge is *about* something or how to do, use or adjust something (e.g. settings of a technology), and it is therefore often referred to as 'know-how'.

A final form of embodiment, which takes a specific form in R&D collaborations, is knowledge embedded in *routines*. The concept of (organizational) routines goes back to Nelson and Winter (1982) who point out 'routines' as being the main unit of analysis to explain selection and variation in organizations. It constitutes a form of storage of organization specific knowledge on a broad range of elements, and it could mean that organizations learn by doing. More specifically, in relation to routines as a form of knowledge embodiment, they can (more specifically) consist of elements such as rules, procedures, instructions, culture, strategy, policies and strategies. These can be both technical and non-technical. This study investigates the existence of 'collaborative routines' and their influence on the tension field of knowledge sharing and protection.

3.3.2 Intellectual Property

The explicit role of knowledge is important to understand how it can be shared and protected. It is therefore necessary to describe its characteristics as a form of property. Basically, intellectual property can be considered as a form of property like 'real' property, such as land or machinery. Intellectual property can however be distinguished from this other kind of property due to is its tangibility, or intangibility to be exact. Real property (land, machinery, etc.) has physical parameters making it tangible goods whereas the main characteristic of intellectual property is its intangible nature. See Figure 9 for an overview. The fact that intellectual property is intangible does not mean it cannot have formal characteristics, meaning it can have an embodiment that is visible or codified. On the contrary, intellectual property might be very well defined in a (detailed) written description (e.g. a patent). This again refers to the distinction between explicitness and tacitness of the different possible embodiments, as described above. The implication of this will be elaborated on in the next chapter.

Another distinction that can be made is between formal and non-formal intellectual property. Formality refers to how systematic and concrete that kind of intellectual property has been developed. An example of non-formal intellectual property is a trade secret, which has in fact not (yet) been managed in a systematic way (Granstrand, 2000). It is important to note though that trade secrets are especially not very clear and specific outside the boundaries of the firm. Although many firms do not manage them very systematically and trade secret legislation is still weak in many countries, some firms have quite specific and detailed trade secrets and do manage them in a systematic manner. Another illustration that is closely related to non-formal intellectual property is contract law, because it does not systematically cover all possible issues in relation to intellectual property but rather provides a general framework that can deal with problems not covered by a specific contract. Formal intellectual property, on the other hand, refers to a more specific and systematic form of intellectual property. It is visible in the sense that the knowledge takes more concrete forms. Good examples of formal intellectual property are intellectual property rights31. These (legal) rights take a very concrete (i.e. formal) form and can be protected systematically. It has to be noted though, as indicated in Figure 9, that the distinction between formal

[31] To be sure, there is a distinction between intellectual property and intellectual property rights, the former being an intangible form of property and the latter being the legal rights that can be assigned to intellectual property.

and non-formal intellectual property is not always very clear-cut and that there is a fuzzy boundary between them.

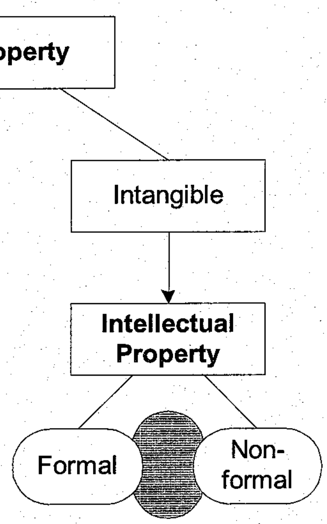


Figure 9. Different types of property

Intellectual property is a distinct form of intellectual capital (as described in Chapter 2) although it also shares important characteristics with real property. The main common characteristic, which makes them forms of property in the first place, is that both real and intellectual property can be bought, sold, given away, leased and exchanged, although there are certain limits to do this (for both forms of properties). In essence, the owner of the property can prevent others from using the property and possibly transacting it in the ways described above by a legal framework. This section continues by setting out this legal framework for intellectual property in relation to possible strategies, starting by discussing intellectual property rights as an important form of (formal) intellectual property.

3.3.3 *Intellectual Property Strategies*

Whereas intellectual property rights are an important means to protect one's knowledge which gives an incentive to innovate, R&D efforts (and thereby development of intellectual property) can be rewarded in different ways. In addition to intellectual property rights, there are several other incentive mechanisms thinkable, for example prizes and contract research of various types can be used (see e.g. Gallini and Scotchmer, 2002). This study mainly focuses formal intellectual property rights, however.

The next step is to describe intellectual property rights and ultimately their implication for how firms can protect their knowledge (in R&D collaborations). According to the World Intellectual Property Organization (WIPO, 2001) intellectual property rights refer to the legal rights which result from intellectual activity in the industrial, scientific, literary and artistic fields. As said before, every country has its own laws to protect intellectual property, although a process of international harmonization is (necessarily) ongoing. Generally, intellectual property law aims at safeguarding creators and other producers of intellectual goods and services by granting them certain rights (for a limited amount of time) to control the use of their knowledge. Those rights do not apply to the physical object in which the creation may be embodied but instead to the intellectual creation as such. WIPO (2001) distinguishes two branches of intellectual property tellectual creation as such. WIPO (2001) distinguishes two branches of intellectual property rights, namely 'industrial property' and 'copyright'. The latter refers to literary, artistic and scientific works (and also some rights related to copyright), whereas the areas mentioned as inventions, industrial designs, trademarks, service marks, and commercial names and designations constitute the industrial property[32] branch of intellectual property rights. The main forms of intellectual property are given in Table 9.

Table 9. Different intellectual property rights

Branch of IPR	IPR	Description
Industrial property	Patent[33]	A patent is an exclusive right granted for an invention, which is a product or a process that provides a new way of doing something, or offers a new technical solution to a problem and it provides protection for the invention to the owner of the patent. The protection is granted for a limited period, generally 20 years.
	Trademarks	A trademark is a distinctive sign which identifies certain goods or services as those produced or provided by a specific person or enterprise.
	Industrial designs	An industrial design is the ornamental or aesthetic aspect of an article.
	Geographical Indications	A geographical indication is a sign used on goods that have a specific geographical origin and possess qualities or a reputation that are due to that place of origin.
Copyright and related rights	Copyright	Copyright is a legal term describing rights given to creators for their literary and artistic works. The kinds of works covered by copyright include: literary works such as novels, poems, plays, reference works, newspapers and computer programs; databases; films, musical compositions, and choreography; artistic works such as paintings, drawings, photographs and sculpture; architecture; and advertisements, maps and technical drawings.
	Related rights (or neighboring rights)	Related rights (or neighboring rights) give protection to those who assist intellectual creators to communicate their message and to disseminate their works to the public at large. There are generally three kinds of related rights: the rights of performing artists in their performances, the rights of producers of phonograms in their phonograms, and the rights of broadcasting organizations in their radio and television programs.

Source: WIPO (2001)

In relation to these kinds of intellectual property rights, some newer forms of intellectual property rights (e.g. breeding rights, maskwork rights and database rights) have been developed. This indicates the ongoing changes in the legal framework of the protection of intellectual property. Although all of these rights are subsumed under the label 'intellectual property rights', sug-

32 Sometimes trade secrets are included in the list of intellectual property rights as well because they also are a form of intellectual property that could be protected by legal rights, although protectability and form (or formality as described above) fundamentally differ from other forms of intellectual property rights.

33 The basic requirements for patentability are novelty, inventive step and industrial application (see e.g. Bainbridge, 2002 for a more detailed elaboration).

gesting some coherence, they in fact comprise a very heterogeneous set of rights with fragmented historical developments. Therefore, they hardly constitute to what could be called a (coherent) intellectual property rights system (Granstrand, 2003).

Although in Table 9 trade secrets are not given as a form of intellectual property right[34] (i.e. by WIPO, 2001), a trade secret is still a (possible) protection tool for intellectual property in some way. The importance and implication of the use of patent and trade secrets will be discussed in the remainder of this chapter by discussing the strategies that can be develop with regard to intellectual property and the main consideration in relation to this. The main focus of the remainder of the report, thus also in the tension field (Chapter 4) and the case studies (Chapter 5), is on patents and trade secrets because these are the most important forms of intellectual property. Moreover, trade secrets are after patents the most used method of protecting intellectual property (see e.g. Hertzfeld, *et al.*, 2001). The use of trade secrets and especially patents is of crucial importance for the protection of knowledge in R&D collaborations.

After the explanation of the (legal) framework of intellectual property, the obvious question is how one can make use of or apply this intellectual property. Intellectual property has become an important aspect in the business of present firms, especially in (high-) technology-related industries[35]. As explained above intellectual property can be bought, sold, given away, leased and exchanged within the legal protection framework. These characteristics have given rise to a strong position of intellectual property in the present economy with a rising value of this kind of property. Some examples of this are given in Table 10.

Table 10. Examples illustrating the rising importance of intellectual property

The Coca-Cola Company protects its recipe by trade secret, making it a huge company with enormous world-wide sales. Consequently, its trademark is one of the most valuable ones in the world (estimated around 50 billion US Dollars).
Some of the top corporations file and are being granted with over a thousand patents each year; e.g. IBM that was being granted 1742 patents in 1997 (Granstrand, 2000).
Infringement cases have had damage claims of around one billion US Dollars; e.g. the infringement case in 1991 in which Eastman Kodak had to pay Polaroid 909 million US dollars as damages (including interest) for 'willful' infringement of several of its instant-camera patents (Chesbrough, 2003b).
The corporation Philips' patent office has over 500 people employees and additionally out sources an additional amount of (legal) work (Bekkers, 2004).

These examples illustrate the importance and economic value of intellectual property. Although some of them are rather extreme cases, the role of intellectual property has become a very significant one in our present economy. One context in which intellectual property can have a

[34] The World Trade Organization (WTO) for example makes the same distinction between copyright and industrial property but does include trade secrets in the latter branch of intellectual property rights (http://www.wto.org, 2004).

[35] More detailed considerations on how intellectual property (rights) can be implemented in the overall business strategy can be found in, for example, Lee and Davidson (1993), Parr and Sullivan (1996), Rivette and Kline (1999), Granstrand (2000), Sullivan (2000), Teece (2000), Arora, Fosfuri and Gambardella (2001), and Poltorak and Lerner (2004).

crucial role (within the broad corporate strategy) is in the case of R&D collaborations. As discussed in the previous chapter, some trends (e.g. the increasing number of participants and university involvement, importance of public funding, internationalization, mutual dependence) can make the importance of intellectual property even more considerable.

One important consideration with regard to the protection of an innovation and thus in the overall intellectual property strategy is the choice between filing a patent and adopting a trade secret. Some of the main considerations in this decision are if patent protection *is* available, if it *can* be kept secret, the life expectancy of the technology (and the duration of the protection), the relation to other patents, risk of losing the protection, the cost of obtaining, maintaining and enforcing the protection, the technology readiness, and the licensing possibilities (Lee and Davidson, 1993). It can be noted that trade secrets have important similarities with intellectual property rights as described in Section 3.3.1. The main point is that a trade secret is an asset based on and embedded in technology (most typically a process technology) and/or people's mind. In the latter case it might or might not be possible to make it explicit or codify it. If this *is* possible, it can be protected and thus transacted more easily. Due to the properties of knowledge, it can be hard to protect and therefore trade secrets might be difficult to enforce. In relation to R&D collaborations, in which the sharing of knowledge is at the heart of its existence, knowledge has to be revealed even if it is difficult to protect (or enforce protection). But still trade secrets can be used, for example by formally agreeing to keep some knowledge secret (to the outside).

3.3.4 Patent Strategies

Because of the importance of patents in general and in R&D collaborations in particular, it is important to consider the main strategies a firm has to exploit is. Once a firm (or individual) is granted a patent, it basically has two main strategies in using or exploiting it as illustrated in Figure 10. The first one is to keep the patent itself. Once this decision is made, two options remain, namely to use it or not to use it. A firm generally develops a certain intellectual property, in this case embodied by a patent, in order to use it, although it can decide not to use it for strategic reasons. A main consideration in this is the (administrative) costs involved getting and keeping a patent right. Though, again, non-use remains an option, for example when a firm wants to block the development of a rivaling technology of a competitor or keep the option to enter in a market at a later stage. A consideration that could also be made is whether the firm wants to license it out, while it doesn't use the patent itself. The other option a firm has (in addition to non-use), is that it *can* use the patent. It can in this case decide to solely exploit the patent (or technology in general), as Philips does with its shaving technology. Alternatively, it can decide to license out (for various reasons, e.g. strategic considerations, royalty income or standard setting), as Xerox did with its Ethernet technology or as JVC did with its VHS technology. This generally creates an additional competitor to the market, although complementary technologies or services could also be provided. In any case, the exact licensing agreements are of interest. One of the main considerations in granting a license is whether to make the license exclusive or not. This is discussed in the next section. The second main strategy, to sell the patent, involves the transfer of the right to the intellectual property, i.e. the transfer of the entire patent. The reason to transfer this right could for example be the risk of litigation and/or the fact that the firm is not interested (anymore) in the patent.

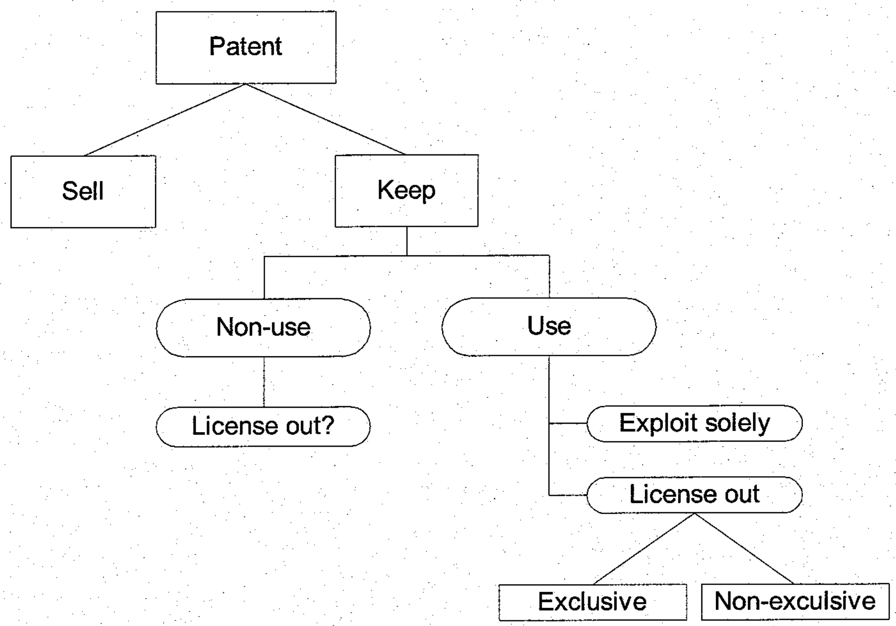


Figure 10. Patent strategies

Figure 11 gives the strategies explained above by taking the viewpoint of the transfer between the two (collaborating) parties. Mainly for illustrative reasons, Figure 11a is included, in which the owner of the intellectual property right, i.e. patent, decides to keep it and thus no transfer takes place (like in the case of Philips's shaving technology). Figure 11b shows the case in which the owner (that now becomes the seller) sells the entire formal intellectual property right as such, in this case a patent as a whole, which is then being transferred to another party, the buyer. The appropriate compensation for this transfer has to be considered, i.e. what the seller receives in return, and will depend on various market and technology factors (such as strategic importance and uncertainty). This compensation can be monetary or not (e.g. the exchange of rights) and can theoretically be for free. The same consideration, though obviously in a distinctively different way, has to be made when the patent right is licensed out, see Figure 11c. This patent strategy entails the licensing of its rights. All the rights, i.e. use, exploit *and* sell, can be licensed or just one specific right, e.g. use, exploit *or* sell. Moreover, the right can be transferred within a designated geographical area, such as a country, or for a limited amount of time. This is also related to the exclusivity of the right (see Figure 10 and the following section). Most typically, the licensee will be granted with a specific, well defined right. The strategy of licensing is especially relevant in the case of R&D collaborations and will therefore be an important focus of this study. The next section elaborates on the concept of licensing in more detail and develops an overview of different licensing strategies.

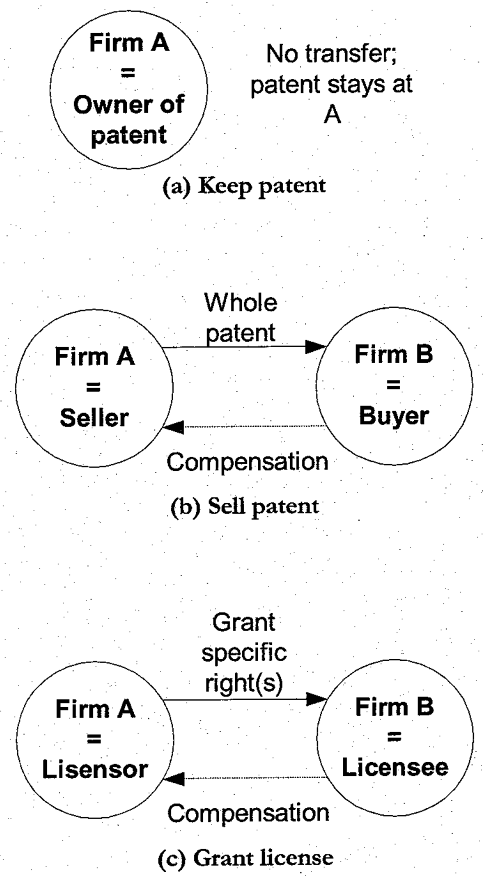


Figure 11. Transfer of rights in patent strategies

3.4 MAIN DIMENSIONS OF KNOWLEDGE PROTECTION

Knowledge protection takes an important place in a firm's corporate strategy in general as well as in its R&D collaborations in particular. The properties of knowledge are shown to highly determine the possibilities and constraints for firms to transfer knowledge. This transfer also entails the protection of the knowledge. It is the nature of knowledge, especially its (semi-) public good character, which causes an inherent tension between the disclosure and protection of knowledge. In relation to this, it is important to consider which body the knowledge takes because this highly determines how it can be transferred and therefore how it can and should be protected. Therefore, the embodiment of knowledge appears to be an intermediate dimension between knowledge sharing and protection.

Table 11. Main dimension of knowledge protection

Knowledge embodiment
IPR (patent)
Technology
People
Routines

Table 11 gives the different embodiments knowledge in R&D collaborations can take. In this context, it is important to distinguish technical from non-technical knowledge. Whereas all four embodiments can in principle be technical, this applies to 'routines' just to a minor extent. Routines are mostly related to organizational structures and interaction between people (and organizations). The other forms of embodiment however deal with knowledge as being technical knowledge embedded in a patent, a technology or people's minds (or a combination of these) and highly relate to 'R&D' characteristic and therefore the importance of (technical) knowledge.

In relation to the body of knowledge, its characteristic as intellectual property should be considered. This highly refers to the embodiment of knowledge in an intellectual property right (especially a patent), which is important in R&D collaborations as well. Therefore, in order to answer research question C (Section 1.4.3), which was 'Which dimensions can be identified with regard to the way a firm can protect its knowledge in R&D collaborations?', it can be said that the embodiment of knowledge is one of the dimensions that comprise the tension field of knowledge sharing and protection. It is an intermediate dimension between the sharing and protection of knowledge, and is determined by the characteristics of knowledge. The concepts of intellectual property and intellectual property rights moreover relate to these characteristics and give insight in which strategies a firm can adopt to exploit its knowledge (e.g. by protecting it).

In this sense, licensing plays an important role. Licensing is a way to arrange the protection of knowledge while it also creates the diffusion of knowledge. It can furthermore be used as a means to share knowledge. Therefore, it can be an important means to cope with the tension field of knowledge sharing and protection (or at least to go about the protection of knowledge). For this reason the following section discusses some main licensing possibilities and elaborates on potential licensing strategies.

3.5 LICENSING

3.5.1 *Licensing Schemes*

Coming back to the third form of patent strategies as described in Section 3.3.4 (Figure 11c, i.e. granting a license), this is an important concept on its own and entails various strategies itself. Again, licensing is a transfer of rights from a licensor, typically the owner of an intellectual property right, to a licensee. For the former it is a means to exploit its intellectual property while at the same time controlling the use or diffusion of it. The latter can use the intellectual property without any fear of being sued for infringement. To be sure, all the different kinds of embodiments (of technical knowledge) identified earlier might be licensed. This licensing can involve the different kinds of embodiment. For simplicity reasons, the remainder of this section will use the term 'technology' as the licensing subject, because in this sense technology can also embed a patent and/or know-how.

The licensor can license out all or just some of the rights and will consider which restrictions to use. Two of the main considerations in relation to licensing are exclusivity and whether the licensee has the right to sublicense. Although this chapter principally takes the perspective of a two partner case (for the sake of clarification), these issues by definition involve more actors. The effect of this is made clear later where appropriate. It is furthermore important to keep in mind that licensing forms other than the 'traditional' ones can be used. One important example of this, in relation to the increasing interest in the Open Source Model and the Free Software Foundation, is the GNU General Public License that intends to guarantee one's freedom to share and change free software by obliging the transfer of the source code and all the right to use and modify the software (the source code in particular). Section 3.5.2 will return to this issue. First some of the different considerations regarding licensing and some different (general) licensing forms will be discussed.

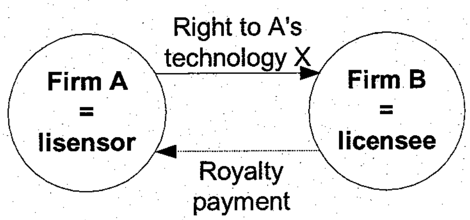


Figure 12. Ordinary licensing

In order to benefit from licensing, the licensor receives a *compensation* of some sort. In the more ordinary, traditional way of licensing, the payment of (monetary) royalties can be seen as a good means of compensation (see Figure 12). This especially holds in the case a licensor is interested in directly generating revenues. The concept of royalty means that the licensee pays a fee to use the licensor's intellectual property right under the license. Different kinds of monetary royalties that be distinguished and are summed up in Table 12. In addition to the kinds of royalties mentioned, other (payment) arrangements can be agreed upon. Alternatively, the licensor can be compensated in other non-royalty (non-monetary) ways, such as access to the licensee's technology.

Table 12. Kinds of monetary royalties

Lump sum payment
Fixed payment per sold product
Fixed fee per year
Percentage of whole sale price
Gradual payment that changes per sales volume

In the case two parties are interested in each other's technology and both of them have an intellectual property rights portfolio of interest to each other, they could agree on a *cross-licensing* arrangement. In this agreement, the parties go into a mutual agreement granting each other (a package or bundle) of licenses. This concept is shown in Figure 13. Essentially, the firms license each other with the compensation being a license, or in fact a package of licenses. Therefore, they are both licensor and licensee (of each other's intellectual property rights) at the same time. Although cross-licensing principally can involve the exchange of the right to one technology from each firm, the firms most typically cross-license each other a bundle of rights (i.e. firm A's technologies XYZ and B's technologies UVW). In general, the rationale for cross-licensing to increase simplicity and decrease transaction costs. Moreover, cross-licensing can create a framework in which firms can access each other technology and thereby (collaboratively) create new technologies or networks. The technologies subject to the cross-licensing scheme can be either related or unrelated, which influences the exact terms. The (a)symmetry of the firms' packages affect the exact terms as well and potentially creates the need for additional compensation (of one party).

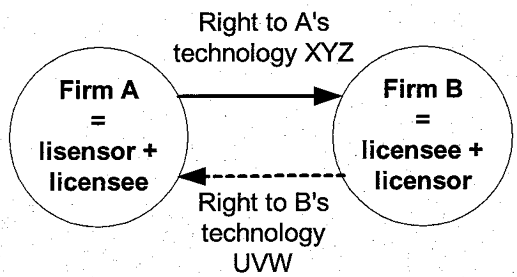


Figure 13. Cross-licensing

An important consideration in relation to licensing is the *exclusivity* of the right. There are two main categories of licenses as illustrated by Figure 14. On the one hand, a licensor can grant an exclusive license by licensing to only one licensee and, on the other hand, he can grant a license to several licensees. Whichever option is considered, it has important implication for the negotiations and thereby compensation. Some possible restrictions are: no right to sub-licensing or re-selling, geographical area, field of application, or a specific mode of commercialization (see e.g. Bessy and Brousseau, 1998). With regard to the exclusivity this means that the main sorts of exclusivity which can be granted are per area and per application. In addition, an exclusive right for a limited period of time could be granted.

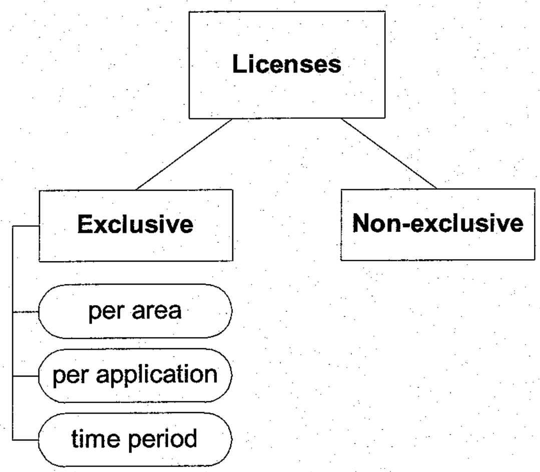


Figure 14. Exclusivity of license

The issue of exclusivity again relates to the patent strategies as shown in Figure 10. Exclusivity is therefore an important consideration from a practical (financial) and strategic point of view, as well as from a legal point of view. As already discussed in Section 2.5, agreements that hamper competitiveness and innovation are prohibited by Article 81 of the EC Treaty (given in

Table 7). This also applies to technology transfer or licensing agreements. It therefore has to be taken into consideration if a license agreement is subject to this article, which can especially be the case for exclusive licenses. Moreover, sometimes an owner of an intellectual property right can even be obliged to grant licenses. However, as already stated in Section 2.5, licenses in (pre-competitive) R&D collaboration are generally subject to the Block Exemption that can be derived from Article 81(3).

Another important consideration, as mentioned above, to be made is whether the licensee is allowed to *sub-license* (see Figure 15), meaning that the licensee itself is allowed to grant licenses (i.e. on the licensed technology) to third parties. The decision to allow sub-licensing depends on what the licensor wants to achieve by its licensing. For example, if the owner of an intellectual property right is not able to fully exploit a technology himself, it can for this reason grant an (exclusive) license to a licensee that will commercialize the technology. In order for the licensee to be able to appropriately exploit the technology, sub-licensing should be part of the agreement (Megantz, 1996). This strategic decision can give the main licensor the ability to profit from its technology when it has not got the resources to perform this commercialization itself. Alternatively, sub-licensing can be considered if the licensor exploits the technology himself. Although this will increase the complexity of the contract and potentially increase the monitoring costs, sub-licensing could be favored to stimulate the development of a technology or to increase revenues, for example.

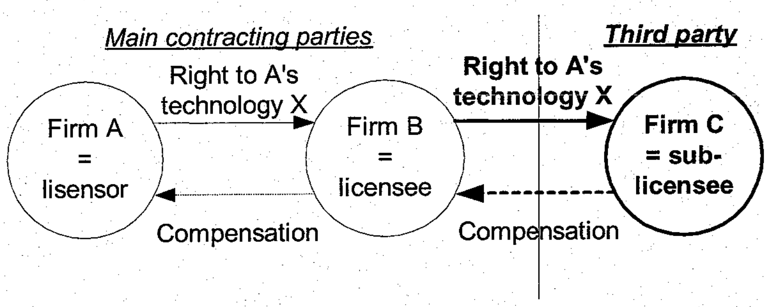


Figure 15. Sub-licensing

An owner of intellectual property rights can also consider the concept of *packaging* (Figure 16) in which it licenses certain rights as a package. In this case, the licensee has to buy all the licenses at once in order to access the individual rights. Packaging can lower transaction costs if several licenses are required to use a certain technology. It can also be a means for a licensor to create additional revenues or an attempt to force a certain development. Alternatively, it is possible that a package of licenses has to be granted, if the owner of the rights does not consider itself to be able to exploit these.

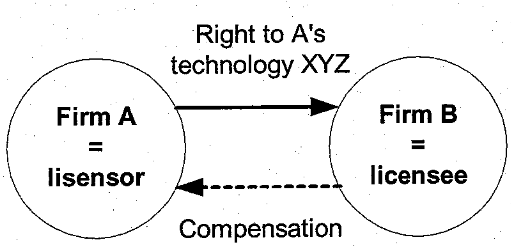
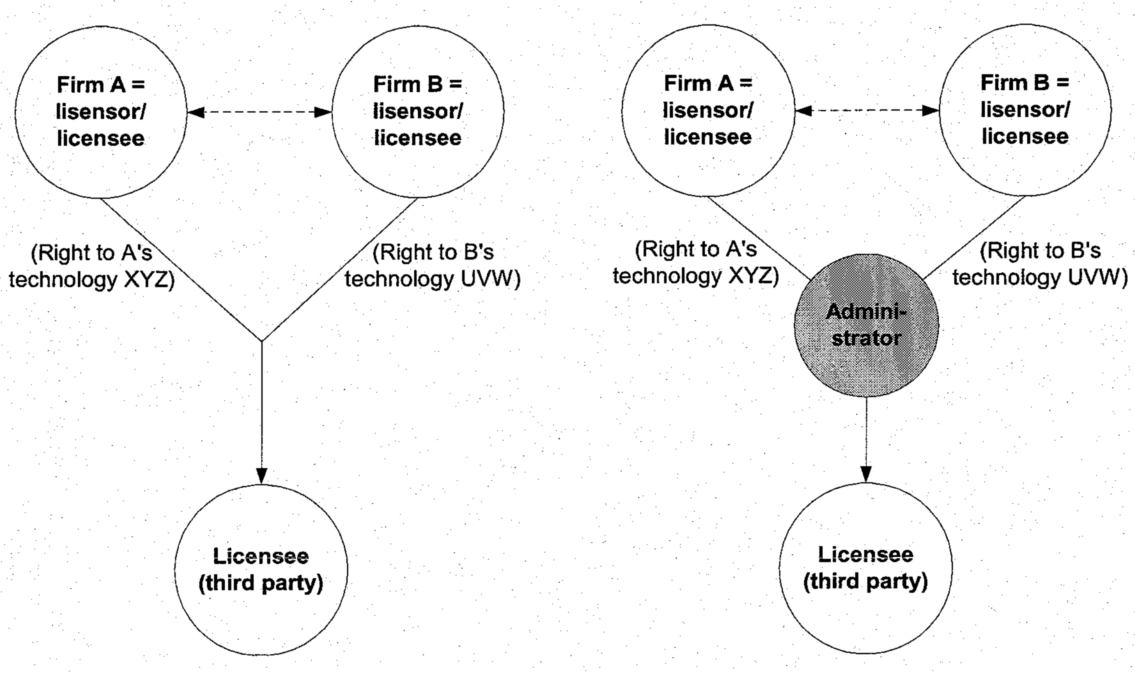


Figure 16. Packaging

Another licensing scheme can be referred to as *joint licensing*. This strategy can be relevant if there are several different holders of intellectual property rights that are needed for a certain development. In the case of patents, joint licensing takes the form of a patent pool. Essentially, joint licensing can take two forms. One is that the two partnering firms both, in a coordinated manner, license a right to a third party. In this case one of the licensing firms often acts as a licensing administrator. In the other case there is an (independent) third party that acts as administrator. Both situations are illustrated in separately in Figure 17.



(a) Joint licencing *without* adminstrator

(a) Joint licencing *with* adminstrator

Figure 17. Joint licensing

One final possible licensing schemes, is a *grant-back license*[36] (Note: X2 builds upon X1

Figure 18). This is a provision which gives the licensor the right to use (any) possible future technological improvements that the licensee makes to the originally licensed technology, usually in combination with a compensation of some sort. So, once the licensee took out a relevant patent to this improvement, the mutual relation in this case consists of a license going both ways. In other words, the license grants a (possible) license. The right for the licensee (firm B) is only related to a specific, defined technology (say technology X1) of firm A, and the license that is being granted back (from B to A) is related to improvements of that same specific, defined technology (say technology X2). Furthermore, the two firms can decide to more specifically define the scope of the grant-back. Some possible distinctions are granting back the property rights on the development, or just the user rights, or alternatively they could agree on just a simple information right (Bessy and Brousseau, 1998).

[36] Also referred to as 'technology flowback' in some literature.

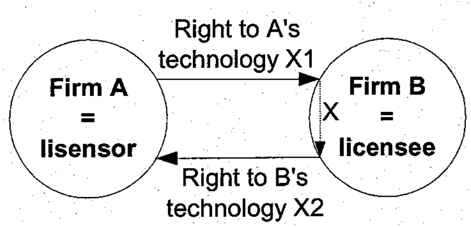


Figure 18. Grant-back licensing.

3.5.2 Licensing Strategies

As discussed above, the role of knowledge is becoming of essential importance in economic activity and it moreover takes a central place in R&D collaborations. The specific properties of knowledge moreover have important implications for how firms deal with knowledge transactions. Because knowledge has different embodiments, it can be protected in different ways. As described before, licensing is an appropriate way to transact less tangible property. Section 3.5.1 gives an overview of possible licensing schemes. In the context of licensing, the most typical body of knowledge that can be licensed is an intellectual property right, although a technology or know-how (potentially in the form of a trade secret) are licensed as well. More tacit knowledge such as know-how is generally much more difficult to license. But in any case the concept of licensing becomes extremely important and has important implications for R&D collaborations. On a more general level, a licensing strategy can be an important element of a firm total intellectual property strategy and therefore in turn in its corporate strategy.

In the case or R&D collaborations, especially the licensing of intellectual property can be of importance. Most specifically, this relates to patents and also trade secrets. The strategy of a firm with regard to its R&D collaborations is thus part of its more general licensing strategy and in its even more general corporate strategy. This clearly relates to the fact that a knowledge-based firm has to acquire and exploit its knowledge-base. All of this can again be seen in the wider context of 'markets for technology' (e.g. Arora, *et al.*, 2001). This means that the market or business environment in which a collaboration takes place also has to be considered. The mere existence of collaborations additionally indicates that firms consider conducting R&D either in-house or in the market place. This also counts for more general acquisition and exploitation strategies.

In relation to a firm's licensing strategy, especially if it takes a more central role in a firm's corporate strategy, licensing can be an important means to generate revenues and to access external technologies (Grindley and Teece, 1997). In this sense cross-licensing becomes an important issue. Cross-licensing as discussed in Section 3.5.1 (Figure 13) as a more general licensing strategy creates an alternative mechanism to in-house development.

In order to adopt the right licensing strategy, a firm has to consider how it can best appropriate the returns form its intellectual property. In R&D collaborations it is also important that both the firm and the collaboration as a whole can best benefit from a certain strategy. Coming back to the different embodiments of knowledge, it can be said that highly codified knowledge, e.g. a patent, will be preferably licensed, if it is not context-specific (Williamson, 1991a; Kogut and Zander, 1993). For knowledge embedded in technology, licensing seems to be less appropriate in general although it can still be used to appropriate returns (Teece, 1998). Which strategy is the best will also depend on the sector in which a firm is active. The importance and efficiency of technology and patents differs across sectors and therefore also the use and benefit from licensing. For example, it is argued that in the chemical sector patents work efficiently (e.g. Levin, Klevorick, Nelson and Winter, 1987). In the electronics sector moreover licensing (i.e. the right licensing strategy) of technology and patents can create a *de facto* standard due to the creation of a certain mass and the inter-operability.

Because firms (especially large ones) have entered an era of open innovation (Chesbrough, 2003a, 2003b) the licensing strategies changed as well. There are many examples of firms opening their boundaries in order to strengthen their intellectual property portfolio (see e.g. Arora, *et al.*, 2001; Chesbrough, 2003b). The presence of a more open innovation paradigm has positively affected the number of collaborations. This is related to the concepts of package licensing and cross-licensing. Taking the Open Source Model into consideration, less restrictive licensing strategies can moreover be identified. This kind of model entails the use of non-exclusive, royalty-free licenses with a grant-back provision. Dependent on the exact design, a form of (local) cross-licensing may moreover be adopted.

Overall, some of the main strategy considerations in relation to licensing are exclusivity, sub-licensing, cross-licensing, requirement of additional licenses, market and territorial (and other) restrictions, future developments, technical assistance, royalties, restraint of trade, and taxes (Megantz, 1996). In relation to R&D collaborations, the characteristics of the collaboration also determine which licensing strategy can and should be adopted. Licensing from universities for example is significantly different from industrial licensing (Megantz, 1996). In general, universities take a very open and therefore publishing-oriented strategy, although changes in this occur as well. With regard to R&D collaboration the different approached could cause some problems. The other strategy consideration might apply to R&D collaborations as well and therefore the licensing possibilities as well as the goals (of the licensing strategy and the collaboration in general) have to be considered.

3.6 Discussion and Conclusions

In order to answer the question 'which dimensions can be identified with regard to the way in which a firm can protect its knowledge in R&D collaborations' (i.e. research question C of Section 1.4.3), the following can be said. The trends in Section 3.2 show that this issue receives a lot of attention from both industry and academia as well as policy makers, and this issue is becoming of increasing importance. It is clear that the properties of knowledge highly determine the way and extent to which it can be protected (while it is shared). Especially the (semi-) public good nature becomes apparent in this. To answer the question the question, it is important to consider the explicit role of knowledge in R&D collaborations. Therefore, the embodiment of knowledge is the main dimension that can be identifies with regard to a firm's knowledge protection in R&D collaboration. These different forms of embodiments to a large extent refer to 'technical knowledge' which is the main asset in an R&D collaboration. The three main technical embodiments are (from least to most tacitness) (a) knowledge embodied in an intellectual property right (most typically a patent in the case of R&D collaboration), (b) technology (which can be a process or product, or alternatively refer to the outcome of a technology such as test results), and (c) knowledge embodied in people's minds (also referred to as 'know-how'). A fourth form of embodiment, which is less technical, is knowledge embedded in 'routine'. These routines can be formal or informal and relate to procedures, rules, instructions and culture. In some instances the boundary with know-how is fuzzy, especially in relation to technical routines. In any case, some sort of 'collaborative routines', referring to a skill to collaborate' might influence the way firms protect *and* share their knowledge in R&D collaborations. Therefore, there seems to be an important relation between the embodiment of knowledge and the relational dimension, through the sharing and protection of knowledge.

It is important to note moreover that the industry setting seems to be important to consider because of the different characteristics (in relation to knowledge and knowledge protection) in various industries. In some industries intellectual property rights appear to 'set the rules of the game'. Moreover, it is argued that in some industries a patent thicket arises that could hamper innovation and growth. In any case, the intellectual property rights framework changes over time in order to address new developments.

This chapter shows that the specific properties of knowledge are extremely important to take into consideration when it has to be protected while transferred. The fact that is has to be protected relates to the importance of knowledge for firms in the present economy. Knowledge is a firm's main competitive asset and highly determines the advances of the (knowledge-based) economy in general, as also shown in Chapter 2. Some trends (identified in Section 3.2) show that knowledge as intellectual property to a large extent and increasingly determines the efforts of firms to protect their knowledge.

Although it is argued that intellectual property rights, and patents in particular, can create a 'protective era' and even an 'overshoot' of patenting, a countertrend can be identified as well, namely the increasing interest of innovation models that put the emphasis on 'open sharing' of knowledge. In this sense, licensing seems to play a less significant role although the open and free sharing strategy could in fact be translated into specific licensing schemes as discussed above. Some of the main consideration in relation to licensing are the payment of royalties, exclusivity, right to sub-license, cross-licensing, requirement of additional licenses, market and territorial (and other) restrictions, future developments, technical assistance, and (legal) restrictions. In this context, it is important to realize that intellectual property rights are not the only embodiment that can be licensed, but technology and know-how as well. Moreover, intellectual property rights are not the only incentive to innovate in the economy (e.g. Gallini and Scotchmer, 2002) and will therefore not explain the 'entire story' of knowledge development in collaborations.

Licensing is thus important to deal with the protection of knowledge while it is shared. In a way, it is not more that an agreement for the transfer of a piece of knowledge (i.e. an intellectual property right, technology or know-how) between two or more parties. This does not mean however that its impact is insignificant. On the contrary, the use of licensing gets more and more important and it is moreover argued that a 'pro-licensing era' arises (e.g. Granstrand, 2004a). In relation to R&D collaborations is has to be investigated how the sharing and protection of knowledge in R&D collaborations can be 'combined' in the exchange of knowledge. Thereby it becomes clear how the specific properties of knowledge shape knowledge sharing and protection. This in turn facilitated the possibility to investigate how firms can deal with knowledge exchange in R&D collaborations and consequently which strategies and agreements can be developed for this.

4 Tension Field of Knowledge Sharing and Protection

4.1 INTRODUCTION

As Chapter 2 shows there are different perspectives on how firms act and evolve over time. These perspectives themselves also went through a change, due to new insights and changes in the economy. Especially in the approaches that take intellectual capital as the main (competitive) resource, i.e. the knowledge-based and technology-based view, the main emphasis is on knowledge or technology (as being a special form of knowledge). Chapter 2 also shows that firms have to develop their resources, for which R&D collaboration is one possible strategy. The sharing of knowledge is obviously at the heart of this. The characteristics of the firms, the environment and the knowledge itself therefore determine the effectiveness of this sharing. As described in Chapter 3, firms face a (logical) need to protect their knowledge from unwanted appropriation, especially as this knowledge is their main competitive asset. The embodiment of knowledge takes an important role in how firms can protect their knowledge in R&D collaborations. The body of knowledge, as the intangible or intellectual form of property, gives constraints to how it can be protected. Intellectual property strategies, with a central role for licensing, play an important role in this. Furthermore, knowledge embedded in people's minds is an essential kind of knowledge in R&D collaborations but is difficult to transfer and appropriate. The combination of patenting and licensing is in turn an important means to establish the protection of knowledge while, at the same time, sharing it. Different considerations exist and various strategies are possible, as shown in Chapter 3.

This chapter deals with the tension that arises when firms want to share knowledge in R&D collaborations but also have the need to protect it. It therefore answers research question A (Section 1.4.3) that asks which dimensions comprise the tension field of knowledge sharing and protection in R&D collaborations. The different dimensions identified in Chapter 2 and Chapter 3 are used to determine what these dimensions are and the next section develops a model that characterizes the tension field by using these dimensions. This chapter furthermore investigates the main considerations for firms that effectively want to cope with the tension field. As touched upon above, the characteristics of the collaborating firms and of the knowledge, among other things, determine how the partners can go about the sharing and protection of knowledge. Section 4.3 gives the considerations and framework that can be used to investigate how firms cope with the tension field and it thereby develops the main strategies a firm can adopt in R&D collaborations. Hereby research question D, which asks what strategies exist for firms to cope with the tension field of knowledge sharing and protection in R&D collaborations, is answered. Moreover, propositions are developed to investigate in which conditions of the tension field a certain coping strategy occurs.

4.2 TENSION FIELD

4.2.1 *Identifying the Tension Field*

Thus far it has become clear that sharing – and more precisely the transfer and combination – of knowledge is at the heart of R&D collaborations. It is also clear that this knowledge comes from the knowledge bases of different firms (or organizations in general) that all have the individual need to protect their knowledge because it is their main competitive asset. Moreover, the protection of knowledge can frustrate the effective sharing of knowledge, which is in turn the main goal of the collaboration. Therefore, there appears to be some sort of paradox although this might just be an apparent one because these two elements (i.e. sharing and protection) may – and will even have to – go hand-in-hand in collaborating with others in order to reach the partners' common goal.

Although this issue is inherent to the nature of collaboration, it has not been identified that explicitly yet (McEvily, *et al.*, 2004). Attention has been given to the rationales for setting up collaborations (Narula and Hagedoorn, 1999), to the determinants for learning through collaborations (e.g. Kale, *et al.*, 2000) and also to the mechanisms that can establish an appropriate transfer of knowledge (e.g. Gulati and Singh, 1998). Especially the latter issue relates to the tension that exists between the sharing and protection of knowledge, i.e. the paradox as mentioned above. More specifically, setting up an appropriate governance mechanism creates an important means to manage the flow of knowledge between different partners of a collaboration (Mohr and Sengupta, 2002). This is required because of the tension that exists between the sharing element and the protection element that is involved in this flow or transfer of knowledge. This tension can be defined as the potentially conflicting and counteracting forces of the sharing and protection of knowledge, in this case in R&D collaborations. The tension field is therefore the set of dimensions and their relations that play a role when firms want to share and protect their knowledge in R&D collaborations. The remainder of this section identifies the tension field of knowledge sharing and protection. In order to do this, it is important to consider the (relative) position of both knowledge sharing and protection in R&D collaborations. In relation to this, the main dimension and their relations are positioned within the tension field by developing a model that shows the main dimensions as well as their relation to each other en knowledge sharing and protection in particular.

4.2.2 Main Dimensions in the Tension Field

From Chapter 2 it becomes clear that the role of knowledge has become very significant in the present economy and therefore also in R&D collaborations in particular. As said before, the exploitation of resources is at the heart of the firm's activities, which can also be seen in relation to learning or knowledge sharing. In the case of R&D collaborations, a firm wants to use its own knowledge in combination with the knowledge of the other partner(s) for some kind of technical development. The characteristics of knowledge are therefore at the core of R&D collaborations. The properties of knowledge moreover explain which implications this has to protect it. The way knowledge can be transferred, which involves both sharing and protection, is thus highly determined by the characteristics of this knowledge. This means that the role of the knowledge that is put into and developed during the collaboration takes a central place in the tension field of knowledge sharing and protection.

The main dimension of importance in the tension field of knowledge sharing and protection is therefore the 'knowledge characteristics'. As described in Section 2.4 (Table 6) these characteristics are complementarity, tacitness (vs. explicitness), codifibility, imitability, the systematic nature of knowledge, teachability, complexity, newness and specificity of the collaborating firms' knowledge. In relation to the tension field of knowledge sharing and protection, these characteristics are important because they determine how and to what extant knowledge can be shared and thereby also give possibilities and constraints to protect it. If a piece of knowledge has to be transferred, the codifibility of it for example has important implications for how firms can share and protect this knowledge. The codification of knowledge can be seen as the language that organizations use to 'communicate with each other'. Understanding each other involves being able to interpret each other's 'code' (by means of previously acquired knowledge) and therefore the other knowledge characteristics as well as characteristics of the collaborating firms are an important context for this (e.g. Cowan, *et al.*, 2000).

A second main dimension derived from Chapter 2 is the 'relational dimension'. Within this dimension the element trust plays an important role. The others elements of this dimension – which are commitment, geographical, cultural and technological distance – affect tension field as well and also influence the establishment of trust in particular. The relational dimension is important in the tension field because it deals with the conditions firms apply to the sharing *and* protection of their knowledge in R&D collaborations.

The 'characteristics of the collaboration' itself also affect the tension between the sharing and protection of knowledge. The number of partners can for example hamper the sharing of knowledge because many sunk costs exist in managing of the knowledge flows. The experience of and with a partners as well as its size can moreover influence the way firms go about the sharing and protection of knowledge. If a university (or other research organization) is involved, this can affect the tension field as well because universities are generally more focused on knowledge sharing than protection. The duration of a collaboration can moreover have an effect on the sharing and protection of knowledge, for example though the establishment of trust. Another important element of the characteristics of a collaboration is its nature. The nature of the collaboration refers to the phase in the value chain of firm activities as given in Figure 4 in which the collaboration is active. More specifically it describes the extent to which a collaboration is pro-competitive or pre-competitive, in which the latter case can be divided into exploratory (or research-orientated) or exploitative (more development-orientated and going toward pro-competitive).

The fourth and last dimension that Chapter 2 identifies is the 'environmental dimension'. In this dimension the sector in which the collaboration takes place and the uncertainty of the market are important elements.

Chapter 3 moreover concludes that the properties of knowledge take a central place in the tension field and that the embodiment of the knowledge is the main dimension to explain knowledge protection in R&D collaborations. The different 'knowledge embodiments' that are identified are knowledge embodied in (a) intellectual property rights, (b) technology, (c) people and (d) routines. The first three embodiments mainly refer to technical knowledge whereas routines also refer to the concept of 'collaborative routines'. The existence of this concept is reinforced by Adler (2002) who states that, in addition to the market and the hierarchy, a third form of coordination mechanism based on trust and community will become more important in the knowledge-intensive economy. Moreover, he argues that this form of trust is new; instead of being derived form tradition or loyalty, the new trust is build upon values of competence and integrity. Although this goes being the mere scope of R&D collaborations (e.g. community refers to network-based relations) it shows the importance of the relative position (e.g. in terms of competence) partnering firms have towards each other. Relating this to R&D collaborations it means that these collaborative routines, which are built up by (among others) competence and trust, are an important element in governing the knowledge transfers in the collaboration. These routines can contain knowledge of how to perform a certain (collaborative) task from both a technological and personal point of view. In this sense, routines can be formal such as rules and procedures or informal such as culture and instructions.

These five main dimensions (i.e. knowledge characteristics, knowledge embodiment, relational dimension, collaboration characteristic and environmental characteristic) are in some way related to each other and in that way comprise the tension field, as shown in the next sub section.

To give an example of the importance of these dimensions and their relations, consider the uncertainty to estimate the value of the knowledge. Based on the properties of knowledge, this concept can possibly create opportunistic behavior. This makes uncertainty one (general) force in the tension field, both affected by the other dimensions in the tension field and affecting them at the same time. Valuation of knowledge (see e.g. Granstrand, 2000; Sherry and Teece, 2004) – and of the licenses or agreements that are used to transfer it – is a very delicate and difficult, though crucial, issue in R&D collaborations[37]. It will therefore to a certain extent determine the tension that exists between the sharing and protection of knowledge. The valuation problem may increase transaction costs because of the difficult and perhaps manifold negotiations that have to take place. An additional problem is the 'disclosure dilemma' (Arrow, 1962) which refers to the fact that a (potential) transferor or seller of knowledge or information explicitly has to show its knowledge to the receiving party. In other words, knowledge cannot be shared without its content being shown in the negotiations. This is an especially delicate issue for trade secrets and patent that have been applied but not yet granted.

A factor significantly contributing to (partly) solving this valuation problem refers to the relational dimension of a collaboration. If the technological distance between two sharing partners is low, which is the case if they are direct competitors, they will be very careful and reserved in showing their knowledge before any actual agreement is made. Therefore, it is important to make a distinction between competitors and other partners (Dubois, 2004). Something that could solve this problem – and relates to one of its main rationales – is the establishment of trust. In this, some level of general trust offers a solution but most specifically 'collaborative trust' can contribute. One factor that influences this collaborative trust in a positive manner is previous (collaborative) experience with a partner, although this increases the probability of potential negative experiences (with this partner) as well. Gulati (1995) already shows that repeated collaboration indeed breeds trust in the relationship (which again positively influences the establishment of a collaboration). And a low technological distance and a high geographical distance could furthermore hamper the establishment of trust. The concept of trust is also related to learning, which is an important concept in general as well as in R&D collaborations in particular.

4.2.3 Modeling the Tension Field

As described above, the characteristics of knowledge take a central place in the tension field of knowledge sharing and protection. These characteristics clearly determine how knowledge can be shared and how it can be protected. They also give the exact embodiment this knowledge takes, most specifically through the tacitness characteristic. As described in Chapter 3, this embodiment determines how knowledge can be protected and because firms have the need to protect their knowledge they will consider which embodiment the knowledge put into the collaboration has. The embodiment of knowledge moreover is related to the concept of sharing knowledge because it is the body with which a piece of knowledge can be shared.

---

[37] Intellectual property, or intangible assets in general, can have great value, whether used in arm's-length transactions or within a collaboration. And although there are considerable efforts to solve the 'valuation problem', it remains a topic that needs substantial research (Nonaka and Teece, 2001b).

On the other hand, the relational dimension is an important element of the tension field. The importance of knowledge in R&D collaboration has important implications for the relationship between the partners. Because the partners have to be able to communicate with each other in an efficient manner, understanding each other's knowledge is necessary for a successful collaboration. Characteristics such as teachability, complexity and specificity therefore shape the relation between the partners. Moreover, the different knowledge bases have to complement each other, although too overlapping knowledge (i.e. of collaborating competitors) can hamper the establishment of a good and open relationship. The relational dimension thus also has an important relation with knowledge sharing *and* knowledge protection. Trust has an important role in this relationship because it can it can facilitate a good 'knowledge sharing atmosphere', which makes the process of knowledge sharing smoother while the partners take a less protective attitude. And in any case, the fact that knowledge has to be shared demands an appropriate relationship to establish this. And the need to protect knowledge can affect the relationship as well. Trust, as a central element of the relationship, is affected by other relational elements such as the commitment of the partners and the distance (vs. overlap) of them. The relational dimension has an important role in the tension field because it is an endogenous dimension, in contrast to the knowledge characteristics and the knowledge embodiment that are (partly) exogenous. While these three dimensions thus take a central place in the tension field, the relationship is the only one that the firms can directly influence. It will therefore prove to be an important mechanism to cope with the tension field (see Section 4.3).

Another endogenous dimension that is active on a higher level in the tension field is the one of the collaboration characteristics. Collaborating firms can shape a collaboration in such a way that it complies with the idea they have on how to reach the goal of the collaboration. To a large extent the partners are chosen in order to establish a good relationship which can in turn affect knowledge sharing and protection in an appropriate way. The more general shape of the collaboration (e.g. number of partners) and the nature of the collaboration affect the tension field as well. It is furthermore clear that the partners are chosen on the basis of the knowledge they can (potentially) put into the collaboration.

The characteristics of the collaboration as well as the central tension field itself are in turn influenced (on a higher level) by the environmental dimension, which has the sector setting and market uncertainty as two main elements. In the telecommunication sector for example the tension field is partly exemplified by considering the tension between standardization and intellectual property rights (Shurmer and Lea, 1995). The market uncertainty for example relates to the valuation problem as described above.

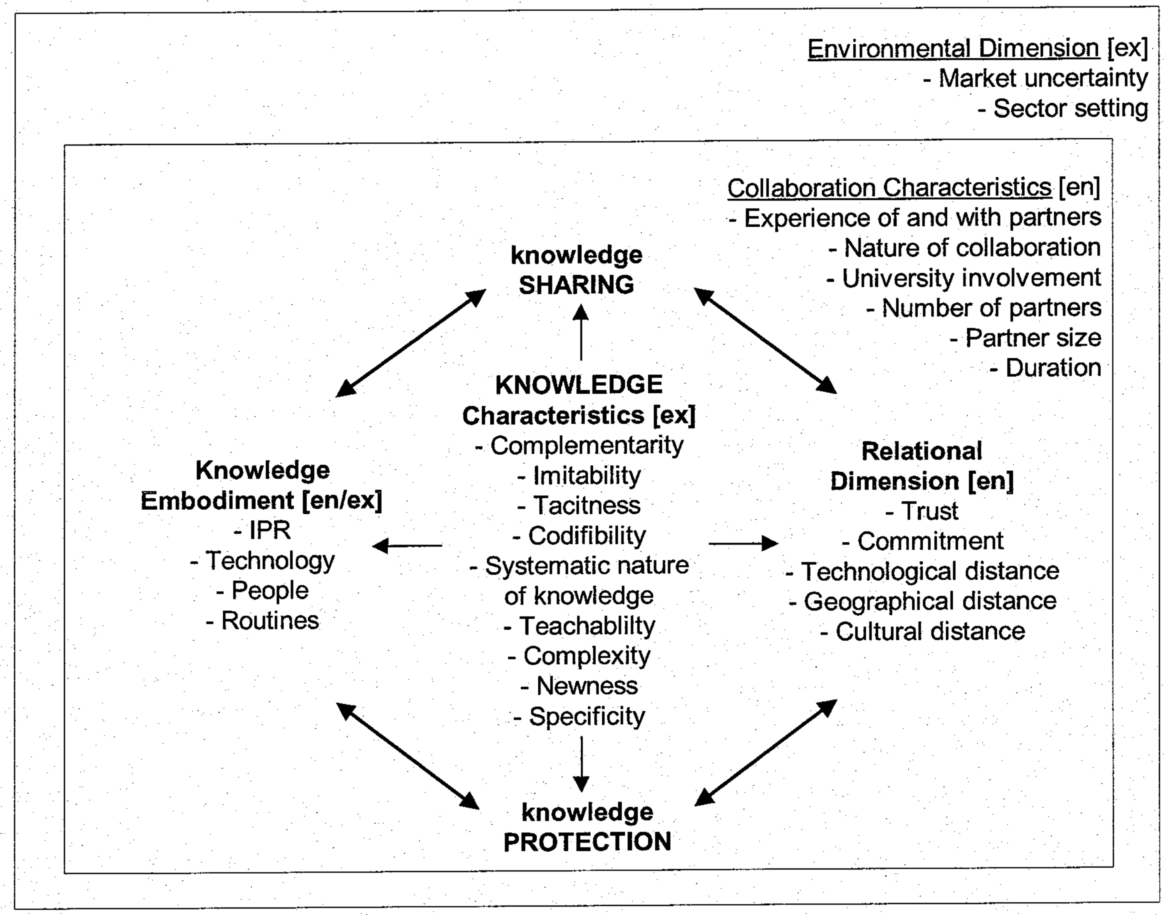


Figure 19. Tension field of knowledge sharing and protection

Figure 19 gives a visualization of the tension field as described above that shows the relative position of the different dimensions. It shows how the two main concepts of 'knowledge sharing' and 'knowledge protection' influence and are influenced by the three central dimensions of the 'knowledge characteristics', the 'knowledge embodiment' and the 'relational dimension'. Furthermore, the 'collaboration characteristics' affect this core of the tension field as a whole. The 'environmental dimension' finally influences the tension field on even a higher level because it affects the central tension field as well as the goal and design of the collaboration. The figure also shows which elements each dimension comprises. The abbreviations 'ex' and 'en' respectively refer to whether the dimensions are 'exogenous' or 'endogenous'. Endogenous and exogenous are defined as whether a firm can or cannot (respectively) influence a specific dimension. Endogenous dimensions can thus be affected by the design of or the effort in the collaboration. Exogenous dimensions cannot be influenced by the collaboration firms themselves but they can still decide to a certain extent to participate in a collaboration with certain (exogenous) characteristics or not.[38]

[38] Knowledge embodiment is considered as being both exogenous and endogenous. On the one hand, it is endogenous because it is the result of R&D which is a process of codification. On the other hand, the knowledge that is put into the collaboration can be considered to be exogenous as the partners have to 'take it for granted'. Because the latter determines the tension field to the largest extent, knowledge embodiment is largely considered to be exogenous for R&D collaboration (in the tension field, that is). A similar argumentation can be given for the 'tacitness' characteristic, which it in fact the main determinant for the knowledge embodiment.

4.3 Coping with the Tension Field

4.3.1 Knowledge Transfer

When applying this tension field on the even more detailed level of the collaboration itself, it becomes apparent that these dimensions in some way determine how the collaborating partners actually go about the sharing and protection of their knowledge. Therefore, it is important to consider how this sharing and protection actually takes place. As already briefly described in Section 2.6, the sharing of knowledge in a collaboration can be divided into different phases. It can be said that at every transfer of knowledge, a piece of knowledge (in whatever embodiment) flows from one partner to the other. The phases in which these knowledge transfers can take place are at the beginning, during, at the end or after the collaboration. The distinction can therefore be made between *background knowledge* as knowledge a partner puts into the collaboration when it starts, *sideground knowledge* as knowledge that a partner develops in-house but uses in some way in the collaboration, *foreground knowledge* as knowledge that is the outcome of the collaboration and transferred to the partners, and finally *postground knowledge* as knowledge developed after the (formal) collaboration had ended. These kinds of knowledge transfer have important consequences for how firms can govern the knowledge transfer and thereby cope with the tension between knowledge sharing and protection. Oxley and Sampson (2004) for example acknowledge that the governance structure used in a collaboration is an important mechanism to cope with "these potentially competing concerns" (Oxley and Sampson, 2004: 723) but they moreover state that this does not exhaust the set of possible mechanisms that are available to the partners. Therefore, they propose an alternative response, namely the reduction of the 'scope' of the collaboration.

One general way to cope with the tension field, which mostly relates to the governance of the knowledge flows in a collaboration is by using licenses (or agreements in general). As stated in the previous chapter, licenses play an increasingly important role in the present industry, as well as in the economy in general. Therefore it is argued that a pro-licensing era might be approaching (Granstrand, 2004a). Licensing is furthermore, on a more general level, considered as being one way to cope with the patent thicket that was briefly described in the previous chapter (Bednarek and Ineichen, 2004). The specific context of an R&D collaboration becomes especially apparent if considering the possibilities to protect one's knowledge. The collaborating partners should therefore have an agreement of some sort for every kind of knowledge transfer. This could effectively mean that every single piece of knowledge transfer, i.e. knowledge sharing, has to be covered by a license or agreement of some sort, in order to protect it while it is shared. This issue can cause a lot of unnecessary efforts and in fact tension, and not the least increasing transaction costs. This can obviously be solved by using 'umbrella agreements' of some sort that facilitate the appropriate transfer of knowledge, possibly (partly) resolve the tension, and potentially even create a more open sharing atmosphere.

4.3.2 Framework

The existence of different stages of knowledge transfer means that the concept of collaboration has different phases and is in some way limited in time. Additionally, the concept of a collaboration scope implies that a collaboration is also constrained by its scope or breath, i.e. the subject of the collaboration. Moreover, taking into consideration that a collaboration does not take place in a 'vacuum', other organizations (or entities in general) in the market or economy also influence the collaboration in some way. And because the firms themselves are therefore not acting in a vacuum either, it means that a distinction has to be made between knowledge transfer *within* and *outside* the collaboration. In other words, there are other firms (or other entities) with which knowledge sharing (and protection) takes place, potentially knowledge in relation to the collaboration. Therefore, the activities of both the collaboration and the partners, i.e. the firms, take place in the market setting. All of this leads to the following framework, presented in Figure 20. As it shows, knowledge transfer or exchange takes place at several occasions (although not continuously). It is important to note that this figure refers to the two-partner case whereas in reality more partners can participate in a single collaboration. That is to say, Section 2.2 discussed the increasing number of partners as an important trend in collaborative knowledge sharing. If an additional partner would be added, the same development and transfer of knowledge is to be included. For the sake of clarity however only two partners are included in this figure. To be sure, the figure indicates Firm A and Firm B as the (two) partners in the collaboration because this study has a firm perspective. Other kinds of organizations (or even persons) could be included in the same way. The increasing involvement of non-firm entities is in fact another main trend as indicated in Section 2.2. The involvement of third parties is given by the embeddedness of the firms and the collaboration in the market place ('market' in the figure). The dotted line on the respective left and right of Firm A and B give the potential transfer of knowledge with the market.

An R&D collaboration can be seen as a *virtual entity* which is limited in time and efforts (i.e. by its start and end), by its scope, and by the resources (i.e. knowledge) that are put into it. At the start of (or during) the collaboration, the partners (two or more) put in a certain amount of *background knowledge* into the collaboration. During the collaboration, i.e. inside the virtual entity, the partners collaboratively develop *foreground knowledge* by sharing and combining their (background) knowledge. In addition, the different partners (typically) develop some knowledge in-house that is needed for and put into the collaboration, i.e. *sideground knowledge*. Furthermore, there is *postground knowledge* which is knowledge in relation to the subject of the collaboration but developed after it, i.e. after the end date at which the virtual entity ceased to exist. An important consideration that has to be made relates to the *environment* of the collaboration, in this case the market. It has to be considered to what extent, if at all, the partners can and should share their knowledge with third parties outside of the collaboration, not the least after the collaboration. For all these issues certain agreements have to be made in order to arrange the exact sharing and protection. Therefore, the role of different kinds of licenses becomes to play an important role and additionally there might be other ways to cope with the tension field. An example of the latter can be the fact that much of the knowledge sharing takes place in an open atmosphere without the use of a high degree of protection mechanisms. This can be especially relevant in relation to the pre-competitive nature of R&D collaborations. The next sub section goes into which strategies a firm can adopt to cope with the tension field of knowledge sharing and protection in R&D collaborations.

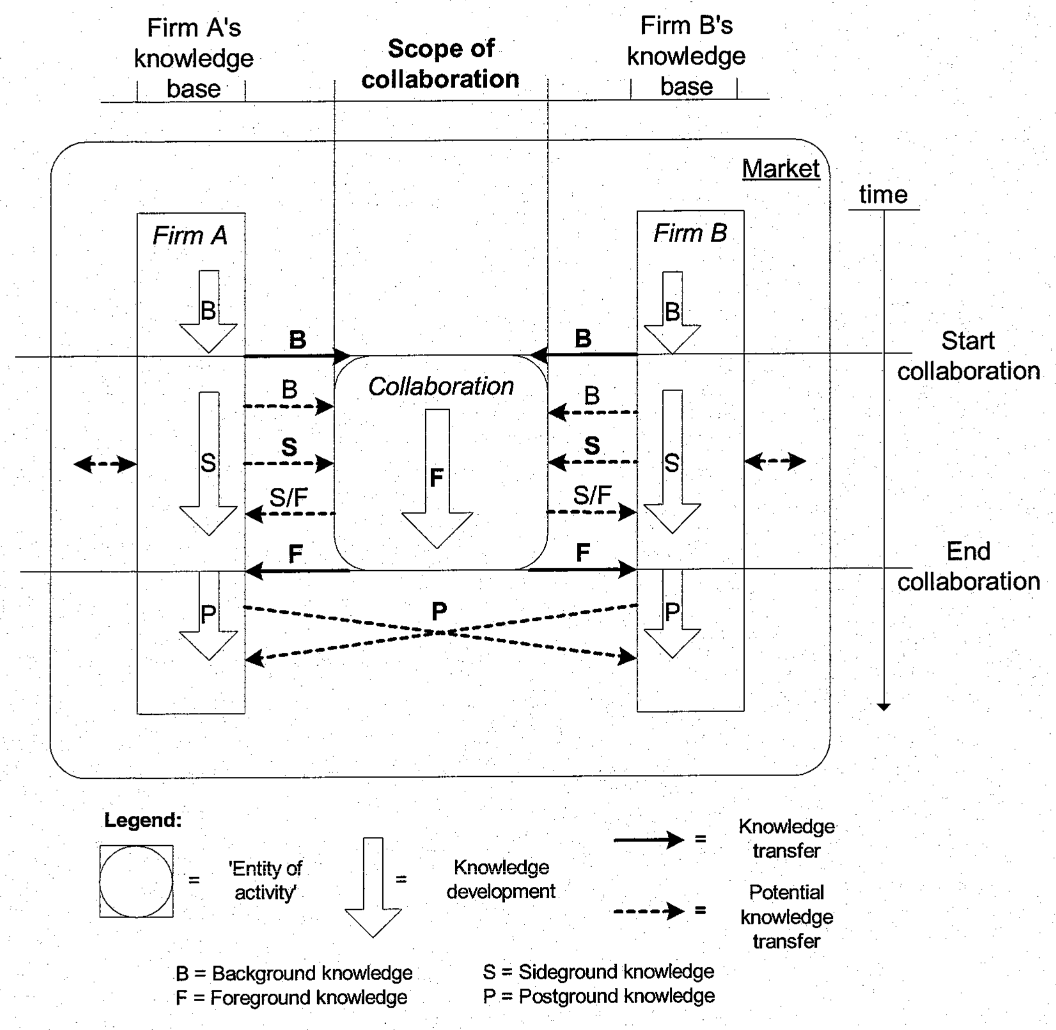


Figure 20. Framework for knowledge development and transfer in R&D collaborations

4.3.3 General Coping Strategies

The previous sub section shows how knowledge flows between the partners and the collaboration as a virtual entity. Every 'transfer of knowledge' can be seen as a moment of sharing knowledge. Because this sharing takes place at discrete moments or intervals, there is a potential tension between the sharing and protection of knowledge at every knowledge transfer (or exchange). In order to resolve this issue and thereby to decrease transaction costs, a collaboration uses some kind of agreement or contract. These agreements can be set up for the collaboration as a whole but can also relate to a specific transfer of knowledge. This will, among other things, depend on how the tension field exactly takes its form in the specific collaboration. In other words, the different dimensions in the tension field and their relations will determine how the partnering firms can cope with the tension field of knowledge sharing and protection.

Governance

Scholars have long identified that collaborations of various sorts set up governance structure to deal with the exchange of knowledge (see e.g. Kale, *et al.*, 2000; Mohr and Sengupta, 2002). These governance structures to a large extent aim at reaching a satisfying level of knowledge sharing while at the same time protecting one's knowledge. In general, the governance structure determines the sort or degree of collaboration. As shown in Figure 3, there are different sorts of collaborations, which can be considered as having a specific governance structure each. The traditional way to govern knowledge or knowledge exchange in R&D collaborations was to use agreements that state what should be shared, to which extent and how it is protected.

Choosing an appropriate governance mechanism is thus a way to promote both knowledge sharing and protection and therefore to cope with the tension field. Kale, *et al.* (2000) moreover argue that building a good relationship (or what they call 'relational capital') in collaborations facilitates learning through close one-to-one interaction *and* at the same time minimizes the likelihood of opportunistic behavior (i.e. unilateral absorption or stealing of proprietary knowledge). More recently, Oxley and Sampson (2004) argue that limiting the scope of the collaboration (see also Figure 20) is a way to decrease the tension between knowledge sharing and protection. In this case the amount or degree of knowledge sharing is limited in order to decrease the potential conflict between the sharing and the protection of this knowledge. This especially applies to the case in which the protection of knowledge is a delicate issue, which is often the case when competitors collaborate.

This study identifies a more general strategy a firm can adopt in which the agreement(s) on how different flows (or exchanges) of knowledge can be governed. In other words, this strategy involves which agreements are made with regard to the sharing *and* protection of knowledge, in relation to the different knowledge transfers as given in Figure 20. In this sense, the licensing agreements play a crucial role, also in relation to the licensing strategy adopted by the different firms. It will be shown that in some occasion firm put more emphasis on knowledge sharing and in other occasions on knowledge protection.

Licensing

Licensing, as described in detail in Section 3.5, has an important role in the governance of knowledge transaction and R&D collaborations in particular. As stated above, the sharing (and thus protection) of knowledge takes place at specific moments. These moments of knowledge transfer are therefore the moments on which the tension field (potentially) becomes active. Licensing can then be the way to resolve the tension that might exist the sharing and protection of knowledge. A license is namely by definition an agreements that states the terms of how a piece of knowledge is protected (and partly how it is appropriated) when it is transferred from the licensee to the licensor. This transfer can in this case be considered as the sharing of knowledge. In the context of R&D collaborations it will not be economical to specificy (i.e. write a license for) every transfer of knowledge. Instead, in order to decrease transaction costs, more general agreements are used that deal with several licensing issues at once. One example of this is a cross-licensing agreement in which the partners license each other the knowledge needed for the collaboration. Alternatively, a less explicit 'umbrella agreement' is used which states that knowledge should and will be shared to the extent needed and the partners will only use this in relation to the collaboration and will not internalize is privately. Still certain terms, such as exclusivity and compensation (in case of asymmetric knowledge exchange), can be agreed upon. These general agreements are more risky in the sense of unwanted appropriation and are therefore based on trust between the partners to a large extent. This latter strategy might be a fruitful one and perhaps even necessary to be able to reach the goal of the R&D collaboration in the face of the increasing pace of innovation as well the increasing complexity and diversity of R&D. In relation to this, it might be required to adopt some kind of grant-back strategy as well (especially in relation to sideground knowledge) with or without exclusivity and/or sub-licensing right. Therefore, a more open exchange of knowledge is important to consider in the case of R&D collaborations.

Open Knowledge Exchange

In relation to licenses (as given in Section 3.5.1) the emphasis seems to be on the protection of knowledge. It is important to note though that a less restrictive arrangement can be used as well. The use of licenses moreover does not exclude the possibility to establish a less protective scheme. In software development for example licenses such as the General Public License are used to more freely or openly distribute knowledge (or development result), although the possibility of appropriation of the results still exists in some way. Copylefting, as referred to in Section 3.2, moreover can be interpreted as a free grant-back license with sub-licensing right.

Open Source models entail several distinct (sub-) types that take different licensing schemes. In general, Open Source can be considered as an incentive system for innovations, which takes a different approach than for example the patent system (Lerner and Tirole, 2002b). Important to note is that Open Source is especially relevant for public good knowledge. Therefore, one could make the distinction between the private innovation model (in which knowledge is appropriated privately) and the collective innovation model (with the emphasis on public knowledge). Von Hippel and von Krogh (2003) propose a 'Private-Collective Innovation Model' that contains elements of both the private investment and the collective action model and can offer society the 'best of both worlds'. This model, in which privately developed results (a code in the case of Open Source) are freely revealed, might have similarities with the strategies adopted in R&D collaborations. On the one hand, 'free' dissemination of knowledge to the public can be applicable to some cases, e.g. in the case of standardization projects. On the other hand, a similar model might be used within the collaboration itself, especially in the case of a large number of participants. This means that there might be a 'layered scheme' in an R&D collaboration in which partners reveal some knowledge (or not) even to others with whom they are not directly involved.

Layered Collaboration Scheme

There are some other explanations for the existence of a layered collaboration scheme. With an increasing number of participants in an R&D collaboration, it becomes more difficult to 'manage' the exchange of knowledge. Therefore, it is generally acknowledged that the number of partners should be kept to a minimum to the extent possible. On the other hand, it is obviously clear that certain developments need the input of more (or even many) partners. If this is the case required and a collaboration consists of many partners, the work is usually divided among the partners and over time. In this sense, certain 'sub-collaborations' can arise within the collaboration as a whole. Furthermore, this layered collaboration scheme can take more structural form with more-or-less fixed core members and outer member if some of the partners play a central role in the collaboration. This can be related to the existence of a 'hub' organization in which one partner (i.e. the hub) takes a central role in the negotiation of agreements (European Commission, 2002). This is especially the case in international collaborations in which different national system complicate the general collaboration agreement. It is furthermore argued that this is a good way to deal with especially intellectual property rights and licensing issues because these are not well covered by general agreements (e.g. the model consortium agreement of the European Framework Programmes) that generally over-specify the terms (European Commission, 2002).

The layered collaboration scheme is visualized in Figure 21. It goes without saying that it refers to the multi-partner collaboration case. The 'core' of the collaboration consists of inner members that generally have a close relationship and adopt a strategy of open knowledge exchange. The 'periphery' consists of the outer members that adopt a specific knowledge exchange strategy among each other (which is not necessarily different). More particularly, the inner members potentially adopt a specific and potentially different knowledge exchange strategy towards the outer members. Additionally, it is important to note that it is still important to consider the organizations (and processes) outside the collaboration (i.e. the market or 'non-members'), just as this has to be done for the non-layered forms of collaborations. One example of a layered collaboration is the Bluetooth standardization consortium in which there are a few core members[39] that set up the consortium and openly shared their knowledge to develop the blue-tooth standard. The periphery of this collaboration consists of many partners that adopt the developments of the core in a strict way, which is also a way for the core members to appropriate the results of the developments.

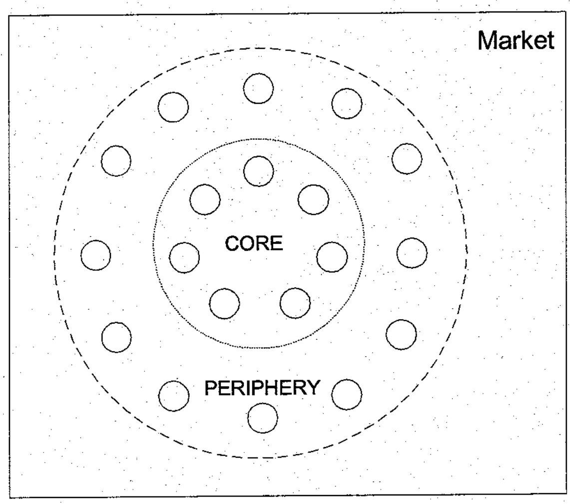


Figure 21. Layered collaboration scheme

An important economic rationale for the existence of a layered collaboration scheme is dealing with the different roles that different partners have in a multi-partner collaboration in order to reach the goal of the collaboration. Although it is essential to pool resources of all the partners to a certain extent, there is an asymmetry of contributions between the different partners. This means that a different exchange strategy is required for the inner and the outer members. In this sense, establishing an open knowledge sharing in the inner structure can economize on transaction costs because there are few costly contracts involved. The contributions of the core members relate to the 'core' of the collaboration's development and their open sharing therefore has to be compensated with a high degree of appropriation of the returns on this development. The open sharing in the core of the collaboration moreover deals with the 'disclosure dilemma' (as does open sharing in general) in a more defined way, which is a way to cope with the tension between knowledge sharing and protection.

[39] There core members are Agere, Ericsson, IBM, Intel, Microsoft, Motorola, Nokia and Toshiba (http://www.bluetooth.com, 2004). The layered collaboration scheme has a rather extreme form in this case because there are thousands of outer member that co-develop the Bluetooth technology and/or adopt it.

In any case, a layered collaboration scheme possibly exists in (international) R&D collaborations, especially because of the increasing number and diversity of different collaborating partners. For different layers in the collaboration, different models or licensing agreements are possible. Most presumably, the core members (or at least the close members for a certain partner) try to establish an open exchange of knowledge in order to facilitate maximum collaborative results. The knowledge exchange with the outer members then will be more closed (i.e. restrictive), formalized and specialized on certain matters, although it can still be expected to be moderate (i.e. less restrictive than with the market). This is potentially the case for all kinds of knowledge transfer, i.e. background, foreground, sideground and postground (see Figure 20). It is important to note that an open sharing or exchange does not directly mean a free exchange. On the contrary, at the least it is negotiated what are the fair and reasonable terms of exchange. Most typically however – and this is at the heart of an open sharing model – some kind of cross-licensing scheme in relation to the collaboration is arranged, possibly also incorporating a royalty payment, exclusivity clause and/or grant-back clause of some sort.

Knowledge Exchange Strategies

Consequently, the 'exchange strategy' in a collaboration can be either open or closed (i.e. restrictive), both within (i.e. internal) and outside (i.e. external) the collaboration. It can furthermore be different (i.e. layered) for different levels of a collaboration. Thus principally four possible general exchange strategies are possible for R&D collaborations, namely (a) open within and outside the collaboration (labeled 'public'), (b) open within and closed outside the collaboration (labeled 'private'), (c) closed within and outside the collaboration, and (d) a layered scheme with an open exchange with the core (or close) members, a moderate exchange with the outer members and a close exchange outside the collaboration. Table 13 gives these strategies in the order from a high degree of open exchange to a low degree of open exchange. The 'degree of knowledge exchange' refers to both the amount of knowledge exchange and the degree of *open* exchange.

Table 13. Possible knowledge exchange strategies in R&D collaborations

Exchange strategies	Degree of knowledge exchange		
	Internal – Core or close members	*Internal – Outer members*	*External – Outside*
Open exchange strategy - public	High	(High)	High
Open exchange strategy - private	High	(High)	Low
Layered exchange strategy	High	Moderate	Low
Closed exchange strategy	Low	(Low)	Low

To be sure, the layered scheme potentially has some variation of its own but for the sake of simplicity that is not taken into account in this overview. Because the other exchange strategies need not to consist of many partners, the expected degrees of knowledge sharing with the outer members are put in parentheses. The 'closed exchange strategy' with a restrictive exchange to all participants indicates a much formalized and therefore potentially tensed collaboration. The open exchange strategy has two main forms, namely a public one and a private one. This partly relates to the private and public innovation model as described above. The next sub section develops propositions that link the conditions in tension field with these possible exchange strategies.

4.3.4 Propositions

Revisiting the tension field (see Section 4.2), it is clear that it comprises two kinds of dimensions, namely exogenous and endogenous ones. The exogenous dimensions are inherent to the collaboration (e.g. to the subject of the collaboration) and have to be 'taken for granted'. In particular this means that the collaborating firm cannot influence the environmental setting and the knowledge (i.e. the dimensions 'knowledge embodiment' and 'knowledge characteristics). However, the endogenous dimensions *can* be influenced by the firm as it can shape the collaboration in some ways (the 'collaboration characteristics'), which also affects the 'relational dimension'. The relational dimension can furthermore be influenced once the collaboration started (i.e. after the partners are selected) by developing the relationship (e.g. building trust).

This study identifies three main elements in the strategy a firm can adopt in order to cope with the tension field of knowledge sharing and protection in R&D collaborations, as described above. These elements that are related to each other are licensing, open vs. closed sharing, and layered collaboration scheme. Together these elements shape the four main strategies as proposed above. The remainder of this sub section will develop more specific propositions when each of these strategies will be adopted. More specifically, a certain condition of the tension field (i.e. active dimensions and relations) will be related to the different strategies. In developing the propositions it is important to consider the distinction between exogenous and endogenous dimensions. These can either only determine the coping strategy that should be adopted or also be influenced by the chosen strategy, respectively.

Open Exchange Strategy

As given in Table 13, there are two kinds of an open exchange strategy, a private and a public one. First, the conditions will be identified for the case that a general open exchange strategy (within the collaboration) will be adopted. After this the private and public forms will be discussed. In an open exchange strategy it is important to consider that the emphasis is on the sharing of knowledge. This means that an open atmosphere is required with limited restrictions on the protection side. The potential success of knowledge sharing is to a large extent determined by the openness in a collaboration (Hamel, 1991). In this sense, open knowledge exchange can be seen as willingness of the partners to share and transfer their knowledge in different embodiments and at different occasions without many restrictions. Therefore, the *embodiment of knowledge* affects which coping strategy will be adopted. The transfer of tacit knowledge requires more complex social interaction (Badaracco, 1991). This is due to the very nature of tacit knowledge (see Section 3.3.1) which makes it difficult to transfer. One way to cope with this is by adopting an open exchange strategy in which social interaction has a prominent place. The embeddedness of economic transactions such as collaborations in a social structure with relations based on trust is long recognized (Granovetter, 1985) and is related to the confidence in each other's actions, thereby lowering (unwanted) appropriability concerns (potential) partners might have. This means that the *relational dimension* has to facilitate this open exchange and that therefore a high level of trust-based and possibly even friendship-based relationship is required. Such a relationship is negatively affected by an increasing distance between the partners. The geographical distance can hamper personal contact which is required to develop a friendship and trust-based relationship. The cultural distance possibly creates some miscommunication and a mismatch in expectations. The technological distance moreover makes it difficult to communicate, especially on the practitioners' level of the collaboration. Thus, an open exchange within the collaboration is expected if the knowledge is tacit (exogenous) and is related to a good and close relationship (endogenous) with a high level of trust, high commitment, and a low geographical, cultural and technological distance between the partners. More explicit knowledge embodiments (i.e. intellectual property rights and technology) can be more easily licensed and transferred, and are therefore expected to relate to an open sharing strategy to a lesser degree.

An open exchange strategy is furthermore required if the *characteristics of the knowledge* (exogenous) that is exchanged are highly complex, new, specific and systematic. If the knowledge is complementary an open exchange strategy is also required and it furthermore facilitates such a strategy due to the few unwanted appropriation concerns (in contrast to overlapping knowledge of competitors). Moreover, an open strategy will be more easily adopted in case of highly teachable knowledge. Furthermore, if knowledge is easy to imitate anyway it will not be 'dangerous' for a firm to openly share its knowledge. However, if the knowledge is easy to imitate *and* protected by an intellectual property right, it can only be (legally) appropriated by others by obtaining a license. From this it again becomes clear that more explicit embodiments of knowledge do not *per se* require an open exchange strategy. If the knowledge is furthermore highly codified, which makes it easier 'talk' to each other and thus exchange knowledge, there is no real need to adopt an open exchange strategy although it does facilitate the establishment of an open relationship. The codifibility of knowledge can therefore be related to the existence of an open exchange strategy to both a positive and a negative degree. Additionally, it is expected that the existence of complementary, complex, new, specific, systematic, tacit and teachable knowledge.

The *collaboration characteristics* that influence the tension field as a whole on a higher level are especially relevant in developing coping strategies. These namely are the endogenous elements in the tension field that can be influenced in the actual design of the collaboration. These furthermore directly and indirectly affect some of the elements of the relational dimension. The nature of the collaboration relates to its goal and focus, and the typology of 'explorative or exploitative' and 'horizontal or vertical'. An open exchange strategy is expected to occur in case of more explorative and vertical collaborations[40], because in these cases the partners have the least appropriability concerns and the complementarity of each other's resources is high. The previous experience with a partner can positively affect the open exchange of knowledge (if the experience was positive, that is) through the establishment of trust (Gulati, 1995). Moreover, because of the importance of (repeated) social interaction and its positive impact on building trust, the existence of an open knowledge exchange strategy is expected to positively relate to the prior experience with this partner. Due to the importance of social interaction and thereby the building of trust, it can be argued that a longer duration positively affect this. A firm's experience (in collaborating and in general) can have a positive effect on the open sharing of knowledge because it knows how to set up a good collaboration, although this does not have to be an open one and will depend on the exact experience. It can be expected however that firms generally choose to collaborate with partners who are known to have good experiences with open knowledge sharing. It can furthermore be expected that the size of the firm is related to the strategy used to cope with the tension field. Smaller firms will overall be more dependent on the success of the collaboration due to their size. It will also be easier to set up an open exchange strategy because of the more direct involvement of management. Therefore, the involvement of small firms is expected to positively relate to the use of an open exchange strategy. The existence of an open exchange strategy is consequently expected to positively relate to an explorative (vs. exploitative) and vertical (vs. horizon-

[40] Still horizontal collaborations are of increasing importance and take an important place in the investigation of this study. Interestingly, it is one of the main challenges for firms involved in a horizontal collaboration to establish an open sharing relationship.

tal) nature of the collaboration, duration of the collaboration, previous experience with a partner and the experience of a partner, and negatively related to firm size.

The *environmental dimension* can also influence the coping strategy that firms adopt in their R&D collaborations. In case of high market uncertainty, firm cannot be sure about which path to follow in their research and development efforts. The uncertainty about commercial success can be related to developing the wrong product or to incorrect marketing. In any case, to cope with a high uncertainty and to stay flexible, a firm should adopt an open exchange strategy so that it can optimally benefit from the developments in the collaboration. A high uncertainty is thus expected to relate to the existence of an open sharing strategy. The sector in which the collaboration takes place moreover affects the other elements in the tension field in a general way. The possible implications of the sector setting are discussed below because it is related to the distinction between private and public appropriation.

Private vs. Public Open Exchange Strategy

As indicated above, the sector setting might play a role in the tension field as a whole and the adoption of an appropriate coping strategy. Among other things, this refers to the importance of standardization efforts in the sector. With regard to the Private-Collective Innovation Model (von Hippel and von Krogh, 2003), as described above, it can be said that it mostly relates to knowledge with a (partly) public good nature. For this reason it is mostly appropriate for R&D collaborations that are related to standardization efforts. This means that a collaboration focused on (public) standardization establishes an open atmosphere for knowledge sharing with all partners of the collaboration. It furthermore typically has a relatively high number of partners, potentially also involving universities (and other research organizations). And the approach towards knowledge sharing with parties outside of the collaboration is open as well, or at least moderate. It is important to realize that even though the open dissemination of knowledge can be necessary for standardization efforts, the appropriation of the results or outcome of the standardization process in some way is required in order to recover the up-front costs (of the open sharing with the collaborating partners). In contrast to this 'public standardization' (which refers to standardization that benefits if more parties participate in the development), a more 'private standardization' exists in which (typically) firms want to set a standard in order to be able to privately appropriate the returns. An example of the former is the development of GSM and an example of the latter is Philips's CD standard.

In this sense, the public standardization tries to establish a standard with a more general and public value that is the basis for future developments and the private standardization relates to the efforts of a firm to develop a technology that will become dominant in the market. Although the boundaries are not exactly the same and fuzzy in any case, the private standard therefore refers more to a 'de facto' standard, whereas the public standard generally refers more to a 'de jure' standard in which the standard has been set or approved by a standardization body. Clearly, there is a main difference in how a private and public standard are established and adopted. The more private standardization creates high market shares and profits for the *individual* firms and is not *per se* beneficial to the public (because the customers or users are mostly interested in using a technology with certain performance parameters regardless of the exact underlying technology). The success of this type of standardization is very insecure and dependent on many factors, although this is generally the case for different kinds of standards. Interestingly, also in order to reach a (de facto) private standard, firms often collaborate with other to increase the pace of development and thus creating a lead-time and increasing their market share, even though they have to share the revenues with the collaborating partner. This kind of standardization typically involves only a limited amount of firms and most typically it does not involve a university due to the private internalization efforts. Moreover, this kind of effort is similar to the case in which no standardization is involved but the firms just privately want to internalize the developments. Therefore, the term 'private internalization' is used to refer to this effort as well as the private standardization efforts, as described above.

In sum, two specific types of an open exchange strategy can be identified. Although these can be applied to the characteristics of the collaboration itself, they will be dealt with in relation to the sector setting because the sector to a high extent determines the kind of standardization and/or internalization. One strategy is the 'public open exchange strategy' which aims at establishing a standard that is adopted by many other firms (in addition to users) and possibly approved by standardization bodies. To establish this, an open sharing towards third parties is adopted. Therefore, it is expected that the existence of 'public standardization' efforts are positively related to the adoption of the public open exchange strategy. Table 14 gives an overview of the full list of expectations for this strategy that comprise proposition 1.

Table 14. Proposition 1: Public open exchange strategy

Dimensions	Expected degree
Knowledge characteristics	
- Complementarity	+
- Tacitness	+
- Codifibility	+/–
- Imitability	·
- Systematic nature	+
- Teachability	+
- Complexity	+
- Newness	+
- Specificity	+
Knowledge embodiment	
- IPR	–
- Technology	–
- Routines	+
- People	+
Relational dimension	
- Trust	+
- Commitment	+
- Geographical distance	–
- Cultural distance	–
- Technological distance	–
Collaboration characteristics	
- Explorative (vs. exploitative) nature	+
- Vertical (vs. horizontal) nature	+
- Number of partners	+
- Previous experience with partner	+
- Experience of partner	+
- Firm size	–
- University involvement	+
- Duration	+
Environmental dimension	
- Uncertainty	+
- Sector:	
- Private internalization	·
- Public standardization	+

In addition to the public open exchange strategy, a second possible open exchange strategy that can be adopted in R&D collaborations is the a 'private open exchange strategy' in which the partners try to privately internalize the developments of a collaboration (possibly being a standard) and therefore restrict the knowledge exchange with third parties outside the collaboration. A private open exchange strategy is expected to be positively related to the existence of 'private internalization' efforts, as described above. Table 15 gives proposition 2 which gives the expected degrees of the different elements of the dimensions in the tension field.

Table 15. Proposition 2: Private open exchange strategy

Dimensions	Expected degree
Knowledge characteristics	
- Complementarity	+
- Tacitness	+
- Codifibility	+/–
- Imitability	.
- Systematic nature	+
- Teachability	+
- Complexity	+
- Newness	+
- Specificity	+
Knowledge embodiment	
- IPR	–
- Technology	–
- Routines	+
- People	+
Relational dimension	
- Trust	+
- Commitment	+
- Geographical distance	–
- Cultural distance	–
- Technological distance	–
Collaboration characteristics	
- Explorative (vs. exploitative) nature	+
- Vertical (vs. horizontal) nature	+
- Number of partners	–
- Previous experience with partner	+
- Experience of partner	+
- Firm size	–
- University involvement	–
- Duration	+
Environmental dimension	
- Uncertainty	+
- Sector:	
- Private internalization	+
- Public standardization	.

Layered Exchange Strategy

The third main general coping strategy, the layered exchange strategy, refers to the use of a layered collaboration scheme (see Figure 21). As described in Section 4.3.3, this scheme can be applied if a need exists to distinguish the knowledge exchange between the core (or close) members and the outer member in the collaboration. This strategy is most directly related to changes in the *collaboration characteristics*. First of all, the most obvious change is the number of partners. Because the layered collaboration scheme refers to the multi-partners case, the layered exchange strategy is positively related to the number of partners. Because this case also refers to division of different tasks (into work packages) performed over time by certain partners (i.e. in 'sub-collaborations'), it can be expected that the duration of such a collaboration is relatively long. As this kind of collaboration has a broad scope and involved many partners, a wide variety of tasks and of partners and therefore of collaboration characteristics is expected. In particular, the collaboration that adopts a layered exchange strategy has both an explorative and exploitative nature, can be characterized as both vertical and horizontal, and involves small and large firms. Furthermore, the average previous experience with the partners is expected to be relatively low due to the need to set up a restrictive knowledge exchange with the outer members. This indicates that there are concerns about unwanted appropriability of the outer member, which is less the case if the partners have good experiences with each other. With regard to the core members however the opposite can be argued. The experience of a partner is not expected to have any specific relationship with the adoption of this strategy. The adoption of a layered exchange strategy is positively related to the number of partners and the duration of the collaboration, negatively related to previous experience with the partners, and the relation with the nature of the collaboration and the firm size can differ.

These collaboration characteristics are also related to the *relation dimension* of the tension field. The broad scope of the collaboration as well as the large number and wide variety of partners make it difficult to reach a high level of trust. The commitment will also be relatively low because of the relative small role each partner plays. Moreover, the existence of low trust and commitment can be a reason for adopting a layered exchange strategy. The same is the case for a large geographical, cultural and technological distance between the partners which can be a reason for adopting different strategies according to the distance. Therefore, low trust and commitment, and high geographical, cultural and technological distance relate to adopting a layered exchange strategy.

The broad scope of the collaboration moreover implies the existence of a wide variety of *knowledge characteristics* and *knowledge embodiment.* The different kinds of partners put in different kinds of knowledge in order to reach the overall goal of the collaboration. Because the different embodiments of knowledge are all of importance, though in different ways, they are all expected to exist in the layered exchange strategy. Furthermore, the knowledge has to be shared through different kinds of relationships and therefore the codifibility, imitability and teachability is expected to be high, and the systematic nature, complexity and specificity is expected to be low. This is reinforced by the main strength of a layered collaboration which is bringing together the knowledge of different partners in order to reach a goal that cannot be reached individually an thereby adjusting the appropriability of knowledge to the extent needed. Because these pieces of knowledge can vary widely the complementarity and newness as well as the tacitness may take different degrees.

In relation to the establishment of a layered collaboration it can furthermore be expected that the environmental dimension is characterized by a high degree of uncertainty. With regard to the sector setting and standardization efforts in particular, it can be argued that the concept of 'private standardization' as described above is of relevance and thus a relatively high degree of private internalization can be expected. This also relates to the establishment of a layered collaboration scheme because the core members include the outer member just for the required input and privately appropriate the results, and the outer members decide to participate because it gives them the opportunity to get private returns as well.

Table 16. Proposition 3: Layered exchange strategy

Dimensions	Expected degree
Knowledge characteristics	
- Complementarity	+/–
- Tacitness	+/–
- Codifibility	+
- Imitability	+
- Systematic nature	–
- Teachability	+
- Complexity	–
- Newness	+/–
- Specificity	–
Knowledge embodiment	
- IPR	+
- Technology	+
- Routines	+
- People	+
Relational dimension	
- Trust	–
- Commitment	–
- Geographical distance	+
- Cultural distance	+
- Technological distance	+
Collaboration characteristics	
- Explorative (vs. exploitative) nature	+/–
- Vertical (vs. horizontal) nature	+/–
- Number of partners	+
- Previous experience with partner	–
- Experience of partner	.
- Firm size	+/–
- University involvement	+
- Duration	+
Environmental dimension	
- Uncertainty	+
- Sector:	
- Private internalization	+
- Public standardization	.

All the expected degrees of the different dimensions that comprise the tension field and their elements for the case of a layered exchange strategy are given in Table 16, which thereby gives proposition 3. Whereas this table gives the average expected degrees of the dimensions, a distinction can be made between these degrees in relation to the inner and outer members. For this means, the degrees in the open and closed strategies can be respectively used.

Closed Exchange Strategy

The closed exchange strategy to a large extent has the opposite determinants than the open exchange strategy as described above in Table 14. A closed exchange strategy is characterized by a restrictive attitude with potentially many specific agreements to cover different knowledge transfers. Specifying the terms in formal agreements is a way to limit unintended knowledge transfer and thus cope with the tension field (Hamel, *et al.*, 1989). In short it can therefore be said that in the closed exchange strategy the emphasis is put at knowledge protection.

With regard to the standardization efforts that are discussed above, the closed exchange strategy relates to the 'private internalization' efforts even to a larger extent than private open exchange strategy. In the closed strategy each individual partner namely privately internalizes all the development and restricts others from appropriating any knowledge without explicit consent. The fact that this is possible implies a lower marker uncertainty because the firm is able to specify all the transaction to a high extent. The *environmental dimension* is thus expected to be characterized by a low uncertainty and a private internalization.

The sector also plays a role in how different kinds of knowledge can be licensed. In any case, there is an important role for the *embodiment of the knowledge* because it determines to a large extent the possibility to restrict and specify knowledge exchange. Knowledge is preferably licensed if it is also protected by a patent (Kogut and Zander, 1993) or if it is embedded in a technology (Teece, 1998). Patents in fact make it easier to trade technology for both the buyer and seller. Translating this to the role of licensing of patents within collaborations (or in general), it means that transaction costs can be reduced because knowledge that is embedded in the patent is both codified and public (and therefore visible and appropriable).In a closed exchange strategy, knowledge embodied in intellectual property rights and technology (thus the more explicit forms of knowledge) are expected to play the most significant goal.

In relation to this, the *knowledge characteristics* are of interest as well. Well-codified knowledge is easy to transfer (especially if the partners 'speak the same language') and therefore the codifibility is expected to be high. Although the knowledge is most probably in some way protected, the imitability is expected to be high, as well the teachability. Because of the high explicitness of the knowledge, the systematic nature, complexity and newness are expected to be low whereas the specificity is expected to be high. Because the main goal of the restrictive knowledge exchange is to get access to other's knowledge, the complementarity is expected to be high.

The *relational dimension* plays a less important role in this closed exchange strategy. The protective strategy on the one hand does not facilitate the establishment of a trust-based relationship and the relationship on the other hand cannot resolve this issue. Because of the low commitment of the partners and their restrictive relationship, the geographical and cultural distance do not quite matter and the technological distance is expected to be low.

In relation to the *collaboration characteristics*, it can furthermore be expected that a low experience of and with a partner causes a more restrictive strategy. The same applies to the duration of the collaboration because it is difficult to build a good relationship in a short period. An important aspect is the nature of the collaboration because a more pro-competitive and thus exploitative collaboration is related to a more restrictive exchange strategy due to the importance to create a competitive advantage, also vis-à-vis their partners (in the case of a horizontal relationship). And if the partners are competitors on the same markets, a more restrictive and formalized strategy might be adopted by default. Therefore, it is expected that a closed exchange strategy mainly refers to a horizontal collaboration (i.e. in a vertical collaboration less need exist to take a very restrictive approach). This is reinforced by the involvement of large firms, especially if these are putting much effort in protecting its resource portfolio. Because universities by definition have an open knowledge exchange strategy it is not expected that their involvement is positively related to the closed exchange strategy. The number of partners is finally expected to positively relate to the adoption of a closed exchange strategy because it becomes more difficult to manage all the contributions creating a need to 'guide' this by using (restrictive) agreements. On the other hand, this 'guidance' or management becomes increasingly more complex with an increasing number of partners which makes it very time consuming and costly. Because of this a more layered scheme could be used.

In any case, in the closed exchange strategy puts more emphasis on knowledge protection and embodiment of knowledge. Table 17 gives an overview of the full list of expectations for this strategy that comprise the proposition 4.

Table 17. Proposition 4: Closed exchange strategy

Dimensions	Expected degree
Knowledge characteristics	
- Complementarity	+
- Tacitness	–
- Codifibility	+
- Imitability	+
- Systematic nature	–
- Teachability	+
- Complexity	–
- Newness	–
- Specificity	+
Knowledge embodiment	
- IPR	+
- Technology	+
- Routines	–
- People	–
Relational dimension	
- Trust	–
- Commitment	–
- Geographical distance	.
- Cultural distance	.
- Technological distance	–
Collaboration characteristics	
- Explorative (vs. exploitative) nature	–
- Vertical (vs. horizontal) nature	–
- Number of partners	+
- Previous experience with partner	–
- Experience of partner	–
- Firm size	+
- University involvement	–
- Duration	–
Environmental dimension	
- Uncertainty	–
- Sector:	
- Private internalization	+
- Public standardization	.

4.4 Discussion and Conclusions

This chapter brought together the findings of chapters 2 and 3, thereby answering research question A (Section 1.4.3). To answer this question, the dimensions comprising the tension field of knowledge sharing and protection in R&D collaborations are 'knowledge characteristics', 'knowledge embodiment', 'relational dimension', 'collaboration characteristics' and 'environmental dimension'. The properties of knowledge, as described earlier, clearly play a central role in the tension field. A model of the tension field developed in Section 4.2.3 and Figure 19 shows the tension field. In this figure the different elements that comprise the individual dimensions are given as well.

This chapter furthermore answered research question D by investigating how firms can cope with the tension field of knowledge sharing and protection in R&D collaborations. In order to further explore these coping strategies, a framework is developed (Figure 20) that identifies different kinds of knowledge, or knowledge transfer more specifically. This framework is used in the interviews, which are the main source of data for the case studies in Chapter 5, in order to identify how firms deal with different knowledge transfers and thereby cope with the tension field. In this sense, the role of licensing is also investigated. Licensing, as an agreement that governs knowledge transfer, is by definition a means to share and protect one's knowledge (at the same time) and is thus a means to cope with the tension field. Furthermore, some more general strategies with regard to coping with the tension field are explored. In particular, it is investigated how 'open knowledge exchange' can take away the tension between sharing and protection in some occasions. One form of this open exchange is a private open exchange with individual (or private) internalization of openly shared and developed knowledge. Another form is a public open exchange in which a broad public standardization is required and in which the research results cannot be directly internalized. In relation to decreasing the tension between knowledge sharing and protection in R&D collaborations, the establishment of a 'layered collaboration scheme' is also investigated. This scheme can essentially 'divide' the collaboration into core (or close) and outer members. Additionally, it is necessary to explore how knowledge transfer with third parties is arranged because this has important implications for which strategy can be adopted in an R&D collaboration.

From these considerations, the concept of 'knowledge exchange strategy' is introduced. Four main knowledge exchange strategies are developed, namely a 'public open exchange strategy', a 'private open exchange strategy', a 'layered exchange strategy' and a 'closed exchange strategy'. By linking these possible strategies to a certain condition in the tension field, four propositions are developed (i.e. one for every strategy). The occasions in which these propositions are expected to be valid are given in Table 18.

In general, the knowledge characteristics are expected to play an essential role because of the key role of knowledge in the tension field (Figure 19). The complexity of knowledge is one of the most important characteristics and the presence of highly complex knowledge is expected to be related to the adoption of a more open strategy. The same can be said about the tacitness of knowledge that determines the dimension of knowledge embodiment as a whole. Therefore, it is expected that the existence of more tacit knowledge (i.e. knowledge in routines and people) is related to the adoption of an open exchange strategy. In contrast, the involvement of more explicit knowledge (i.e. technology and/or intellectual property right) is expected to relate to the establishment of a closed strategy (mainly due to the ease to exchange this kind of knowledge in a restrictive manner). The adoption of the layered exchange strategy is expected if all the embodiments are present and of importance giving rise to the need to set up different 'regimes' according to the input of a specific kind of knowledge by a certain partner.

With regard to the relational dimension, the key role of trust in the establishment of an open sharing atmosphere causes it to be highly related to the 'open exchange strategies'. The characteristics of the collaboration (and the collaborating firms) furthermore determine the relationship between the partners to a large extent. For example, previous experience with a partner is expected to relate to an open exchange strategy.

Table 18. Proposition 1 to 4: Knowledge exchange strategies

Dimensions / Proposition – Strategy	1 - Public open exchange	2 - Private open exchange	3 - Layered exchange	4 - Closed exchange
Knowledge characteristics				
- Complementarity	+	+	+/–	+
- Tacitness	+	+	+/–	–
- Codifibility	+/–	+/–	+	+
- Imitability	.	.	+	+
- Systematic nature	+	+	–	–
- Teachability	+	+	+	+
- Complexity	+	+	–	–
- Newness	+	+	+/–	–
- Specificity	+	+	–	+
Knowledge embodiment				
- IPR	–	–	+	+
- Technology	–	–	+	+
- Routines	+	+	+	–
- People	+	+	+	–
Relational dimension				
- Trust	+	+	–	–
- Commitment	+	+	–	–
- Geographical distance	–	–	+	.
- Cultural distance	–	–	+	.
- Technological distance	–	–	+	–
Collaboration characteristics				
- Explorative (vs. exploitative) nature	+	+	+/–	–
- Vertical (vs. horizontal) nature	+	+	+/–	–
- Number of partners	+	–	+	+
- Previous experience with partner	+	+	–	–
- Experience of partner	+	+	.	–
- Firm size	–	–	+/–	+
- University involvement	+	–	+	–
- Duration	+	+	+	–
Environmental dimension				
- Uncertainty	+	+	+	–
- Sector:				
- Private internalization	.	+	+	+
- Public standardization	+	.	.	.

Note: [+] indicates that an element is present as such to a high extent, [–] to a small extent, [+/–] can be both, [.] average. For values (e.g. number of partners or size): [+] = high, [–] = low, [+/–] = average. Average values for number of partners is (approximately) 3 to 5, for duration 3 to 5 years. Firm size is either [+] large or [–] low, or [+/–] can be both.

5 Case Studies

5.1 Introduction

After the theoretical consideration of knowledge sharing and protection in R&D collaborations, the case studies in this chapter are used to gather empirical insights in what the tension field of knowledge sharing and protection is. The presence of each of the previously identified dimension, which combined comprise the tension field, as well as their relationships are tested. Furthermore, it is explored how the investigated firms deal with the tension field in the collaboration they have been involved in. From this it is identified which 'knowledge exchange strategy' was adopted in the specific case. And by relating the adopted strategy to the condition of the dimensions in the tension field, the propositions developed in the previous chapter are tested.

By answering research question A as given in Section 1.4.3 ('Which dimensions comprise the tension field of knowledge sharing and protection in R&D collaborations?'), this chapter combines the results from the two preceding chapters. While Chapter 2 showed which dimensions can be identified with regard to a firm's knowledge sharing in R&D collaborations and Chapter 3 revealed the dimensions that can be identified with regard to the way a firm can protect its knowledge in R&D collaborations, this chapter gives a full overview of the tension field.

The following section elaborates on the selection criteria and research design used in the case studies, while in Section 5.3 a general introduction is given to the eight case studies conducted in this study. These case studies are in turn individually discussed from Section 5.4 to 5.11. The chapter closes by summarizing and discussing the main findings.

5.2 Methodology

In relation to the selection criteria for finding appropriate case studies, it can be said that several considerations were made. First of all, it is essential that the case study gives good insights in the problem addressed in this study and therefore firms were identified that have some sort of experience with R&D collaborations. To be sure, this study takes the firm perspective and therefore mainly focuses on the involvement of firms. These firms were sought in the Netherlands and in Sweden. The second step was to identify potentially relevant collaborations of these firms which could give good insights and were accessible to a reasonable extent. Five out of eight collaborations were identified through the database of the 'Framework Programmes' of the European Commission accessible through the website www.cordis.lu. The others were identified on a more personal basis. In order to obtain as much insight in the tension field as possible, collaborations were selected of which the firm was the leader of the consortium. In order to identify the (potential) effect of this leadership, one collaboration was selected in which the investigated firm did not was the collaboration leader[41]. The next step was to approach a key person of this collaboration for an interview. In addition to this interview, documentation was gathered and used – both before, during and after the interview – in order to obtain the highest possible level of insights[42].

[41] In the database on www.cordis.lu there is always a (formal) project leader, which is often also the initiator of the collaboration.

[42] Although documentation was available for all of the partners (in most cases), the focus was on one partner. This translates into the fact that only one party was interviewed. Obviously, future research will contribute from investigating of more (or even all) the partners.

Dependent on the exact case study either publicly available or privately available material was used, or both if available.

More specifically, a case was selected on the basis of 'pre-competitiveness'. Because R&D collaborations are (by definition) related to *research* and *development* (see Section 1.3.2), they are highly associated to pre-competitive collaboration. With regard to the distinction between 'exploration' and 'exploitation' as given in Section 1.3.2 this means that one selection criterion was the collaboration's explorative nature. Additionally, in order to comply with the increasing diversity and internationalization of R&D collaborations, the cases another selection criterion was the involvement of partners from different countries. Furthermore, cases with different characteristics were chosen in order to create some variety that can be used to comparatively analyze the different cases across each other. In relation to this the selection criteria were the sector of the firm and its collaboration, the size of the firm, the duration and scope of the collaboration, the number of partners, and university involvement.

More concretely, the main focus was on the Information Technology (IT) sector because R&D collaborations are important in this to cope with the high pace of innovation and to set standards. In order to compare the effect of the sector setting, collaborations were chosen that dealt with a different degree of uncertainty. Moreover cases in the Chemicals sector were sought because the collaborations and especially the knowledge embodiments have a specific role in this[43]. Furthermore, this study focuses on both large and small firms with the emphasis on the former. Six case studies are therefore conducted in large firms and two in small firms. In addition, collaborations were selected that have different durations and scopes. This means that the cases vary from short, low budget and relatively large potential to long, high budget and a large potential. In relation to this, the numbers of the different case studies had to differ widely. Additionally, some cases were selected that had university involvement and some that had not, because the involvement of a university can affect the tension between the sharing and protection of knowledge. Table 19 in Section 5.3 gives an overview of the investigated case studies and shows some of the characteristics for the collaboration and the interviewed firm in relation to the selection criteria as discussed above as well as some other characteristics.

In relation to the design of the case studies, it has to foster a high degree of validity and reliability. Because this research entails exploratory case studies, the two kinds of validity (in addition to reliability) that have to be considered, namely construct validity and external validity (Yin, 2003). The establishment of *construct validity* involves creating correct operational measures for the concepts that are measured in the case studies, in this case for the dimensions that comprise the tension field of knowledge sharing and protection as well as the coping strategies. In this research the construct validity is dealt with by using a general structure of questions and framework to investigate and analyze the different cases[44]. An overview of different possible influencing factors was known and was thus used in the case studies. Therefore, the (theoretical) preparation contributes a great deal to the establishment of construct validity. Furthermore, it was made explicit in the case studies in what way certain events caused particular effects (chain of evidence). One of the ways in which this was done is by applying a chronological order in the discussions during the interviews. In addition, especially because the interviews are the main source of data, the key in-

43 In relation to these two sectors (i.e. IT and Chemicals) it can be argued that the Netherlands and Sweden have a relatively strong role in these.

44 This structure was based on the theoretical considerations in relation to the dimensions as described in the earlier chapters of this study.

formant (i.e. the interviewee) reviewed the draft of the case study report in order to check if the case study correctly used the operational measures. Furthermore, some follow-up questions were posed on various issues. In addition to the interviews, available documentation of the collaboration and the firm in particular was used. In case of European projects this documentation is generally quite generously available. In the other cases, more dependency on the availability at the interviewed firm exists.

In addition *external validity* needs to be obtained. This concept refers to the 'domain to which the findings of the case studies can be generalized'. The case studies are conducted to generalize the findings to a broader level in order to contribute to the theoretical development of the dimensions that are active in the tension field of knowledge sharing and protection, and how firms can cope with this (i.e. analytical generalization). The selection criteria play an important role in the establishment of external validity. By choosing cases that are insightful on different fields, incorporating several issues, these case studies should provide insight in the different relevant factors and therefore provide a reasonable overview of the more general field of R&D collaborations. Furthermore, by conducting multiple case studies this research tries to achieve 'literal replication' (predict similar results) *and* 'theoretical replication' (predict contrasting results but for predictable reasons), i.e. the replication logic (Yin, 2003). Conducting different case studies is intertwined with the development of the theoretical model and framework. On the one hand, these were the basic input for the case studies. On the other hand, while the different case studies were conducted, they were an input themselves to further develop them. Additionally, the 'themes' of appropriability, licensing and 'knowledge exchange strategy' were used in both conducting and analyzing the case studies in order to improve the ability to compare and generalize the different, independent case studies. Hereby, a cross-case synthesis is established as an analysitic technique.

The *reliability* of these case studies is obviously an important issue. This also relates to choosing the correct selection criteria. Also, several (primary and secondary) sources of information were used to base the case study analysis on such as documents, interviews, participant observation, and physical artifacts. Although different sources of information were used, the case studies are primarily based on interviews[45]. Before conducting the case studies moreover (and most specifically before conducting the interviews), they were thoroughly prepared. First of all, while finding appropriate cases, the collaboration and the participating firms, as well as the potential interviewee, were screened in order to assure the quality and value of that possible case. This screening was based on the criteria mentioned above, the accessibility and possible insights. While approaching potential interviewees, they were sent a short abstract of the research, briefly stating the background of the study, the main elements of the tension field identified thus far, and the specific goal of the this (possible) case study as well. During the first (semi-structured) interviews[46], conducted at an early stage of the study, some issues already arose that helped to design these case studies more appropriately. Furthermore, a case study protocol was used that was also sent to the interviewees before the interview was actually conducted[47]. This protocol was divided into three main parts and these parts were subsequently divided into sub questions or elements. Each part consisted of a main concepts of interest in this study, namely (a) the background of the study including issues as environmental dimensions and collaboration characteristics, (b) the role of the partners and their relationships, and (c) the characteristics of the knowledge with special

[45] Appendix B gives an overview of the interviews with the name of the firm and the interviewee, the date of the interview, and the role of the interviewee in the collaboration and the firm.
[46] An overview of these semi-structured interviews is given in Appendix A.
[47] This case study protocol is attached in Appendix C.

reference to the complementarity and embodiment of knowledge, the tension field of knowledge sharing and protection, and attention was also given to the themes 'appropriation of knowledge', 'licensing' and 'knowledge exchange strategies'. An important method in the investigation of these issues was the use of Figure 20, which was a means to identify different kinds of knowledge transfers at different occasions in the collaboration. A final logical step was the evaluation and analysis of the different case studies by testing the model of the tension field, identifying the applicable exchange paradigm and linking these in order to test the propositions. A case study analysis was also sent to the interviewees in order to check it and comment on it. Lastly, a cross-case comparison was made to investigate the influence of the different characteristics of the investigated R&D collaborations.

5.3 Cases

This section describes the different case studies that were conducted during the period August to November 2004. It describes which cases were selected on the basis of the above-described criteria. The remainder of this chapter gives the results for every subsequent case and discusses the findings. For each case, the description is divided into the elements that were used while conducting them. More specifically, it is divided more-or-less in the same way as the interviews were designed, meaning that first the background of the specific collaboration is discussed as well as the role of the firm in question. The first part of the description therefore consists of a general background. Secondly, the role of partners and their relationships is discussed. Thirdly, the characteristics of knowledge are described, as well as the sharing and protection of it. The impacts of these knowledge characteristics are also elaborated upon. Subsequently, the complementarity of knowledge, the embodiment of knowledge and its impact (with specific reference to the role of intellectual property rights), and the agreements (of various sorts) that were used are discussed. After this, the main findings summarize these results and test the existence and degree of the different dimensions that comprise the tension field, as well as their relations. Hereby, it is also investigated if the firms actually experience the tension field (as developed before). Furthermore, the adopted 'knowledge exchange strategy' is identified and the propositions are tested by linking the condition of the tension field to the adopted strategy. All in all, it is thereby investigated if the empirical results comply with the theoretical ones.

Table 19 gives an overview of the different case studies that were conducted during this study. It shows several characteristics of the collaboration and the investigated firm, partly in relation to the selection criteria as mentioned above.

Table 19. Case study overview

Characteristic \ Case	Array	Eka Chemicals	Akzo Nobel	Lionix	Telia	KPN	Philips	Ericsson
Subject of collaboration	Development of Toner Jet printing technology	Speciality Colloidal Silica applications	Development of new CD-R technology	Provide integrated optics technologies for microsystems	Increase understanding of automated spoken dialogue technologies	Analysis of UMTS system-behavior and development of UMTS planning tools	Development and implementation of personalized services for digital television	Creation of network solutions for mobile and wireless systems beyond 3G
Main focus of collaboration	Exploration	*Exploitation*	Exploration	Exploration	Exploration	Exploration	Exploration	Exploration
Potential	Large	Relatively large	Large	Relatively large	Relatively small	Relatively small	Relatively large	Large
Partner's complementarity	High	High	High	Moderate	Moderate	Moderate	High	High
Number of partners	2	2	2 (second collaboration: 3)	5	6	8	9	41
Period of collaboration	1996 - 1998	2002 (- 2005)	1996 - 1998	2002 - 2004	2001	2001 - 2003	2001 - 2003	2004 (- 2009)
Total man-years	70	2	*Confidential*	5	12	27	60	600 (100 a year)
Budget	*N/A*	€0.4 million	*Confidential*	€1.3 million	€0.8 million	€3.5 million	€6.9 million	€22.1 million
(Main) sector	IT	Chemicals and Construction	IT	IT	IT	IT	IT	IT
University involvement	No	No	No	Yes	Yes	Yes	Yes	Yes
Firm's country	Sweden	Sweden	Netherlands	Netherlands	Sweden	Netherlands	Netherlands	Sweden
Firm's size[48]	Small	Large	Large multinational	Small	Large	Large	Large multinational	Large multinational
Firm's R&D intensity	High	High	High	High	Moderate	Moderate	High	High
Firm's specialization vs. diversification	Highly specialized	Diversified within Chemicals	Diversified[49]	Specialized	Specialized	Specialized	Diversified	Diversified within IT

Note: 'Firm' refers to the interviewed firm.

[48] All firms are internationally orientated to a large extent. KPN's and Telia's main market is the domestic one, however.
[49] The R&D collaboration of Akzo Nobel was outside the scope of its three main business units to a large extent. The collaboration's sector can be noted as IT.

5.4 AKZO NOBEL: 'FABRY-PEROT CD-R TECHNOLOGY'

5.4.1 *Akzo Nobel's Collaboration*

Today, the Compact Disc (CD) is one of the most commonly used media to store data of various sorts, including data storage such as information and software as well as for entertainment purposes such as audio and video. Therefore, the CD industry is a flourishing one with increasing sales and fast developments. Especially the introduction of affordable recordable CDs gave a boost to the sales on the consumer market. This is most specifically the case for CD-Rs (or CD-Recordable) that can be written only once. (This in contrast to CD-RWs (or CD-Rewritable) that can be written several times, of which the sales increased to a minor extent, mainly due to their relatively high price.) Nowadays, the DVD[50] industry goes through a similar development with the caveat that recordable DVDs have a more heterogeneous distribution over the world, meaning different parts of the world have adopted a different standard. With regard to recordable DVDs, there is a main distinction between DVD-R and DVD-RW on the one hand and DVD+R and DVD+RW on the other hand.

With this background, knowing that the CD-R (and DVD-R) business could be a profitable one, Akzo Nobel decided to enter it by developing a new concept for optical recording media, e.g. CD-R and DVD-R. In order to succeed, especially because it was outside of its core market, the Dutch firm Akzo Nobel initiated a collaboration with the Korean electronics firm Samsung. Table 20 shows these partners, as well as a third partner that was included in a subsequent collaboration, as is discussed later.

Table 20. Partners in 'Fabry-Perot CD-R' collaboration

Participants	Country
Akzo Nobel Corporate Business Development	Netherlands
Samsung Advanced Institute of Technology	Korea
(Toolex/ODME)	(Netherlands)

The background of Akzo Nobel for entering the development of a new concept for optical recording media is founded in the existence of a 'Corporate Funded Budget' for conducting highly innovative and fundamental research. This budget was 'decentralized' in 1998, which means it was transferred to the three main groups of business units of Akzo Nobel (Pharma, Coatings and Chemicals). From this budget a significant part[51] was allocated to 'Photonics' research and development, which consisted of three main projects. One was related to photonic switches, another to LCD displays, and a third one to CD-R technology. Ultimately, all of these (including the one of interest to this study) were spun-off in some way because they were too far from Akzo Nobel's core business after the strategic reorientation of 1998.

Then coming back to the new CD-R collaboration, it had a great *market potential* even though it overall required a relatively small investment in terms of money and man-years[52]. Akzo Nobel had patented an idea to develop CD-Rs based on a new optical recording technology, instead of the commonly used technology based on using dyes in the recordable layer of a CD-R. These ex-

[50] DVD: Digital Versatile Disk, which in to a large extent the next generation of optical recording media with a significantly larger storage space than the CD.
[51] The exact figures are confidential.
[52] The exact figures are confidential.

isting CD-Rs do not have pits and lands such as conventional (non-writable) CDs[53] but they have a smooth reflective metal layer, which rests on top of a layer of photosensitive dye. When the disc is blank, the dye is translucent, meaning that light can shine through and reflect off the metal surface. But when the dye layer is heated with concentrated light at a particular frequency and intensity, i.e. the 'write laser' of a CD burner, the dye turns opaque, which means that it darkens so that no light can pass through (after the 'writing'). By selectively darkening particular points along the CD track, and leaving other areas of the dye translucent, the CD burner creates a digital pattern that a standard CD player can read. The light from the player's laser beam will only bounce back to the sensor when the dye is left translucent, in the same way that it will only bounce back from the flat areas (lands) of a conventional CD. Consequently, even though the CD-R disc does not have any bumps pressed into it at all, it behaves just like a standard (non-writable, pre-recorded) disc, after it has been written.

Alternatively, one can use the so-called Fabry-Perot principle based technology to make recordable CDs. This technology is based on the use of (semi) reflective parallel mirrors that allow optical interference, i.e. light is reflected or not reflected depending on the distance between the mirrors and the wavelength of the light. Having essentially the same functionality as the ordinary CD-Rs, as described above, the underlying technology works quite differently. Moreover, part of the light is absorbed in the (semi) reflective mirrors, thereby creating heat. The 'writing' laser of the CD-burner, which is switched on will locally heat the mirrors, resulting in a change of their relative distance, which in turn changes the interference conditions for the 'reading' laser in the CD-player. Consequently, laser light is reflected in non-heated areas and not reflected in the heated areas (i.e. the 'pits'), which forms a contrast that is then translated into a digital signal. The advantages of this technology are (a) it is does not need the use of dyes, which are expensive and toxic, and (b) it can easily be adapted to other laser wavelengths by selecting other distances between the mirrors. Therefore, it is cheaper and more versatile. The technology can be used for recording with different wavelengths, e.g. CD with 785 nm, DVD with 435 nm and 'blue laser' with even a smaller wavelength.

In 1994 Akzo Nobel and Samsung were in contact to possibly set up a collaboration in order to develop this new CD-R technology. Essentially, Akzo Nobel had the knowledge on the Fabry-Perot technology and Samsung the knowledge how to produce CD-Rs, although based on a dye layer. When they started the collaboration in 1996, one of the main goals was to share their knowledge with the (concrete) objectives of product development, concept testing, process demonstration, and ultimately market and business strategy development. Even more specifically, the aim of the collaboration was to develop a CD-R (technology) that fulfills the requirements of and was therefore compatible with the Orange Book II[54], which gives all the requirements that (the

[53] In conventional (non-writable) CDs, the information is presented by binary code, i.e. a series of 1s and 0s. These 0s and 1s, or bits, are respectively represented by millions of 'pits' and 'lands', i.e. bumps and flat areas, on the disc's reflective surface. The pits and lands are arranged in a continuous track of about 0.5 microns (millionths of a meter), which is in total 5 km long. To read this information, the CD player passes a laser beam over the track. When the laser passes over a land in the track, the beam is reflected directly to an optical sensor on the laser assembly. When the beam passes over a bump, the light is bounced away from the optical sensor.

[54] This Orange Book II is developed by Philips that owns the essential patent on the general CD technology, and therefore receives enormous amount of royalty revenues though licenses. To be more precise, the CD technology has been jointly developed by Philips and Sony and they therefore jointly set up the requirements for every other CD technology, e.g. audio-CDs, CD-Rs, CD-RWs and even DVDs because these have to be backward compatible with CDs. One of the most basic and apparent requirements for every CD is the size (i.e. intersection) of it, which has to be 120 mm.

design of) a CD-R has to meet. In 1998 the collaboration of Akzo Nobel and Samsung had developed their own CD-R, the 'SAN[55]-CDR', which was Orange Book II compatible. The technical development in the collaboration can therefore be considered as (technologically) successful.

After this collaboration, Akzo Nobel and Samsung continued with this new technology by setting up a new collaboration, additionally including one of the major manufacturers of CD production machinery, Toolex (see Table 20). The objective of this collaboration was to implement the process for making these new CD-Rs into a CD-R production line and to eventually market the new concept and the production line. The result of this collaboration was the technical possible to produce the new CD-R concept and the production line was also commercially available. Moreover, a business (licensing) strategy was already developed in which the earning (e.g. royalties) flows to the different firms were determined[56]. In order to successfully market a product like this one, it was argued that the teachability of the knowledge has to be high. The partners in the collaboration should namely be able to explain their know-how to (for example) a CD-R producer, which will be the one that has to produce the CD-Rs. This CD-R producer is therefore the link between the owners of the technology and the customers.

Coming back to the actual knowledge sharing and protection in the collaboration between Akzo Nobel and Samsung, their *relationship* was considered as being amicable, loyal, open, direct and pleasant. In this context it is interesting to note that the relationship with Toolex involved much more caution – to a minor extent regarding technical information but especially in relation to its business plan of which it did not disclose the details – even though it was not a direct competitor and geographically very close (for Akzo Nobel, that is). This is attributed to the very high dynamics in the market, and at that time the dramatic overcapacity in CD-R production globally in particular. This then caused big downturns on sales of production lines. Therefore, the collaboration with Toolex can be considered purely business-oriented[57]. The relationship between Akzo Nobel and Samsung, on the other hand and in contrast, was based on a healthy competitive research attitude and even on friendship. Personal chemistry was in fact considered to be essential for a successful collaboration. It moreover creates a basis for potential future collaborations and the success of these. Because of this and in order to establish an 'open sharing atmosphere', there were not so many specific contracts used. The contract that was signed in 1996 mainly stated what had to be done in case something goes wrong and was based on more-or-less standard terms.

Even though a (standard) non-disclosure agreement was used (between Akzo Nobel and Samsung), the 'disclosure dilemma' was an apparent one. The way to solve this related to the technical (and explorative) nature of this collaboration which caused the participants to respect and acknowledge each other's level of technical knowledge. This was reinforced by the academic level of the collaboration and thus of the people involved. Moreover, it was clear for everybody that the common goal was a challenging and valuable one. All of this counts for the sharing of knowledge in all kinds of embodiment, so also for intellectual property rights, which were shared to the extent needed.

---

[55] SAN stands for 'Samsung Akzo Nobel'.
[56] The exact figures are confidential.
[57] This is also due to the more exploitative nature of this collaboration, in contrast to the collaboration between Akzo Nobel and Samsung which can be considered as being highly exploitative. Therefore, the latter is the main focus of this study (although the other collaboration reveals some interesting aspects as well).

Both parties had an idea of each other's *background knowledge* due to their general knowledge and publications. Moreover, Samsung's knowledge of the market was essential (for Akzo Nobel) in order to be able to market the new product. But the most essential form of background knowledge that was brought into the collaboration was the knowledge embedded in the people's minds. The people are the ones that develop the technology (e.g. the chemical layer of a CD-R or the architecture of the CD system). In addition to this, one of the main pieces of background knowledge (which was essential to develop this technology) that Akzo Nobel brought into the collaboration was embodied in an intellectual property right. It namely had a patent for this way of using optical recording media. These kinds of patents take an important place in a collaboration such as this one. Moreover, there are some essential patents that the collaborating firms do not have in-house and therefore have to acquire licenses for. These obviously involve the payment of a compensation of some sort, most typically being a fixed royalty payment (per unit sold). In this project the most apparent basic patents were on the field of the chemicals used and the Orange Book technologies, in addition to the new concept CD-R.

Licenses and royalties also played an important role in relation to the *foreground knowledge* of this collaboration. The royalties on the foreground knowledge or technology were designed in a dynamic way because of the large development that was involved with a high insecurity. Overall, the royalty streams were considered to be well arranged, to everybody's satisfaction. The foreground knowledge developed during this collaboration consisted to a large extent of the knowledge of the new concept technology (and its components). Therefore the product itself (i.e. prototype) was an important outcome as well as the know-how that was developed in the collaboration, which can be considered to be highly specific. It was even so specific that trying to write a patent was not preferred but instead trade secrets were used. This was even stronger in the collaboration case with Toolex because the settings of CD-R producing equipment, e.g. the speed and viscosity settings of the spin coater, are very specific and based on know-how (which is in fact also part of the background knowledge). It can be said that the knowledge in this collaboration is highly specific and complex. For the general CD-R concept, the fast development and marketing of it was considered to be crucial, and thereby establishing a distribution network and quickly attain a high number of sales, in order to recover the R&D costs. In the specific case of some Asian-Pacific countries, applying for a patent makes even less sense because the patent system is not that established yet which makes it difficult to get a patent granted in the first place and a firm moreover cannot be sure to be able to file a litigation case. Another possibly created foreground knowledge could be that this collaboration created some kind of collaborative competence and routines that could be the basis of other future collaborations.

In relation to *sideground knowledge*, it can be said that this was shared very openly due to the necessity to do this for a successful collaboration. *Postground knowledge* takes quite a special role in this collaboration. First of all, although Akzo Nobel unilaterally stopped the collaboration and development activities in 1998 (which, although solved, in fact required intensive discussions due to the cultural difference), there were no real issues regarding postground knowledge. Especially not because the technical objective was already reached to a large extent, i.e. the developed technology proved to function. And the collaboration was moreover followed up by the collaboration between Akzo Nobel, Samsung and Toolex.

The end result of these two collaborations of Akzo Nobel was that, although there was technological success, the dynamics of the specific business led to fast selling price erosion and reduction of estimated royalty income. The main reason for this was the rapidly decreasing price of the already established CD-R technology whereas the SAN-CDRs still had to be marketed. Whereas a (conventional) blank CD-R cost around €50 in 1995, this was already €5 two years later due to decreasing production costs. In 1999 the wholesale price of a CD-R was already below €1, and in 2004 below 10 cents. For this reason, it was impossible to successfully market the new CD-Rs because it was now not even possible to recover the fixed costs constituted in the royalties that had to be paid to Philips[58]. It was especially Toolex that suffered from this economic downturn (eventually leading to bankruptcy) and hesitated regarding a continuation of this collaboration. Akzo Nobel and Samsung wanted to take this technology one step further by applying it to DVD-R because the price of these was higher and therefore involved a higher royalty income. But it ran into the problem, among others, that the market was divided by the two competing technologies DVD-R and DVD+R, tending to delay introduction and limit the business perspective of the format(s). The present situation is that the developed product is further developed and commercially exploited in the new generation DVD-R and blue laser DVD, by a spin-off firm of Samsung in Korea, called 'Be All' that now owns all (former) Akzo Nobel's patents on the technology. The developments at Akzo Nobel have been terminated due to strategic reorientation, together with all other photonics related projects.

5.4.2 Main Findings from the Akzo Nobel Case

In this case, the role of the market (in terms of changes and uncertainties) appeared to determine the economic success of the collaboration with Samsung, which in this case counteracted the long-term success for the two parties in the end. Despite this commercial failure, the technical success became apparent and in this case the *market uncertainty* took a less explicit role in the actual knowledge sharing and creation.

Relational characteristics appeared to be very important in this collaboration. The building of a good relationship was among other things possible due to the limited amount of partners in this collaboration, i.e. just two (or three in the second collaboration that wasn't successful due to other reasons). In this case it was not so much the geographical distance, which played a role to a minor extent, but more the cultural difference that determined the development in this R&D collaboration. This was reflected in both the sharing and protection of knowledge. The cultural distance in some way hampers an effective sharing of knowledge, which is also related to the establishment of trust and commitment. This was also reinforced by the fact that the two firms had other ways of communicating, meaning that saying the same thing does not necessarily have to mean that they actually mean the exact same thing. This was also reflected in the protection of knowledge, although this was basically taken care of by means of 'standard' agreements. Overall however other elements of the relationship, such as commitment, mutual respect and (professional) friendship, made the relationship trustful and successful.

One of the main lessons from this case is that the sharing of knowledge is directly related to the relationship between the partners. This can be clearly seen in the different relationships and thus eventually in a different way of knowledge sharing between Akzo Nobel and Samsung on the one hand, and Akzo Nobel (and also Samsung) and Toolex on the other hand. The key factors for a good relationship in this collaboration were mutual appreciation and confidence (based on common academic standards for excellent research) and trust (based on some sort of personal chemistry). The establishment of trust was considered to directly facilitate the sharing of knowledge, also knowledge embedded in intellectual property rights.

[58] The exact figures are confidential.

Furthermore, *licensing* played an important role. In general, licensing takes an important place in these collaborations, as well as royalties. It has to be taken into consideration that licensing to third parties is an important issue. In these collaborations, the licenses that had to be acquired appeared to be crucial. Furthermore, the licenses granted to the collaboration partners (i.e. among each other) were based on a royalty-free basis and the ones to third parties (i.e. the market place) were based on unit sales. Royalty payment to the collaborating partners was (going to be) arranged through the producers of CD-Rs which bought a CD-R production line and therefore directly paid royalties. Moreover, the partners received the royalties from the consumers through this CD-R producer. It has to be noted though that most of these licensing issues are dealt with on a different level in the firm hierarchy and most typically are not related to the knowledge development process in the collaboration itself.

One issue that can be identified in this collaboration in relation to patents is that there appears to be a gap between the legal people in the firm and the people who are actually involved on the technical level. Another gap that exists is the one between the practitioners that actually develop knowledge in some way and the strategic level that deal with the higher managerial issues such as licensing and royalties.

All different *embodiments* identified earlier in this report take an important place in the collaboration of Akzo Nobel and Samsung, as well as in the one of Akzo Nobel, Samsung and Toolex. The newly developed CD-R itself, i.e. product technology, was obviously one of the main embodiments of the knowledge developed in the collaboration. Regarding the collaboration with Toolex the embodiment in the production process is equivalent. Furthermore, knowledge embodied in people (i.e. the practitioners) had an essential role in both collaborations. In order to sufficiently explain this, the teachability of this knowledge is an important issue. Additionally, knowledge embedded in intellectual property rights (i.e. patents) and trade secrets, was very important as well. It can furthermore be argued that knowledge involved in this collaboration is highly complex and specific, and the imitability is rather high which, in this case, caused the need to create a lead time.

Table 21. Tension field in Akzo Nobel's collaboration

Dimensions	Measured degree
Knowledge characteristics	
- Complementarity	+
- Tacitness	+/–
- Codifibility	+
- Imitability	+
- Systematic nature	+
- Teachability	+
- Complexity	+
- Newness	+/–
- Specificity	+
Knowledge embodiment	
- IPR	+
- Technology	+
- Routines	+
- People	+
Relational dimension	
- Trust	+
- Commitment	+
- Geographical distance	+
- Cultural distance	+
- Technological distance	–
Collaboration characteristics	
- Explorative (vs. exploitative) nature	+
- Vertical (vs. horizontal) nature	–
- Number of partners	–
- Previous experience with partner	+
- Experience of partner	+
- Firm size	+
- University involvement	–
- Duration	+/–
Environmental dimension	
- Uncertainty	+
- Sector:	
- Private internalization	+
- Public standardization	–

From this case it becomes clear that the *dimensions in the tension field* of knowledge sharing and protection indeed take an important place to explain the developments in this collaboration. Table 21 shows the dimensions identified in Akzo Nobel's collaboration with Samsung (and to a lesser extent with Toolex). The table shows that the knowledge characteristics indeed play a central role in the tension field. The knowledge itself determines how it can be shared and protected. It obviously also directly influences the embodiment of the knowledge for which it can be said which all the different kinds of embodiment were important in a specific manner. Additionally the knowledge characteristics affected the relationship. This is especially related to the fact that the sharing of knowledge is invaluable for the collaboration's success. Because of this, a relationship based on trust (also on a personal level) is required. Trust is in turn created by a high degree of mutual respect and commitment. To a large extent this also determined the '*knowledge exchange strategy*' in this collaboration. As given in Table 22, an open knowledge exchange strategy was adopted in order to cope with the tension field of knowledge sharing and protection. This was reinforced by the significance of the potential result of the collaboration. This again made the firms to adopt a closed exchange paradigm with third parties. Furthermore, the technological distance (which was low) and the geographical distance (although it was high) did not cause any problems. The high cultural distance on the other hand created serious issues in the relation between the partners, even though these were resolved in the end.

In relation to the exchange strategy it can furthermore be argued that there exists a gap of some sort between the practitioners' level and the strategic (management) as well as the legal level. Therefore, the relation between the partners on the practitioners' level is not determined by the fact that the knowledge has to be protected. On the other hand, the fact that the relation is that open and trust-based on the practitioners' level partly causes the low level of protection that appears on this level.

Table 22. Knowledge exchange strategy in Akzo Nobel's collaborations

	Degree of knowledge exchange		
Exchange strategies	*Internal – Core or close members*	*Internal – Outer members*	*External – Outside*
Open exchange paradigm - private	High	N/A	Low

In relation to the knowledge exchange with third parties, it can be argued that in order to appropriate the (potential) results, the foreground knowledge was licensed out with a unit-based royalty. The partner's cross-licensed each other on a non-exclusive and royalty-free basis. This is the case for all the different forms of knowledge, especially background, sideground and foreground. Postground knowledge was a minor issue in this collaboration because the (technical) objectives were reached and the collaboration ended without any joint commercialization. The fact that especially the background and sideground knowledge was licensed to each other on a royalty-free basis is an exemplar of the open sharing strategy. For the sake of completeness, no distinction can obviously be made between an inner and outer layer in the collaboration due to limited number of partners.

Finally, in relation to the identification of the different elements of the tension field, the 'meta-dimensions' of the *environment* and the *collaboration characteristics* appear to influence the tension field. The nature of the collaboration, being very exploring and pre-competitive in first instance, created the need to establish an open sharing strategy and made it possible for the partners to grant each other royalty-free licenses. This is related to the limited number of partners and their experience. All of this is in turn related to the challenging goal and potential value of the results. The environmental dimension played a role as the sector is characterized by a high degree of increasing returns and lock-in effects, which cause the difficulty for manufacturers to deal with competing technologies (such as with CDs and DVDs) and therefore creating the need for private internalization. Furthermore, to a certain extent, this eventually caused the commercial failure of the developments of the collaboration, although it was considered successful from other perspectives, e.g. technological and relational.

5.5 ARRAY: 'TONERJET PRINTING TECHNOLOGY'

5.5.1 Array's Collaboration

Array was founded in 1987 as a small research and technology-based firm focusing on conducting research and development on the 'TonerJet' printing technology. The inventor of the base technology for TonerJet (invented in 1986) founded Array holding the base patent (applied in 1987) for the TonerJet technology. Array was worth almost €500 million, at its heyday by March 2000. In 1999, Array had around 45 employees, of whom 32 are engaged in research and development and most of the research took place at Array's research facilities in Västra Frölunda, Sweden and in Yokohama, Japan (Array Printers, 2000). At the end of the company's existence in 2004, it had approximately 9000 shareholders and owned around 350 patents (and applications). The business goal of Array was to commercialize the TonerJet printing technology, eventually in color applications. The main vision was to supply affordable and fast (around 16 pages per minute) printing equipment for offices with color application.

The alternatives to the TonerJet technology are other printing technologies used in printers, copiers and fax machines, essentially being (a) inkjet and (b) laser printing. Therefore, Array's main competitors were the producers of such inkjet and laser equipment with the emphasis on the latter because Array's primary target market has been printing equipment for offices.

The central property of TonerJet is that is prints directly on paper. Particles of pigment (toner) are ejected through microscopically small holes in a flexible printer circuit board (FPC) by electrostatic forces directly onto the passing paper (or other print medium). This is done by transporting charged toner to the FPC, which is fitted with an array of microscopic holes. Each hole is surrounded by a ring electrode connected to a printer controller via a high voltage driver. An electrostatic field created by a background electrode creates a strong field that can 'shoot' the particles on the paper. This process is controlled by the changing voltages on the ring electrodes. On standby, no toner passes through the holes in the FPC, but changing the voltage for a few ten thousandths of a second causes a small jet of toner to pass through the hole onto the paper (and each jet of toner forms a dot on the paper). The toner is lastly bond to the paper because the document is fused with heat and pressure.

This process is fundamentally different from the laser printing technology in which picture information is converted into light, stored on a light-sensitive drum which then releases charged toner onto the paper. This laser printing technology, called electrophotography (also called xerography in copiers and laser technology in laser printers), requires nine steps in total whereas TonerJet needs three processing steps to create a color printout. The inkjet technology, on the other hand, is made up of many microscopic ink jets in a shuttle type of print head. This technology is a direct printing technology as well but the printing speeds are low because the number of nozzles through which the ink jets are ejected is limited due to its price. Therefore, a shuttle has to pass the paper horizontally instead of using a page-wide print head.

Because TonerJet can easily (i.e. at a low cost) apply four page wide print heads in series[59], it can give a good performance in color printing at a relatively low (production and copy) cost. The indirect printing method of the laser printer does not permit the simultaneous development of many colors and it must therefore either run the process four times in sequence or place four complete engines in a series. Because TonerJet involved fewer processing steps and components, it provided a good and promising alternative color printing to laser printers due to the faster printouts and lower costs.

Whereas Array started working with monochrome or black-and-white printing it changed to color application in 1995[60]. This was shown by the management's focus on strengthening the po-

[59] In order to print in color, the four basic colors cyan (blue), magenta (red), yellow and black are required. By combining the four colors in different intensities color printouts are produced. Furthermore, to be sure, in the discussion of the (different) printing technologies most emphasis is put on what the technologies looked like at the time the TonerJet technology was developed by Array. In other words, the most recent developments are not always taken into consideration.

[60] The monochrome technology was licensed to ITO/Trety on an exclusive basis in 1995.

sition of TonerJet to become the leading digital printing technology for offices in the future and by the divestment of monochrome operation in order to focus on color applications. This was reinforced by the management's vision that all offices in the future will have printing equipment that has color printing capability.

In addition to exploiting TonerJet for color applications, a second main part of Array's business strategy was to collaborate with some of the leading players in the industry. With this "alliance strategy" (Array Printers, 1996: 4), as Array called it, it wanted to pursue the objective of making TonerJet the world-leading printing technology of the future. This resulted in the establishment of collaborations with firms such as Sharp, Minolta and Matsushita. In the end, Array worked with all the large Japanese firms that develop printing technologies. Licensing also was an important element of Array's business strategy.

The significance of Array's collaboration strategy is shown by the fact that it wanted to establish a large consortium around the TonerJet technology with the world's leading printing firm, especially the Japanese ones. The idea was to create a patent pool around TonerJet in order to leverage the developments of the technology as well as the commercialization of TonerJet products, while at the same time ensuring long-term financing of the firm. Although this pool was never actually established[61], it clearly shows Array's open sharing strategy. Array did not want to establish protective, on exclusivity based, partnerships which is often the case if early partnership are established and the other party wants to capitalize the technology. Especially because Array has to compete with two technologies, i.e. inkjet and laser, which were already more diffused and established in the market, it had to create momentum in the development of TonerJet by getting it widely accepted.

An important element in Array's collaboration strategy is that it mainly collaborates with large Japanese firms. The 'Japanese culture' did not give any problems with exclusivity, although it can be considered to be protective. The Japanese generally wanted to protect their technology themselves and therefore they were usually hesitant to license their technologies. For Array this was especially an issue in relation to essential patents that were required to utilize the base patent, although in the end licenses were obtained for this (with some pressure). Additionally, the Japanese had a different idea of 'technology readiness'. Whereas Array would have liked to take the step from research to development sooner and based on more (well-estimated) guesses, the Japanese partners generally wanted more prove and test before going into the next step.

Table 23. Partners in collaboration 'Four-color TonerJet printing technology'

Participants	Country
Array Printers AB	Sweden
Matsushita Electric Industrial Co. Ltd.	Japan

One of the main R&D collaborations Array was involved in was with Matsushita, a large Japanese manufacturer of printing technology (see Table 23). The collaboration started early 1998 and entailed 40 man-hours on Array's side and 30 man-hours on Matsushita's side. The main goal of this collaboration was to launch a four-color printing product based on TonerJet printing technology. This intensive collaboration was preceded by a technology exchange and smaller

[61] The efforts to create such a consortium were most significant in the year 2000, at the time Array and the printing business as a whole entered a downward trend. Because this consortium was not established, Array decided to cut costs by reducing expenses by over 65 percent (among others by reducing the staff from 42 to 21) (Array Printers, 2001).

agreements from 1995 onwards. In this collaboration Array was mainly focused on technical research, although in the end (through this collaboration) product development was an eventual aim. Because of the crisis in the high-tech (IT) market, this product development phase was not reached in the end. It can be said Matsushita had a different attitude towards the sharing of knowledge for research on the one and product development on the other hand. Although it openly shared its knowledge in the research part, it took a very confidential approach in relation to product development.

The main evaluation criteria for the collaboration were reaching a certain performance specification, at a certain price target and at a certain date. Because of some technological problems this date was moved a couple of time (by extending the collaboration). After the burst of the IT bubble, Matsushita withdrew some of its 'risky' projects. This and some other difficulties and delays in the collaboration caused that Matsushita ended the collaboration with Array in March 2000.

As said before, Array had a very collaborative strategy and collaborated in some way with almost all large players in the printing business. An early strategy however was that it did not collaborate with the market leader, Canon. As a market leader, Canon (naturally) had a high degree of self-confidence and even some kind of ignorance. Co-operation with Sharp for example proved to be difficult due to Sharp's protective attitude. A very fruitful relationship on the other hand was established with Minolta. This collaboration had a very open atmosphere with a high degree of trust, and did not continue for other reasons.

Coming back to the collaboration with Matsushita, this was based on previous long-term relationship. It is important to consider Matsushita's internal culture because it is known for being imitator (whereas most Japanese firms want to be innovative market leader and first mover). This means it generally does not want to take many risks and is not so co-operative. But in any case Array convinced Matsushita to start their collaboration, among others to become more innovative.

Because the Japanese are known for their 'management by fear' in which a non-risk-taking middle management does not want to risk its own career, the collaboration started in a rather uncomfortable manner. There were also both friendly and unfriendly meetings of the two partners. But during the collaboration a more trust-based relationship was established because Matsushita realized that it was important to 'become friends' and to become loyal to Array. This created an open atmosphere between the partners that were collaboratively conducting research.

In general, the results (also sideground knowledge) were exchanged in a rather open manner, although the patenting issue remained to be a difficult one. The agreement between Array and Matsushita was that the party that invented something had the obligation and the right to file for a patent. If however the other party helped in this invention, the patent should be co-owned. The way to deal with this issue was by having regular 'invention inventory meetings' in which array and Matsushita discussed their lists with invention and contributions. It is interesting to note that these meetings took place with the product development department, whereas this was with the strategic department in Array's other collaborations. In the end, patents were usually co-owned (also the essential patents). Co-owning involves a lot of legal parameters. In this case the partners were allowed to sub-license, also the other's part of the patent. The more co-owned licensing is used, the more kickback is created. There was one case in which Matsushita solely applied for a patent on a technology that Array claimed to have co-developed. Although this caused some arguments, the issue was resolved appropriately by arranging co-ownership.

The fact that the invention inventory meetings took place on a more practitioners' was considered to be valuable. The collaboration on the practitioners' level is namely characterized as an open sharing atmosphere whereas the strategic level takes a more protective approach.

In the *relationship* between Array and Matsushita, it became apparent that the difference between organization cultures played an important role, mostly based on the general cultural differences. A main cultural difference that was noticed in this collaboration was that 'in Japan the individual is shaped by the group whereas in the West the group is shaped by the individual.' The geographical distance furthermore played an interesting role in this collaboration. Whereas the distance was in some way a hamper for a good relationship, it made the collaboration more interesting on the other hand as well. And although Array opened a research department in Japan, Matsushita (and other partners) made little use of it because there was something 'exotic' about this cross-continent collaboration. It can be said that Matsushita was attracted by Array's inventions (i.e. technology and patent portfolio) and not that much by its endurance in research. In fact, Matsushita generally considered Array's research approach to be too quick, too much based on guesses and not analytic enough.

Interestingly, Array and Matsushita had a different technological approach (related to technological distance). Array's approach can be considered to be wide (i.e. knowing a bit though enough about different field of the technology and market) and Matsushita's approach is deep (i.e. knowing a lot or everything about a specific technology). This caused some friction, especially in the beginning of the collaboration, because it created some frustration but eventually it proved to be a fruitful combination.

The ease to collaborate is considered to be essential for the success of a collaboration. A trust-based relationship will therefore contribute to an open sharing within the secrecy agreement. And because secrets were kept secret, this strategy worked out well. And it was argued that, if one does not want the partner to know or use a certain piece of knowledge, one just does not provide this knowledge anyway. And in any case, in this collaboration there was no inappropriate knowledge acquisition.

In relation to the *embodiment* of the knowledge, patents played an important role. This was firstly due to the general importance of patents in the development and commercialization of a technology such as TonerJet. And moreover the involvement of a Japanese partner and the Japanese market created a special importance for patents because of the patent structure and culture in Japan. It can namely be said that almost all kinds of knowledge (so all kind of embodiments that are important in this collaboration) are patentable according to the Japanese patent law, e.g. know-how. Array had to adopt this, although patents played a central role in its strategy anyway. Because of the different approaches towards patenting, Array tried to categorize their inventions according to their inventive step. It used three main categories, one being a 'pure' (essential) invention, another being a 'protection patent' with no real inventive step (according to European patent law), and yet another one that is in between these two.

In relation to Array's general patent strategy it can be said that it had to apply for many patents for protection and (royalty) income through licensing. The establishment of a strong patent portfolio was furthermore invaluable to be competitive in this market, also to be able to set up cross-licensing schemes. The importance of knowledge embodied in settings of technologies was high and these were treated as confidential (or as trade secrets in the general patent strategy) and protected by using non-disclosure agreements. In relation to R&D collaborations, co-ownership with sub-licensing right of patents took an important place in the patent strategy. Apart from patents, creating lead times is an important general strategy for Array to stay competitive.

The TonerJet technology (with all its elements) and other technologies were obviously important as well, although often in relation to the patents. With regard to the technologies themselves, the performance parameters (and improvements of these) were essential within the collaboration, as well as for the market as a whole. Test results, as an output of the technology, furthermore had an important role as well because these showed the performance of the different parameters and their developments. In the collaboration typically, Matsushita expected Array to reach a certain performance before taking the next step in the agreement.

Routines were mostly identified as being some kind of collaborative routines that improved over time. In the case of Array, it became more and more skilled in collaborating with Japanese firms in a period of 15 years of collaborations. The collaboration with Matsushita was considered to be a summary of these skills because Array was able to deal with many of the issues that arise in collaborating with a firm like Matsushita. Inside the collaboration itself, on the level of the practitioners, formal and informal routines were established by setting up collaborative teams. The members of these teams were very loyal to each other, and it is argued that they were even more loyal to the collaboration than to their own firm (also due to the importance of the success of the collaboration, both for the position of them in the firm and for the firm in general).

In relation to the *environmental dimension*, the importance of standardization efforts becomes apparent. In the printing industry (i.e. printers, copiers, faxes) standard in the markets arise *de facto*. Therefore, there is no formal way to 'force' a standard. For this reason, there was little to do for Array (e.g. in their collaboration with Matsushita) than to convince manufacturers to adopt the TonerJet technology. In fact, the target for Array was to eventually get all the manufactures to use the TonerJet printing technology. In this sense the performance of the technology it the essential factor. It was furthermore important that the technologies (and markets) for inkjet and laser had matured much more than for TonerJet. And even though Array made many performance improvements on TonerJet, it had still a long way to go before it gained on their competing technologies. The higher performance increase for TonerJet than for inkjet and laser can be to a high extent attributed to the maturity of the technologies, which means that TonerJet was still driving down a steep learning curve. In the end Array appeared not to be able to break the barrier with laser (and inkjet), which eventually caused the downfall for Array.

The present situation is that Array was closed down and sold its entire patent portfolio[62]. A part of it was sold and the co-owned patents were split up and were typically transferred to the other owner for free. The TonerJet is still developed although on a very small scale[63].

5.5.2 Main Findings from the Array Case

The *market uncertainty* has an important role in this collaboration. On the one hand, it explains the main rationale for this collaboration because Array needed to create a lead time and a large market share at the same time in order to the first one to implement the TonerJet technology (with color application) in the market *and* to 'catch-up' with the competing technology (especially color

[62] In 2003 Array acquired a low-cost airline, FlyMe Sweden AB, and will continue its business under that flag.

[63] It is interesting to note that, in the end, one product with Array's TonerJet technology reached the market, namely a fax machine that was commercialized by Array's licensee ITO/Trety. The fax (Challenger II) was sold through Deutsche Telecom's retail chain in Germany, creating Array's first royalties in 1997 (Array Printers, 2000).

laser printer). Clearly, this also relates to the '*private internalization*' efforts inherent to this sector. This furthermore explains why Array entered into earlier collaborations and smaller licensing agreements with other players in the market (not the least with competitors or potential competitors). In the collaboration case with Matsushita it had positive previous experience which fostered the building of trust in this relationship in turn causing an open sharing atmosphere. In the end, the market setting (especially related to the high uncertainty) caused the commercial failure of the TonerJet color application.

Therefore, the *collaboration characteristics* partly determine how the partners go about knowledge sharing and protection. The competence and experience of the partners determines the success of technological development in general. In addition, good experience at previous occasion proved to be important as well. In combination with the low number of partner, this collaboration was considered to be a fruitful one. Even though the relationship could in the future turn out to be potentially competitive, it was acknowledged collaboration was a necessity to create new revenues. The explorative nature has a large impact on the consequences of the different kinds of embodiments, the complexity of the knowledge and the significance of a trust-based relationship. The small size of Array played an important role as well in this collaboration. Being highly knowledge-based, it had a great need to protect its knowledge base but still the sharing of knowledge (by collaboration) was essential to develop new products and thereby stay competitive. As indicated above, the *relational dimension* has trust as a central element. The high cultural distance (especially in relation to the research and patenting culture) required some additional caution in the sharing and protection of the results in the collaboration. The cultural distance is exemplified by the different management styles of the Japanese, especially because the middle management generally takes few risks. This issue was resolved by creating some sort of (professional) friendship as the basis for a relationship build on trust and mutual appreciation. Moreover, especially the geographical distance made a collaboration as this 'exotic' to some extent, also reinforcing commitment of the partners.

With regard to the *knowledge embodiment* it can be argued that (in relation to the sector setting) a strong patent portfolio is crucial, for both small and large firms. Essential patents moreover highly determine a firm's competitiveness. Small firms (such as Array) therefore need to assure a strong patent portfolio, in order to be able to develop new technologies and also to be able to set up cross-licensing arrangements (e.g. in R&D collaborations). In this collaboration, all kinds of embodiment were recognized to be important (moreover due to the different (i.e. lower) requirements for patentability in Japan). A strong patent portfolio in addition to having capable people is the main reason to collaborate with a partner in explorative research and development.

In this kind of explorative collaboration (although exploitation was an eventual goal), the *knowledge characteristics* clearly play an essential role. The high complexity, specificity and systematic nature were a main reason to collaborate. Due to the complementarity and codifibility of the knowledge, Array and Matsushita were able to make clear agreements on the transfer of knowledge, which in fact fostered an open and innovative atmosphere in the collaboration. This was also possible due to the explicitness of the knowledge (i.e. patents) although tacit knowledge was important as well. In relation to this, it can be argued that the knowledge is not new *per se* (e.g. Array's essential patent dates back to 1987) and the imitability is high. Table 24gives an overview of the characteristics of all the dimensions in the tension field.

Table 24. Tension field in Array's collaboration

Dimensions	Measured degree
Knowledge characteristics	
- Complementarity	+
- Tacitness	+/–
- Codifibility	+
- Imitability	+
- Systematic nature	+
- Teachability	–
- Complexity	+
- Newness	+
- Specificity	+
Knowledge embodiment	
- IPR	+
- Technology	+
- Routines	+/–
- People	+/–
Relational dimension	
- Trust	+
- Commitment	+
- Geographical distance	+
- Cultural distance	+
- Technological distance	–
Collaboration characteristics	
- Explorative (vs. exploitative) nature	+
- Vertical (vs. horizontal) nature	–
- Number of partners	–
- Previous experience with partner	+
- Experience of partner	+
- Firm size	–
- University involvement	–
- Duration	+/–
Environmental dimension	
- Uncertainty	+
- Sector:	
- Private internalization	+
- Public standardization	–

In general, it can be said that licensing is very important in this collaboration. This is due to the importance of (essential) patents in this collaboration, as in this industry as a whole. With regard to the background knowledge put into the collaboration, Array and Matsushita cross-licensed each other the required access to their (essential) patents. The partners filed for patents on foreground technology together (i.e. co-owned patents) and individually if they developed the knowledge themselves (i.e. sideground knowledge). In the latter case, a non-exclusive and royalty-free license was granted to the other. These licensing arrangements were a way to share the knowledge as this was required for the collaboration but protect it as the same time. Therefore, licensing was a means to cope with the tension field and in fact also to set up an open sharing atmosphere in the collaboration. The open sharing of knowledge becomes clear from the general attitude to freely share knowledge (in different phases in the collaboration). Patenting thus had an important role in this because these determine the future success and profitability to a large extent. Especially on the management level this was a delicate issue. In this collaboration this was discussed (in the 'invention inventory meetings') on the product development level which was considered to be much less tensed. Co-owning of patents was used if the two firms jointly developed a certain piece of patentable knowledge. In addition to patent protection, secrecy agreements were used, which were considered to work well.

From this it can be derived that a *private open exchange strategy* was adopted, although to a limited extent (Table 25). As argued in Section 4.3.4, a strong position of patents in a collaboration is expected to relate to a closed exchange strategy. As patents take a very important role in this collaboration, some elements of a closed strategy can be identified, such as a more restrictive exchange of knowledge. But because of the importance of tacit knowledge and the explorative nature of this collaboration, a more open exchange strategy was needed to reach the collaboration's goal. Therefore, although the degree of internal knowledge exchange is limited to a certain extent (i.e. moderate to open), it is argued that this collaboration adopted an open exchange strategy. Clearly, the importance of private internalization created a low degree of external knowledge exchange.

Table 25. Knowledge exchange strategy in Array's collaborations

	Degree of knowledge exchange		
Exchange strategies	*Internal – Core or close members*	*Internal – Outer members*	*External – Outside*
Open exchange strategy - private	Moderate to High	N/A	Low

5.6 Eka Chemicals: 'Speciality Collodial Silica Application'

5.6.1 Eka Chemicals's Collaboration

Eka Chemicals is one of the subsidiaries of Akzo Nobel within its chemical business. Eka Chemicals's main business is the pulp and paper industry. Besides pulp and paper, it is involved in several other activities, such as speciality (paper) chemicals. This latter activity in turn consists of 7 groups of activities, one of which being the Colloidal Silica Group. The Colloidal Silica Group uses one of the base chemicals that Eka Chemicals itself uses. The existence of a group as this one relates to the vision of Eka Chemicals, which is to be the leader in the pulp and paper industry and also develop other businesses. The Colloidal Silica Group is a small unit, i.e. 25 people, that is active on a global scale. Its main focus is market development with help of R&D and it is active in several industry segments, i.e. electronics, construction, coating, foundry and other selected industries.

The R&D collaborations of Eka Chemicals, and also of the Colloidal Silica Group, are manifold with different designs and in different regions. Quite typically, the financing of a Ph.D. student is involved in a collaboration to establish the more basic research. Although there is no explicit rule, the rule of thumb is that a collaboration should take approximately three years. The R&D collaborations often take the form of a 'Joint Development Project' with different phases during its lifetime. The Joint Development Project starts with a Joint Development Agreement that derives from a market perspective. In general, the collaborations are set up to come closer to a partner in order to create new demands. The R&D collaborations nearly always consist of two firms that have to bear their own costs and bring in their own recourses. A limited amount of collaborations involves (European) funding and these are seen to be less relevant for various reasons, e.g. more partners and therefore managerial more complex, the bureaucracy involved, the lower profitability. The European projects generally take more time and might be more general. The 'ordinary' collaborations, on the other hand, are considered to be more profitable, have a higher speed and are to large extent based on trust which is reflected in the use of a secrecy agreement. Concerning the outcome with relation to the amount or level of knowledge sharing, these can differ widely over the different collaborations. These collaborations are very much business related and usually involve (future) customers. To a minor extent the collaborations involve already existing customers.

Table 26. Partners in 'speciality collodial silica concrete application' collaboration

Participants	Country
Eka Chemicals	Sweden
'Construction Chemicals Firm'[64]	- (Europe)

The collaboration that will be the specific focus of this study involved a global firm based in Europe, as also shown in Table 26. This global firm supplies the speciality chemicals market. Its main business is in processing materials used in construction chemicals. After the Colloidal Silica Group of Eka Chemicals successfully conducted some small internal research on a speciality application of colloidal silica in concrete, it sought a partner to develop this. For this, it had contact with three different firms and eventually in 2001 it decided to collaborate with the Construction Chemicals Firm. It officially started the collaboration with the Construction Chemicals Firm early 2002. The Construction Chemicals Firm, which is involved in organic chemistry, was already selling concrete whereas the Colloidal Silica Groups was not (yet) in the concrete business, except for the well-cementing with certain special demands. Therefore, one main motive for Eka Chemicals to go into this collaboration was to be able to make use of the Construction Chemicals Firm's sales channels. On the other hand, acceptance on the market place is an important issue as well, because the use of colloidal silica is needed to be accepted in this segment, which is in turn a reason for the Construction Chemicals Firm to collaborate with Eka Chemicals. The collaboration itself mainly focused on product development and product modification, i.e. mostly exploitation. The more explorative (or basic) research activities are performed by a Ph.D. student who receives funding from Eka Chemicals.

The choice for the Construction Chemicals Firm as a partner was thus dependent on its quality, capacity, size (of distribution channel) and familiarity with colloidal silica. The *relationship* is considered to be quite smooth and there is a high level of commitment and trust. To a certain extent, this is created by the mutual dependence (and therefore necessity to collaborate, in a way) but the relation on a personal level is essential in this as well. Although both firms have an 'official' communication channel, there is regular contact between the people involved on a lower level of the collaboration. And in fact, the 'mutual hostage situation' (or just mutual dependence) only exists to a limited extent because both firms had a good possibility of reaching the same goal on their own although this would have taken a significant longer time with a higher uncertainty. Interestingly, the relation between Eka Chemicals and the Construction Chemicals Firm could be described as being both horizontal and vertical. It is horizontal because they are (now) active on the same segment and especially after the collaboration they will be competitors to a certain extent. It is vertical because Eka Chemicals makes use of the Construction Chemicals Firm's sales channels to exploit its innovation. But obviously they are also jointly developing a new product that they will also market together and therefore their relation as collaboration partners is essential as well. In this collaborative effort the technological distance can give some difficulties to establish an appropriate sharing of knowledge. This issue can be resolved to a large extent by the professional background that people have, and the Colloidal Silica Group even has a consultant

[64] The name of this firm and its exact business are confidential. From here onwards this firm will be referred to as 'Construction Chemicals Firm'.

that knows the market in order to deal with this. Moreover, the personal characteristics and relationship is essential to crate a good connection.

Then looking in more detail at how this appropriate knowledge sharing was actually established it is important to show the product one is working with in order to make clear what you are talking about and to prove your point. In this case, it was for example important to explain the exact functions of colloidal silica. One way to cope with the existence of technological distance between the partners is by trying to explain it in terms the other is used to. And again, just showing something can already convince the other. Sometimes moreover well-known and therefore older knowledge is used, although in general the knowledge in the collaboration can be considered as being new. Overall, the ease to use and appropriately share each other's knowledge is considered to be high.

The role of intellectual property rights (as *knowledge embodiment*) was very important in this collaboration. There were some patents that were an essential part of the background knowledge put into the collaboration. Eka Chemicals had to bring in three patents on concrete that were considered to be extremely strong. The Construction Chemicals Firm also had to bring in an extremely strong patent it has in the area[65] and also in concrete application without colloidal silica. Eka Chemicals was in fact hesitant to bring in one of its process patents while it had fewer problems with sharing its product patent because this just involved a particular application. Patents are generally considered as some sort of security. Furthermore, knowledge embodied in technology takes an important place, especially for the foreground knowledge because a product will be the end result of the collaboration. Knowledge embodied in people is very important as well because know-how entails a large part of the knowledge brought into the collaboration. Furthermore, the less technical knowledge from the (formal) project leader is considered to be important as well because he has a crucial role for the success of the collaboration. This is also reflected in the routines that are recognized to exist in some way in the collaboration. More formal routines are seen to be embedded in the (formal) communication channels that were set up, although the more informal and personal communication is important as well. Another example of more informal routines is that a sort of culture exists that allows people to do 'stupid' things, which could have very new and valuable outcomes.

The *characteristics of the knowledge* that is being shared and developed in the collaboration is considered to be an important issue that also influences the way the actual knowledge sharing and protection are established. First of all, the knowledge in this collaboration was extremely complex. Both partners did not always understand each other's knowledge, although this is not a necessity to reach a successful collaboration. The collaborating partners cope with this by adopting some sort of mixture between chemical understanding and functionality, meaning that one does not always have to fully understand a piece of knowledge of some sort as long as one is convinced about the performance. Although, the imitability of the knowledge in this collaboration is high, this is not a major concern because all the important knowledge is protected by patents. So, if another firm uses the knowledge, it would infringement Eka Chemicals's (and the Construction Chemicals Firm's) patents. Infringement can be rather hard to detect, however. The way to go about this issue is by using licenses, the access to which is also one of the main reasons to collaborate. The teachability of the knowledge, which sometimes can be low, creates the need for good personal relationships that foster learning. In this collaboration, because colloidal silica has

[65] Details about the patent are confidential.

not been used in this application before, it can have different forms. The learning relationship can therefore be based on the fact that not all colloidal silica is the same and that not all concrete is the same, and subsequently realizing that one needs to learn from each other to sufficiently understand the underlying knowledge. The newness of the knowledge is in general very high which in a way gives an advantage because it creates a lead time relative to the competitors. Though, because of the importance of patents, a significant amount of knowledge can be considered as old, i.e. over 10 years (in the case of the Construction Chemicals Firm's patent).

At this moment, the collaboration is still ongoing and approximately one third of the thus far defined work packages are completed. Concerning postground knowledge is can be said that this is arranged by the agreement that both firms will be silent about any developments to each other after the three (or perhaps three and a half) years of collaboration. This secrecy strategy clearly prohibits any exchange of postground knowledge.

5.6.2 Main Findings from Eka Chemicals Case

Considering the *market* background of Eka Chemicals's collaboration it can be said that it partly uses its core knowledge and material but that it is also outside of its core business and involved more peripheral and new (for the firm) knowledge, which answers to its vision to develop other businesses.

The use of a secrecy agreement is considered to be very important because *open knowledge sharing* is essential for the success of a collaboration. In the case of Eka Chemicals this is moreover the case because their collaborations are very much business related and usually involve (future) customers. Therefore an open-minded atmosphere creates appropriate knowledge sharing, and thereby the collaboration can be a success and moreover it assures (to a certain extent) future business. Consequently, Eka Chemicals's collaborations involve partners with complementary resources bases. This can on the one hand facilitate the knowledge sharing because of the non-competitive relationship but on the other hand it can hamper it because of the technological distance between the firms. Moreover, success is considered to be dependent on the knowledge in the minds of people and the access to this knowledge, and on the tradition or culture of the firms and the impact on the relationship.

The reason for collaborating with the Construction Chemicals Firm was to get access to its know-how (it namely has some basic knowledge that facilitates the development of their colloidal silica application in concrete), its patent a part of this know-how, and its sales channels. Overall, with regard to the *knowledge embodiment*, the knowledge that has to be shared in this collaboration can de seen as a mixture of know-how and more explicit knowledge such as patents and (process and product) technologies. In addition, it is recognized that some sort of collaborative routines exist that could be based on formal and informal rules, and culture. Overall, it can also be said that knowledge is openly shared to the extent needed, and most of this is covered by a standard non-disclosure agreement.

The *characteristics of the knowledge* that is being shared and developed in the collaboration is considered to be an important issue that also influences the way the actual knowledge sharing and protection are established. In order to deal with the complexity of the knowledge, which was very high, it can be sufficient to actually see a performance of some sort that shows the functionality that is enough to convince someone of the validity of the knowledge. Therefore, teachability is an important issue that can be resolved (if problems occur) by creating learning fostering relations.

Table 27. Tension field in Eka Chemicals's collaboration

Dimensions	Measured degree
Knowledge characteristics	
- Complementarity	+
- Tacitness	+/–
- Codifibility	+
- Imitability	+
- Systematic nature	·
- Teachability	–
- Complexity	+
- Newness	–
- Specificity	+
Knowledge embodiment	
- IPR	+
- Technology	+
- Routines	+
- People	+
Relational dimension	
- Trust	+
- Commitment	+
- Geographical distance	+
- Cultural distance	–
- Technological distance	+
Collaboration characteristics	
- Explorative (vs. exploitative) nature	–
- Vertical (vs. horizontal) nature	+/–
- Number of partners	–
- Previous experience with partner	–
- Experience of partner	+
- Firm size	+
- University involvement	–
- Duration	+/–
Environmental dimension	
- Uncertainty	+
- Sector:	
- Private internalization	+
- Public standardization	–

From this case, several elements of the tension field of knowledge sharing and protection can be identified, as shown in Table 27. First of all, it has to be noted that this collaboration just partly complies with the original goal of the case study because it is very much business related and therefore less pre-competitive although it still had important pre-competitive characteristics. Interestingly, whereas the collaboration involves the collaborative development of a new product and there is a high degree of mutual interdependence, the two partners will act competitively towards each other in this business. Therefore, the nature of the collaboration can be considered mainly exploitative[66] and horizontal as well as vertical. Because of this specific background of the collaboration, the fact that was no previous relation with the Construction Chemicals was a motive for the collaboration and created an open atmosphere, which is in contrast to the expectations. Eka Chemicals has furthermore some rules of thumb it applies to its collaborations in relation to the number of partners (i.e. two), partner size (in this case the size of the distribution channel), and duration (approximately three years). In relation to the *environmental dimension*, the

[66] The explorative part of the development is to a large extent taken care of in-house or by financing a Ph.D. student, in the case of Eka Chemicals.

uncertainty was important to set up the collaboration and caused a mutual interdependence, which again established a good open and professional relationship. The sector setting becomes especially apparent with regard to the use of patents in this collaboration. The use of product patents namely works rather well but process patent are more difficult to protect.

Coming back to the tension field, the *knowledge characteristics* take a central place in it. The high complementarity, complexity and therefore low teachability create the need for a good relationship that can establish a good knowledge sharing. Especially the relationship on a personal level is important. It was possible to establish this *relationship* because of the mutual interdependence and the professional attitude of the people that were involved. Trust takes a central role and was also set up within the boundaries of the secrecy agreement. A hampering element of the relationship was the technological distance between the firms. By using an open sharing and appropriate terminology this was resolved, in addition to building a relationship that was based on trust and friendship as well as using a consultant that can bridge some issues.

Thus, an open sharing or *knowledge exchange strategy* is used in this collaboration. Because the appropriation of the results is privately internalized within each partner (due to of the partly competitive nature of the collaboration) there is no exchange of knowledge with third parties. As said before, the open exchange between the two partners was based on trust and a professional though friendly relationship. This was reinforced by the mutual dependence of the two partners. On the other hand, formal communication channels were used, although much contact took place outside these. But moreover the technological distance was high which constrained the exchange of knowledge in some way (also shown by the use of a consultant within Eka Chemicals to bridge this gap) even though it was not considered as being a big issue. In sum, a private open exchange strategy can be identified in this collaboration with a moderate to open knowledge exchange (Table 28).

Table 28. Knowledge exchange strategy in Eka Chemicals's collaborations

	Degree of knowledge exchange		
Exchange strategies	*Internal – Core or close members*	*Internal – Outer members*	*External – Outside*
Open exchange paradigm - private	Moderate to high	N/A	Low

The open exchange of knowledge was generally considered to be required to reach the goal of the collaboration. The competitive nature and the technological distance together with the strong position of the (essential) patents however created a need for a more formalized knowledge transfer by means of 'ordinary' licenses. Transfer of know-how on the other hand was covered by a general secrecy (non-disclosure) agreement, thus facilitating a more open sharing atmosphere. The embodiment of the knowledge therefore directly affected how the knowledge could be shared and protected. In short, the main background knowledge consisted of the essential patents that were required to develop the product as well as the people's knowledge on different processes and marketing issues. The product itself is the main foreground knowledge, in addition to the developed know-how. Certain routines were also identified, both formal (e.g. official communication channel) and informal (e.g. collaborative culture). And to be complete, the exchange of postground knowledge is ruled out by agreement.

5.7 Ericsson: 'Network Solutions Beyond 3G'

5.7.1 Ericsson's Collaboration

It is widely acknowledged that the telecommunications industry is in a continuous flux. This is brought about by the developments from the providing firms' point of view as well by as the changing demand of the customers. Major players like Ericsson acknowledge this and try to go into these developments in order to stay competitive in the long run. Especially in an industry such as telecommunications there is a need to establish operability across different equipment suppliers, network operators and service providers. Therefore, (cross-operability) agreements and thus standardization are needed to get a foothold in the market. In addition to this 'vertical' operability, the establishment of 'horizontal' operability is an important trend to consider. This means that there should be inter-operability between the different suppliers, operators and providers, respectively. In other words, users should be able to switch between the different independent networks and applications. All of this also applies to making agreements with one's (direct) competitors. The way this is typically dealt with is by setting up pre-competitive collaboration or forum in which the different involved organizations can pool their resources (both know-how and patents) in order to establish a common standard. For example, the Wireless World Initiative tries to provide a framework that maximizes the critical mass and global impact of the proposed technical work in the wireless industry and ensuring the transfer of results into the global market by building on the work of the previously established Wireless World Research Forum (http://www.wireless-world-initiative.org, 2004). The Wireless World Initiative involves four partner projects within the 6th Framework Programme. These are 'Ambient Networks', 'WINNER'[67], 'E2R'[68] and 'MobiLife'[69]. The first one, with Ericsson as project coordinator, is the one of interest in this study.

The 'Ambient Networks' collaboration addresses the above-mentioned need to create a common basis for standardization on the basis of pre-competitive R&D. It will try to establish horizontal inter-operability between independent providers by providing a common network. More specifically, the collaboration will create the network solutions for mobile and wireless systems beyond 3G[70] and it will enable scalable and affordable wireless networking while providing rich and easy to use communication services for everybody (http://www.ambient-networks.org, 2004). In other words, it wants to create a pervasive, reliable communication environment hiding the heterogeneous infrastructures, supporting the ever changing needs of users and services (http://www.cordis.lu, 2004). Although the collaboration is pre-competitive, it wants to stimulate increasing competition and co-operation in order to address the needs of the whole environment, consisting of by a multitude of user devices, wireless technologies, network operators and business actors. While the collaboration in total will span six years (with 100 man years per year) it

---

67 WINNER: Wireless World Initiative New Radio. WINNER (with Siemens as project coordinator) is a consortium of 38 partners coordinated by Siemens working towards enhancing the performance of mobile communication systems (http://www.ist-winner.org, 2004).

68 E2R: End-to-End Reconfigurability. E2R (with Motorola as project coordinator) is an Integrated Project of the 6th Framework Programme of the European Commission, addressing the core of the strategic objective 'Mobile and wireless systems beyond 3G' (http://e2r.motlabs.com, 2004).

69 MobiLife (with Nokia as project coordinator) is to bring advances in mobile applications and services within the reach of users in their everyday life by innovating and deploying new applications and services based on the evolving capabilities of the 3G systems and beyond (http://www.ist-mobilife.org, 2004).

70 3G stands for 'Third Generation' referring to a set of mobile technologies based on the digital wireless technology 'CDMA' (with the cdma2000 and W-CDMA variants) constituting to the third generation mobile telephony.

consists of three main phases. The first phase[71] concentrates on exploratory research and identifies key technologies and requirements, the second phase will deal with the technology development and detailed system definitions, and phase three will focus on system synthesis and demonstrations (Abramowicz, Niebert, Mohr, *et al.*, 2004).

In order to achieve its goal, i.e. to create cross-industry consensus and to drive standardization, Ambient Networks had to bring together some of the leading operators, vendors, SMEs and research organizations. For this reason it involves a number of 41 partners[72] that are given in. Because a secondary goal of the collaboration is to create a world-wide standard, it also includes three non-European partners, being Motorola from Japan, University of New South Wales from Australia and University of Ottawa from Canada. Whereas the preparations for this collaboration started in January 2002, the first phase started in January 2004. A good preparation (of about at least one to one-and-a-half years) is considered to give a collaboration such as this one a 'flying start'.

For this collaboration it was not difficult to find partners, while it is more difficult to find the *right* partners that can contribute significantly[73]. The main selection criteria for finding the right partners is that it should have an impact on standardization, it should be involved with academic and qualified research, and it should contribute to the overall acceptance of the result because the different players (i.e. suppliers and vendors) should act as a unity.

Regarding the *relationships* between the different partners, it is considered necessary to physically meet each other. For this reason, the geographical distance could hamper a good knowledge sharing. In this case, the involvement of non-European partners makes this issue even more apparent, due to the travel times and the time difference. Although e-mails are extensively used to share knowledge (on developments), this latter issue (i.e. time difference) can create problems if the partners want to have a (phone) conference. This is often done for a limited amount of partners that work together on a certain work package (or sub-project).

The work in this collaboration is divided into work packages that consist of 7 to 8 partners each, on average. This means that the partners of the collaboration as a whole are distributed over different 'sub-projects'. Each of these work packages typically involves partners from the same technical area, i.e. operators, vendors and academics. Different resources and efforts are required to reach the respective objectives of the individual work packages. There are usually leading partners that drive the process in a certain work package.

Technical distance is not considered to be applicable in this collaboration, as for the telecommunications industry in general to a large extent. In this case, the partners are part of a certain 'community' in which people meet on a regular basis (e.g. via forum meetings) and there are certain common partners to collaborate with. Everybody knows the leading organizations (industry and academic) and they all know each other very well. The relationship between partners grows over time, also on a social level (which is important as well). This creates trust and a 'collaborative spirit'. No conflicts have arisen in this collaboration, which is also due to the fact that it is of general strategic importance, i.e. pre-competitive research.

---

[71] Because this collaboration is still ongoing (in the first phase) the focus of this study will be on the first phase. It is important to note that this case can therefore not explain any issues in relation to postground knowledge.

[72] That is, 41 legal partners, also including a couple of subsidiaries *and* parents. Because of the large number of partners in this collaboration it is interesting and important to note that Ericsson had the financial and administrative control for this project.

[73] In this context it is interesting to note that there are still organizations interesting in joining the collaboration.

Table 29. Partners in collaboration 'Ambient Networks'

Participants	Country
Ericsson AB	Sweden
Alcatel SEL AG	Germany
British Telecommunications plc	UK
Budapest University of Technology And Economics	Hungary
Concordia University	Canada
Consorzio Ferrara Ricercha	Italy
Critical Software S.A.	Portugal
DaimlerChrysler AG	Germany
DoCoMo Communications Laboratories Europe GmbH	Germany
Elisa Corporation	Finland
Ericsson Eurolab Deutschland GmbH	Germany
Ericsson Magyarorszag Kommunikacios Renszerek K.F.T.	Hungary
France Telecom SA	France
Fraunhofer Gesellschaft zur Foerderung der Angewandten Forschung e. V.	Germany
Instituto de Engenharia de Sistemas e Computadores do Porto	Portugal
Kunglia Tekniska Hogskolan	Sweden
Lucent Technologies Network Systems GmbH	Germany
Lucent Technologies Network Systems UK Limited	UK
Motorola Japan	Japan
National ICT Australia (University of New South Wales)	Australia
NEC Europe ltd	UK
Nokia Corporation	Finland
Oy LM Ericsson AB	Finland
Panasonic European Laboratories GmbH	Germany
Rheinisch-Westfaelische Technische Hochschule Aachen	Germany
Siemens AG	Germany
Siemens AG Oesterreich	Austria
Siemens Mobile Communications SPA	Italy
Swedish Institute of Computer Science AB	Sweden
Technical Research Centre of Finland	Finland
Technische Universitaet Berlin	Germany
Telecom Italia SPA	Italy
Telefonica Investigacion y Desarrollo SA Unipersonal	Spain
Telenor Communication AS	Norway
TeliaSonera AB	Sweden
TNO - Netherlands Organisation for Applied Scientific Research	Netherlands
University of Surrey	UK
Universidad de Cantabria	Spain
University College London	UK
University of Ottawa	Canada
Vodafone Group Services Limited	UK

No problems in the sharing of knowledge are observed. A model contract (of the European Commission) is signed that commits every partner to share its knowledge (to the extent needed), although different terms could be designed (as long as these are fair and reasonable). Also the knowledge embodied in intellectual property rights should be shared. Furthermore, all foreground knowledge that is developed during the collaboration should be shared as well. Because of the pre-competitive nature of this collaboration and because it wants to create a (world-wide inter-compatible) network and therefore create a standard, the strategy in relation to foreground knowledge is publishing instead of patenting. A more general point here is that the protection of knowledge will be more important in the next phase of the collaboration, whereas this first phase mainly focuses on *exploratory* research. Therefore, the knowledge is rather complex (although understandable) and very new. What is more, one wants to find out the state-of-the-art by identifying novelties and focusing on them (and integrating them). In this collaboration, intellectual property rights will especially be used in order to prevent software development by others. These intellectual property right will also be used as a demonstration to show the 'proof of concept' in order to convince others about the quality of the technology. In order to lower transaction costs, large firms might establish some cross-licensing scheme in relation to the intellectual property rights on this collaboration.

In order to appropriate each other's knowledge, the partners take their competence as a staring point and share (only) the knowledge that is relevant. The different partners (in their subprojects) write papers that everybody can see (and will read if appropriate). These contributions drive the collaborations. In addition to writing papers, it is important to actually meet the people one collaborates with. Additionally big meetings are held for both each work package as well as for the consortium as a whole. In these meeting people exchange and moreover discuss documents (and ideas). This process is also driven by the deliverables for which the dates are fixed. Sometimes, if needed, additional meeting are scheduled.

Because it is important to get to know each other, to facilitate an appropriate knowledge sharing, the collaborating partners (on the practitioners' level) have to see each other (by arranging real, physical meetings). In this sense body language plays an important role and so does potentially cultural differences. In general, it is crucial that the partners speak a 'common language'.

In relation to collaborative routines, it is argued that there is a certain skill to recognize potential collaborations. Furthermore, the importance of collaborating is sometimes underestimated. Another skill (or perhaps knowledge) is how to transform the research results into a successful project. Thus, 'collaborative skills' are important and even a necessary (but not sufficient) basis for collaboration.

The collaboration as a whole is set up to create a certain market momentum. To be successful it is important to 'build standards, not fences'. In order to make the pie bigger, one needs to share its knowledge. A successful collaboration needs an open collaboration climate, a humble attitude and people should have the opportunity to have their say (which again relates to collaborative skills and routines). All of this is based on (and reinforces) trust which is considered to be an intermediate variable to reach success. Good communication (in relation to the specific industry or branch) is clearly important as well. In order to be successful in a collaboration as this one, a trade-off has to be made between creating momentum (or mass) and effectiveness (especially with this amount of partners).

5.7.2 Main Findings from the Ericsson Case

One of the most apparent *characteristics of this collaboration* is its large number of partners. This highly determined how the sharing and protection of knowledge was designed. In general, a large amount of partners is bound to be related to a wide variety of partners. This complies with the reason for setting up a large collaboration, which is the pooling of a broad range of resources. This also applies to this collaboration, which wants to establish a world-wide standard or at least set up the basis for this. For this a wide variety of organizations are needed indeed. University involvement is therefore one other characteristic of this collaboration. In general the nature of the collaboration can be characterized as being very explorative (i.e. highly pre-competitive) and both horizontal as well as vertical.

The large variety of this collaboration is also reflected in the *knowledge embodiment* dimension. In order to reach the explorative goal and to be able to set up a world-wide standard, different kinds of knowledge embodiments are required. Know-how and routines need to be used in order to explore the possibilities and constraint of such a development. With regard to technology and especially patents it is essential to have access to the knowledge of all partners.

This is in turn important in relation to the market uncertainty and sector setting, as part of the *environmental dimension.* In relation to standardization, this collaboration is involved with 'up-front standardization', i.e. standardization before actual products and services are introduced on the market. This kind of standardization is in general considered to run smoothly, both while establishing it as well as when it is introduced. A problem in this context however is that the rules, in this case most specifically of the European Commission, change over time and therefore flexibility is a key concept. In any case, the ultimate goal of this collaboration is to create a common platform, on top of which others can build applications. These applications of foreground knowledge, i.e. postground knowledge (to a certain extent), will be protected (by intellectual property rights). This will be the way also for the collaborating partners to internalize the results of the collaboration. With these constraints, the *knowledge characteristics* play a specific role as well. The knowledge used and developed in this collaboration is complex and new, though teachable. The complementarity of the knowledge is also very clear because it refers to the wish to set up a world-wide standard. The full list of the different dimensions and their conditions in the tension field of knowledge sharing and protection are given in Table 30. In this table, it can furthermore be seen how the *relational dimension* is shaped. As it is generally the case in this sector, the technological distance is low. Because of the professional character of the relationship the cultural distance is also considered to be low. These issues can be important in reaching the goal of this collaboration because an appropriate combination of each other knowledge is essential to create a standard. A hampering element in the establishment of a world-wide standard is the involvement of partners from different continents, although this is obviously inherent to this goal. A prerequisite in a collaboration as this one is a trust-based relationship with a high commitment from all partners.

Table 30. Tension field in Ericsson's collaboration

Dimensions	Measured degree
Knowledge characteristics	
- Complementarity	+
- Tacitness	+/–
- Codifibility	+
- Imitability	+
- Systematic nature	+
- Teachability	+
- Complexity	+
- Newness	+
- Specificity	+/–
Knowledge embodiment	
- IPR	+
- Technology	+
- Routines	+
- People	+
Relational dimension	
- Trust	+
- Commitment	+
- Geographical distance	+
- Cultural distance	–
- Technological distance	–
Collaboration characteristics	
- Explorative (vs. exploitative) nature	+
- Vertical (vs. horizontal) nature	+/–
- Number of partners	+
- Previous experience with partner	+
- Experience of partner	+
- Firm size	+
- University involvement	+
- Duration	+
Environmental dimension	
- Uncertainty	+
- Sector:	
- Private internalization	.
- Public standardization	+

As described above, there are several elements (as a part of the dimensions comprising the tension field) reinforcing the tension that exists between knowledge sharing and protection. The main elements in this are the large amount and variety of partners (also reflected in the characteristics of knowledge and its embodiment) and the highly explorative nature of this collaboration. As also decried above, two main strategies in relation to this can be identified. These are the use of a joint licensing scheme to access all (essential) patents and the use of '*sub-collaborations*'. These sub-collaborations consist of a limited amount of partners that together are very well capable to perform a certain (to them assigned) task. Because of the complexity of the knowledge the partners working closely together have to openly exchange their knowledge, which then diffuses to the other (i.e. outer) member through the joint licensing scheme. Although it is more difficult to appropriate this knowledge, the outer members still have easy access and are free to use this knowledge in relation to their collaborative efforts. Table 31 gives the degrees of knowledge exchange for the different kinds of collaboration members. Because access to the pool of joint licenses is accessible through a more general forum and adoption of the outcome of this collaboration will benefit to its results, the knowledge exchange with third parties can be considered to be moderate.

Table 31. Knowledge exchange strategy in Ericsson's collaborations

Exchange strategies	Degree of knowledge exchange *Internal – Core or close members*	 *Internal – Outer members*	 *External – Outside*
Layered exchange paradigm	High	Moderate to High	Moderate

All in all, it is important in this collaboration to consider the layered scheme that is used in order to cope with the knowledge exchange of the large number of partners. The establishment of certain 'sub-collaborations' (that vary according to the exact work package) is slightly different from the concept as discussed in Section 4.3.3 but is still valid to a high extent.

5.8 KPN[74]: 'UMTS Planning Tools'

5.8.1 KPN's Collaboration

KPN, being the old incumbent public telecom operator in the Netherlands, traditionally has some resistance to the collaborative sharing of knowledge and therefore it has not been very active in projects or programs that foster an open sharing of knowledge such as the European Framework Programmes. This was reinforced by the (bad) economic situation the telecom market had been in for a long time. Even though this was the case, it participated – through their research department KPN Research – in programs such as COST[75] during the 1990s, although not that actively. In this period KPN explored the possibilities, together with some other organizations such as E-plus[76], ZIB[77] and IST/TUL[78], for a collaborative project in relation to the modeling of UMTS[79]. Another European collaboration was established for this under the ACTS program of the under the Fourth Framework Programme, namely STORMS[80]; though, it was not that successful. These organizations decided that there were some partners they needed in order to be able to reach the objective they had in mind. In addition to another telecom operator and a specialized SME[81], a manufacturer of UMTS telecom equipment was needed. After approaching some potential manufacturers, Siemens was the one that was interested to participate. And so, finally, the collaboration was established under the IST program of the Fifth Framework Program with the name MOMENTUM[82], and it ran from August 2001 to October 2003, covering roughly 27 man-years. The main objective of MOMENTUM was to pool the capabilities of the major

74 Because of the transfer of the activities of KPN Research to TNO telecom, KPN's responsibilities for this collaboration were also transferred to a large extent (see text for more details).
75 European Co-operation in the field of Scientific and Technical Research. COST ran from 1971 onwards, and aims at ensuring that Europe holds a strong position in the field of scientific and technical research for peaceful purposes, by increasing European co-operation and interaction in this field (http://www.cordis.lu, 2004). The specific COST program that is referred to in the text took place under the Fourth Framework Programme.
76 E-plus is another telecom operator, from Germany, that was later acquired by KPN.
77 Zuse Institute Berlin. ZIB is a research institute for applied mathematics and computer science.
78 Instituto Superior Técnico, Technical University of Lisbon.
79 Universal Mobile Telecommunication System.
80 Software Tools for the Optimisation of Resources in Mobile Systems.
81 SME: Small/Medium Enterprise. In addition to the specialized knowledge that can often be found in a SME, which can be required to reach the objective of a certain collaboration, it also complies with the Framework Programme because the European Commission requires to involve an SME in a consortium in order to receive subsidy.
82 MOdels and siMulations for nEtwork plaNning and conTrol of UMts. See momentum.zib.de and www.cordis.lu for more information.

players of system manufacturers, network operators, service providers and operations research facilities to jointly meet the challenge of analyzing UMTS system-behavior and of developing powerful new planning methods for UMTS. MOMENTUM therefore aimed at characterizing new services that UMTS is going to deliver, building usage profiles and planning scenarios to model the future demands, building the most advanced UMTS real-time system-level simulators, using the scenarios and the simulator to better understand the dynamics of UMTS networks and their sensitivity to system parameter settings, and developing flexible models, algorithms and new planning methods for the deployment of the future wireless telecommunication infrastructure. Although the main objective of MOMENTUM was explorative, the results will ultimately be commercially exploited. This will be outside of the scope of this collaboration, however, and will be done in some future collaboration. Additionally, standardization of the outcome of the collaboration, i.e. modeling tools, did not take place because it appears to be difficult in these kinds of collaboration with a (for standardization) limited scope. This is often left to some other party, most specifically the suppliers of the modeling equipment. So, even though there has been contact with the standardization bodies such as the UMTS Forum and the ITU[83], the standardization efforts on this collaboration were very limited.

Table 32. Partners in collaboration 'MOMENTUM'

Participants	Country
Koninklijke KPN N.V., KPN Research (Later: TNO Telecom; see below)	Netherlands
Instituto Superior Técnico, Technical University of Lisbon	Portugal
Telecel Comunicações Pessoais, S.A.	Portugal
Atesio GmbH	Germany
Siemens AG	Germany
E-plus Mobilfunk GmbH & Co KG	Germany
Konrad-Zuse-Zentrum für Informationtechnik	Germany
Technische Universität Darmstadt, Chair on Discrete Optimisation	Germany

As said before, the partners of this collaboration were some among the important organizations in relation to system manufacturers, network operators, service providers and operations research facilities. The actual collaboration partners are shown in Table 32. These partners were dependent on each other's resource complementarities to jointly meet the challenge of analyzing UMTS system-behavior and to develop new planning methods for UMTS. Every partner had a specific role and several 'sub-collaborations' were set up. Moreover, some partners used sub-contractors to perform some of the tasks they had to do (e.g. Siemens sub-contracted the University of Bremen, whereas KPN Research sub-contracted QQQ Delft). KPN Research worked mainly for KPN, although it had its own program. Because of the difficult financial situation of KPN from the 1990 onwards, their research department, i.e. KPN Research, was transferred to TNO Telecom as a part of the TNO[84]. And although it caused some managerial problems, the ownership of the collaboration MOMENTUM was also transferred to TNO[85].

[83] International Telecommunication Union.

[84] Netherlands Organization for Applied Scientific Research.

[85] This issue involved some formalities, especially because the collaboration was funded by the European Commission. Therefore, at 1 January 2003, KPN officially resigned and TNO officially joined the collaboration. There were some important practical issues as well, such as the right to intellectual property. KNP and TNO agreed that KPN was the rightful owner of any intellectual property right (mainly tools such as software) developed by TNO in the

Despite this development, the *relationship* between the different partners can be considered quite smooth. Knowledge was shared rather openly, as long as it contributed to the collaboration. Some difficulties could arise, though, when certain partners did not perform to the extent that they were expected to do. In this the involvement of universities, among others, can be considered as a complicating factor. In this sense, the important issues are capability, integrity and commitment that have to make sure the different tasks are done properly. Therefore, technical expertise and consequently technological distance are important issues to facilitate good relationships. Leadership is also an important issue in this, because it sometimes has to be decisive and powerful. Another relational factor that brings about an appropriate sharing of knowledge is trust, which can be for example influenced by previous experiences with a collaboration partner. This is in turn related to geographical distance between the partners. This can constrain the development in a collaboration because it hampers the possibility to breed trust, which is important because the actual knowledge sharing takes place at the 'personal level'.

Every partner of the collaboration has its own capabilities and puts in its *background knowledge*, which is necessary for the collaboration. In this collaboration, in which there is an important role for modeling tools and software, most of the knowledge is put into the collaboration only to the extent that the other partners can see that it works and that it can be used. For example, the Konrad-Zuse-Zentrum is a well respected research institute in the field of network optimalization and dynamic simulation. Its knowledge (also software) was needed in the collaboration and it used it very openly, which created high quality foreground knowledge. Trust is a key word again and it is important that other partners do not intent to (illegally) appropriate the knowledge of others, which would have dramatic effects for the collaboration. To put this in a more delicate way, it is important that the partners do not necessarily have to know all 'ins and outs' of the other partners' knowledge. Another example is the methodology that KPN used (and uses) for the fast evaluation of UMTS radio networks. It was essential for the collaboration and therefore used, but the methodology itself was not shown because it is one of the competitive assets of KPN. The way to cope with this is (again) by giving the 'basic idea' to the extent needed in the collaboration. Thus, background and also *sideground knowledge* is shared on an open based limited to the extent that is necessary for the collaboration to succeed. Regarding *postground knowledge*, this is mainly covered by the standard (European) consortium agreement which states that knowledge that has been developed after the collaboration is part of the 'collaboration knowledge' and shall thus be dealt with similarly as foreground knowledge[86]. Additionally, the partners in the collaboration tend to use the same 'open sharing' attitude in relation to postground knowledge, as long as it is directly related to the subject of the collaboration.

The distinction between the different *embodiments* is indeed valid in this collaboration. Considering routines, it seems that these in some way exist and facilitate the transfer and appropriation of knowledge. An important element of routines is competence, which can be considered as the ability to cope with the tension between knowledge sharing and protection, especially on the personal level, and which is a 'skill' that can be developed over time. For knowledge embodied in people, rules of thumb are important; in this case for example how to build a certain system. Often, in collaboration and sometimes also in organizations in general, this kind of knowledge is unclear, unstructured and non-explicit. This is due to the (im)possibility to make this kind of

collaboration. The transfer of these rights back to TNO is currently still an issue of debate, which again relates to the general interest KPN has in TNO.

86 As a matter of fact, the European Commission defines (foreground) knowledge as all results of the collaboration.

knowledge explicit, the time consuming activity it entails, and the fact that people will be reluctant to write down his/her 'know-how' because it is his/her personal 'competitive asset'. For this kind of tacit knowledge, it is important to consider how it can be transferred and appropriated. Although pure tacit knowledge cannot be codified, the codification also seems to be important. Different kinds of people have to be able to understand each other, which is something that can especially cause problems when the technological distance is high. One specific elements of this is the 'breath' of the technological distance which refers to background that people have. Imagination plays an important role in this and can cause problems if different people do not 'speak the same language', e.g. when physicians and technicians collaborate. The main kind of knowledge that is embodied in technology is software, as well as certain tools and methods (which can be the same). As mentioned before, these technologies are shared and used to the extent needed. This also relates to the fact that one does not want to give a lead to others, i.e. its competitors. The intellectual property right embodiment appears to play a limited role in this specific collaboration. No patents were part of this collaboration, although trade secrets are used to prevent (illegal) appropriation and to create a lead-time. This is especially the case for the software used.

One partner that is traditionally known for its strong intellectual property right portfolio and its strategy to protect this is Siemens. Because of the participation of a partner as this one, the role of intellectual property rights (protection) does become more apparent. It mainly causes an increase in limitation for knowledge sharing because it decreases the 'open atmosphere', although it does not have to cause any major problems as long as the knowledge can be shared and appropriated to the extent needed for a successful collaboration.

A collaboration by definition creates new knowledge and also typically uses recently developed knowledge as input, i.e. background knowledge. In this collaboration, new (foreground) knowledge, in this case models and (parts of) tools, was especially created during the latter part of it. In relation to the *knowledge characteristics*, the complexity of the knowledge also increases during the collaboration and moreover plays an important role in the codification issue, discussed above. This means that the problems that arise when collaborating partners who do not 'speak the same language' rapidly increase with increasing complexity of knowledge. Therefore, teachability is an important characteristic of knowledge as well. It first of all has to be explicit what has to be shared and therefore potentially thought. This makes it clear which knowledge has to be transferred in some way, and commitment is important in this because it facilitates an efficient transfer. There is furthermore a natural tension between teachability and imitability, which is coped with in the same way as the unwanted appropriation by knowledge, namely by sharing to the extent that is needed. Moreover, if the collaboration develops smoothly, the partners know each other well enough to collaboratively work on something in an efficient way.

Clearly, a significant part of the knowledge in this collaboration is embedded in software and tools, i.e. technology, with an important role for know-how. The licensing scheme used during this collaboration to deal with the protected transfer of the knowledge can be considered 'standard'. Software simply is not exchanged and the agreements to cope with the protection of knowledge do not go beyond the standard (non disclosure) agreements that are part of the consortium agreements of the European Commission. If there is a partner with a strong focus on intellectual property rights, due to its strategy, can limit the open sharing of knowledge, although it does not have to be a constraint for proper knowledge sharing and appropriation. Again, trust is a main element to foster open knowledge sharing, which is the case in this collaboration, although to the extent needed.

The general strategy of KPN, and later especially for TNO, is to share what is necessary and protect everything for which there is no need to share it. In the case of software and tools, these have to be protected, sometimes in a more or less ingenious way, in order to prevent unwanted appropriation, which can be especially the case if these have to shown publicly.

5.8.2 Main Findings from the KPN Case

The open sharing of knowledge is considered to be crucial for the success of this collaboration because it facilitates maximum results. Therefore the *relational dimension* should be shaped in such a way that an open atmosphere is fostered. In order to achieve this, the establishment of trust is essential. In this case it also became very clear that the technological distance is an important element of the relation between two (or more) collaborating partners. More particularly, it has to be considered that this concept is especially relevant on the personal level (i.e. the collaborators on the practitioners' level). This relates to the *knowledge characteristics*, which take a central place in explaining the balance between the sharing and protection of knowledge, because the complementarity of knowledge is high. The exact codification of knowledge can be important to bridge the gap of understanding between two (or more) collaborating partners that are, for some reason and in some way, technologically distant from each other. This becomes more apparent with increasing complexity of knowledge. On a more general level, codification has important impacts for the teachability of knowledge in an R&D collaboration, in which the knowledge is typically highly complex. Codifibility can therefore deal with a low level of teachability.

In this collaboration, the main *knowledge embodiments* are knowledge embedded in people's minds and in technology (i.e. software, tools, databases and methods), as well as (less technical) 'collaborative routines'. With regard to the *collaboration characteristics* it can furthermore be argued that the nature of this collaboration was rather explorative and the partners were highly complementary are therefore related to each other in both a horizontal and vertical way. The number of partner is quite high, although not very extreme at all. Because the partners were selected on their competence, they were chosen on the basis of their experience and also the experience with them. The involvement of a university was moreover considered to be a potential problem, also due to their generally less protective attitude.

In relation to the *environmental dimension*, it can be said that the standardization efforts on this collaboration were very limited. This can be considered logical because these kinds of planning tools gives the partners of the collaboration a competitive advantage in this market, and there is no need for network effects because these kinds of tools can be successfully exploited without a broad adoption or standardization. Therefore, private internalization is most appropriate. These and the other dimension are given for this case in Table 33.

Table 33. Tension field in KPN's collaboration

Dimensions	Measured degree
Knowledge characteristics	
- Complementarity	+
- Tacitness	+/–
- Codifibility	+
- Imitability	–
- Systematic nature	+
- Teachability	–
- Complexity	+
- Newness	+
- Specificity	+
Knowledge embodiment	
- IPR	–
- Technology	+
- Routines	+
- People	+
Relational dimension	
- Trust	+
- Commitment	+
- Geographical distance	–
- Cultural distance	.
- Technological distance	+
Collaboration characteristics	
- Explorative (vs. exploitative) nature	+
- Vertical (vs. horizontal) nature	+/–
- Number of partners	+
- Previous experience with partner	+
- Experience of partner	+
- Firm size	+
- University involvement	+
- Duration	+/–
Environmental dimension	
- Uncertainty	.
- Sector:	
- Private internalization	+
- Public standardization	–

Although the number of partners in this collaboration is not extremely high, there were enough for the partners to adopt some sort of layered collaboration scheme. It is namely argued that not all partners need to know all the details of every other partner's (knowledge) development. Towards the outer members in the collaboration, secrecy is therefore used to a certain extent. The knowledge exchange with close partners on the other hand is much more open in order to develop the required knowledge. Therefore, as illustrated in Table 34, a *layered exchange strategy* can be identified in this case.

Table 34. Knowledge exchange strategy in KPN's collaborations

	Degree of knowledge exchange		
Exchange strategies	*Internal – Core or close members*	*Internal – Outer members*	*External – Outside*
Layered exchange strategy	High	Moderate	Low

5.9 LIONIX: 'THROUGH-WAFER INTEGRATED OPTICS'

5.9.1 Lionix's Collaboration

Lionix is a small spin-off firm of the University of Twente in Enschede, the Netherlands, founded in 2001. With its 17 employees, it is a service provider of high-tech state-of-the-art technology. Lionix has two core competences, namely integrated optics and micro fluidics, and its main customers are OEM companies (original equipment manufacturers). Because Lionix is a technology provider it is dependent on collaborations with others (mostly universities and customers) to a large extent.

One of its collaborations, of which it is the project coordinator, is the project 'TIOM'[87]. The partners in TIOM are five SMEs, given in Table 35.

Table 35. Partners in collaboration 'TIOM'

Participants	Country
LioniX B.V.	Netherlands
Hymite A/S	Denmark
Lambda Crossing Ltd.	Israel
Mierij Meteo B.V.	Netherlands
University Twente	Netherlands

The TIOM project took place during 2002, 2003 and six month of 2004 (i.e. two and a half years), and was involved with integrated optic devices. An optical wave transmitter contains information that can be delivered codified. This codification can be in colors (by dividing the color spectrum into part of approximately 10 nanometers and use every color for a specific kind of information, e.g. phone data) or in time (by sending out different pulses over time). For optical data transmission it is therefore important to get the information on the fiber and to get it off of it again. For this, components are available (e.g. lambda switches) that make use of an optical wave transmitter on a chip, which can be applied on glass fiber. The TIOM collaboration aimed at combining integrated optics technology (developed by Lionix) with electronics technology (developed by Hymite), to create electrical contacts on the back side of the chip. The combination of these technologies will enable easy assembly, and therefore reduce costs. Optical components (i.e. Lionix's business) have been standardized already in the telecommunications industry but are not yet widely adopted in the optical world (although a breakthrough is expected soon). There are many technologies that (potentially) use these kinds of components. The wave transmitters made by Lionix are not standardized either and therefore the goal of this collaboration is to develop a standard, or at least go towards one. An underlying goal is the creation of a network (of technological organizations) as described above. Because of this the end result of the collaboration was the development of an end product in relation to telecommunication (due to the more fixed requirements) whereas on the optical sensor side no end product was developed eventually. On a more general level, it can be said that this collaboration was involved with product development that mostly incorporated development with a little bit of research.

Regarding the *relationships* between the partners, it is important to note that the actual experiences can differ from the expectations. Furthermore, relationships are subject to change (not

[87] TIOM: Through-wafer connection for Integrated Optic devices for iMproved assembly and packaging to manufacture Microsystems (http://www.cordis.lu, 2004). TIOM was part of the IST program in the Fifth Framework Programme.

necessarily positive) over time. In this collaboration a more-or-less specific situation was created due to the involvement of Small Medium Enterprises (SMEs), which have to find a trade-off between their needs and wishes. This could cause an instable situation in a collaboration such as this one. Because of this, they are generally also careful with exchanging information. In the case of Lionix, the relationship with Mierij was considered to be good, whereas relation with Hymite was more difficult and with Lambda Crossing more superficial and very formalized. In this context, the technological distance between the partners did not appear to play an important role, not the least because this was quite low. In contrast, the geographical distance was considered to play an essential role in the good relationship. This relates to the fact that good personal contacts are invaluable. Communication is crucial, while the partners assume the development of the technology will work out well. This is reinforced by the aim to create a standard.

In relation to the development of the collaboration, the partners (obviously) tried to reach the pre-defined goal, i.e. creating functioning optical components. Some elements of these components were already available (i.e. commercialized). While the collaboration was able to reach its goal (and the commercialization of the products is performed independently by the other partners), a new feature of this technology was discovered during the collaboration which could was even more interesting than the initial goal. Regarding the commercialization of the outcomes of the collaboration (i.e. the development of a technology) there were not many agreements. Again this is assumed to work out well (by the collaborating partners as well as the European Commission), partly because it is necessary to recover the R&D costs. It is important to note however that commercialization takes place at the individual partners *outside* the scope of the collaboration.

The recovery of investments in R&D was different for the different partners involved in the collaboration. Whereas the product (or component) developers (such as Mierij, Hymite and Lambda Crossing) have to recover their costs by exploiting their products, the technology suppliers (such as Lionix and the university to a minor extent) do not have to exploit any product but will only benefit from future sales (of services and technologies). This means that the product developers will have the need to protect their knowledge embedded in this product. The technology suppliers, on the contrary, will benefit from making their knowledge public. This 'contradictio in terminis' could potentially damage the collaborative relationships. If the collaboration goes well, this does not have to cause any problems. For example, the good relationship between Lionix and Mierij caused them to share even more information and to more co-operation (e.g. by Mierij buying technologies from Lionix). The (more-or-less) opposite is the case for the relationship between Lionix and Lambda Crossing because Lambda makes and buys its technologies somewhere else and can even be considered as being a competitor of Lionix (which also created the more formalized relationship).

Clearly, the horizontal part of the collaboration created a formalized collaboration (not meaning it was not successful as such, on the contrary). But it is also an essential element of an SME's business (in this case) because it wants to have access to a broad range of technologies and also want to offer this. In this sense, the technological distance can be important. This namely requires the existence of an integrator, which is in fact the main competence of Lambda Crossing.

In relation to *embodiment of knowledge* it was stated that especially routines are of crucial importance. The technological routines within the individual organization were considered to contribute to the technological routines of the collaboration as a whole and therefore this was one of the main selection criteria for choosing the partners. These routines become especially apparent in relation to the different sub-technologies that have to be integrated, for which compatibility is also important. It is argued that a collaboration such as this one does not develop 'rocket science' but integrates technological routines, by regulating instructions. In addition technical know-how and the input of the different (sub) technologies are also important to reach this goal. Intellectual property rights were important for the end users to protect the end product (i.e. outside the scope of the collaboration) but were not so much of interest for the technological components themselves (partly because revenues have to be shared anyway and it involves administrative costs).

Overall, it can be said that the technological outcomes were moderate (meaning the goals were reached but without commercial breakthrough) but especially the underlying goals were successful. These underlying goals were the development of a (technology) network and the dissemination of knowledge. This latter aspect took place through the network that was build during the collaboration and moreover through the 'technology marketplace' set up by the European Commission.

5.9.2 Main Findings from the Lionix Case

In this case, the most specific characteristic compared to the cases is the involvement of SMEs. In relation to the strong competition in the market, this hampered the establishment of trust-based relationships. This was in turn important because communication plays an essential role in collaborative R&D. In this collaboration, the geographical distance moreover reinforced the problematic or formalized knowledge exchange.

The degree to which a certain element of a dimension was considered to be applicable in this collaboration is given in Table 36.

Table 36. Tension field in Lionix's collaboration

Dimensions	Measured degree
Knowledge characteristics	
- Complementarity	+
- Tacitness	+
- Codifibility	+
- Imitability	+
- Systematic nature	.
- Teachability	+
- Complexity	+
- Newness	+
- Specificity	+
Knowledge embodiment	
- IPR	–
- Technology	+
- Routines	+
- People	+
Relational dimension	
- Trust	+
- Commitment	+
- Geographical distance	+
- Cultural distance	.
- Technological distance	–
Collaboration characteristics	
- Explorative (vs. exploitative) nature	+
- Vertical (vs. horizontal) nature	+/–
- Number of partners	+/–
- Previous experience with partner	+/–
- Experience of partner	+
- Firm size	–
- University involvement	+
- Duration	+/–
Environmental dimension	
- Uncertainty	+
- Sector:	
- Private internalization	+
- Public standardization	+/–

The involvement of just SMEs and a university made this case a very specific one. Especially because the nature of the collaboration was partly horizontal and partly vertical, different kinds of relationships arose between the different partners. Although Lionix (in this case) had preferred partners to work with, the involvement of all partners was required to reach the goal of the collaboration. And even though some of the relations were rather formalized, generally an open (or at least moderate) knowledge exchange was adopted. The different ways of internalizing results (from open to close) moreover caused an additional tension with regard to the knowledge transfer. In general however the (limited) standardization efforts and public dissemination goal (from the European Commission) made the knowledge exchange with external parties moderate on average. In conclusion, especially the importance of tacit knowledge and the complementarity of knowledge together with the general private internalization efforts made this collaboration to adopt a private open exchange strategy.

Table 37. Knowledge exchange strategy in Lionix's collaborations

Exchange strategies	Degree of knowledge exchange		
	Internal – Core or close members	*Internal – Outer members*	*External – Outside*
Open exchange strategy - private	Moderate to High	N/A	Moderate

5.10 PHILIPS: 'PERSONALIZED DIGITAL TELEVISION'

5.10.1 Philips's Collaboration

In the year 1995, Philips took the initiative to investigate the possibility to develop a (local) storage system of some sort for multi-media applications, especially in the home environment, in collaboration with some other interested partners. This was done by creating a project that included (among others) some universities, Olivetti and Thomson, which received European funding under the ACTS[88] program of the Fourth Framework Programme of the European Commission under the project named SMASH[89]. SMASH used a hard disk as cache for the tape (D-VHS) in which the two storage media had to behave as an integrated system. A next important step was to replace the tape by only using a hard disk as a storage medium. This was done in the project STORit[90] (also within ACTS), and also some content providers (such as the BBC) were part of the collaboration. This was done because, in order to make a technology like this one commercially successful, there has to be suitable broadcasting (in addition to the technical possible to actually receive and store this of course) in order utilize this technology. This also related to the 'cross-operability' (see Figure 22 for simplified visualization) that has to exist, which means that the technology, or more specifically signal or medium, used by the different broadcasters has to be compatible with the technology on the user side. Therefore, standardization issues come into being and for this reason the (global) standardization forum TV-Anytime was founded (see http://www.tv-anytime.org, 2004). Organizations are free to participate in this forum, and a second step is to become a member which, among other things, involves the signing of a Memorandum of Understanding (MoU) and an IPR declaration, which in short requires the sharing of their intellectual property rights, i.e. licenses, on a reasonable and non-discriminatory basis with the other members of the forum. On the basis of this forum, several organizations started to develop technologies and services (both with and without funding). One of the initiatives that addressed the (practical) need for standardization was the collaboration MyTV[91], which was established under the IST[92] program of the Fifth Framework Programme, which also incorporated the application of broadband, and now included Nokia (which had developed a similar technology as Philips) as a partner, and lasted from January 2001 to December 2003, covering 60 man-years. It is important to note that both the ACTS and IST program are pre-competitive. The collaboration now involved three broadcasters (BBC, NOB and RAI), two equipment manufacturers (Nokia and Philips) and a university (to investigate new services). With these partners, the collaboration

88 Advanced Communications Technologies and Services. ACTS ran from 1994 to 1998, and aimed at research, technological development and demonstration in the area of advanced communications technologies and services (http://www.cordis.lu, 2004).
89 Storage for Multimedia Application Systems in the Home.
90 Storage interoperability technologies.
91 MyTV: personalised services for digital television.
92 Information Society Technologies. IST ran from 1998 to 2002 during the Fifth Framework Programme (and now continues under the sixth Framework Progamme, 2002-2006), and at research, technological development and demonstration on a 'User-friendly information society' (http://www.cordis.lu, 2004).

covered the complete broadcast chain and it had three main objectives[93]. The first objective is to develop, standardize, implement, validate and demonstrate a consumer platform with built-in local storage, for personalized services in digital broadcasting and broadband communication. In this way the consumers will have access to content and services at their convenience, independent of the moment of broadcasting. The second objective is to develop new services that exploit this platform, such as the ability to turn local storage into a personalized television channel, non-linear browsing of television content, interactive and targeted advertising, and easy navigation through the massive amount of content offered. A third objective is to provide true inter-operability, both across different service providers and across different box manufacturers. Therefore, the contribution to and adherence to standards is an explicit part of the collaboration. Typically, these developments are divided into 'sub-collaborations' between the appropriate partner and one of them takes the lead in this, just as the general project leader does for the entire collaboration.

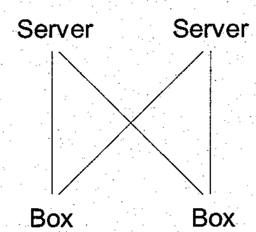


Figure 22. Cross-operability

The full list of partners is given in Table 38. Although most of the partners can be considered being complementary to each other, the competitive nature of some of them becomes apparent. This is most specifically the case for Philips and Nokia, both of which developed their own 'MyTV box' as a medium for local storage on a hard drive. But still, because of their common goal and mutual interest, both parties (as well as all other) very openly shared their knowledge, although to the extent that was needed to make the collaboration successful. The relationship between the collaborating partners is of crucial importance. In addition to their capability, the 'personal factor' is essential as well. The actual sharing moreover takes place on a 'low level', i.e. in the collaboration itself, whereas decision-making and permissions come from a higher level in the organizational hierarchy, i.e. outside of the collaboration. Therefore, the technological distance should furthermore enable to partner on the one hand understand each other but it also should not create friction. In this sense, cultural aspects and relational distance are considered to be important as well because they can both hamper and foster an effective knowledge sharing.

93 These, among other things, can be found at http://www.extra.research.philips.com/euprojects/mytv (2004) and http://www.cordis.lu (2004).

Table 38. Partners in collaboration 'MyTV'

Participants	Country
Philips Electronics Nederland BV	Netherlands
Philips S.p.A.	Italy
Philips Electronics UK Ltd	United Kingdom
RAI – Radiotelevisione Italiana S.p.A.	Italy
British Broadcasting Corporation	United Kingdom
Nokia Corporation	Finland
Nokia Multimedia Terminals OY	Finland
Nederlands Omroepproduktie Bedrijf N.V.	Netherlands
University of Ljubljana	Slovenia

Considering the knowledge that was shared in the collaboration, there are several issues of importance. One is the *embodiment of the knowledge*. In the case of Philips, the main goal of this collaboration was to develop (and standardize, implement, validate and demonstrate) a device with built-in local storage, i.e. the 'MyTV box', for consumer-orientated personalized services. Therefore, the main foreground knowledge they were interested in was that what was embodied in this box, which is i.e. a product (technology). Another, partly overlapping form of knowledge Philips is traditionally interested in, and thus also now, is the intellectual property right that came out of the project. Because in this collaboration the intellectual property right issues were arranged through the standardization forum, this matter was fairly easily dealt with. All the patents had to be accessible for a fair and reasonable basis. In this case meaning that the standardization body makes use of a licensing authority (called VIA) to act as a joint licensing administrator. All the licenses were administrated by this forum in order to cover all potentially needed intellectual property rights. Moreover, because this collaboration was a European consortium, (more or less) all potential intellectual property right issues were covered by the standard contract (which, in short, states that access to intellectual property right has to be provided on a fair, reasonable and non-discriminatory basis). Still agreements have to be made during the collaboration about who will own a certain intellectual property right. Patent that were developed in relation to certain parts were being applied by a single party. In this case joint patenting was not considered to be appropriate but the partners rather chose to license each other (in relation to knowledge that was directly related to the collaboration) on a fair and reasonable basis. Trade secrets also take an important place in this collaboration, especially because they 'precede' a possible patent application.

Another embodiment that was important was the knowledge embedded in people, which is in fact a criterion that is used to decide which people will participate in the collaboration. It also helps to identify, get to know and educate people that could be of (future) interest to Philips. This embodiment is seen as a dynamic one, meaning that people have a certain amount of knowledge and become more knowledgeable. It is furthermore seen as a driver for future development, which obviously makes it a crucial one for the survival of the firm. The reasons for making certain decisions, for doing something the way it is done, for developing a certain standard, etcetera is embedded in the people's minds. Additionally, intellectually property rights can be created due to the knowledge that is embodied in the people's minds. A fourth form of embodiment, in addition to intellectual property rights, technology (i.e. products) and people, are certain 'routines' that take an important role as well. Philips acknowledges that there is some kind of 'collaborative routine' that is built up by being part of subsequent collaborations. In the case of the MyTV collaboration, which is the case for more European collaborations in general, these routines take its most explicit form by the design of the start-up of the collaboration and the circulation of meeting locations, in order to foster an open atmosphere by creating commitment.

Looking in more detail at the *characteristics of the knowledge* itself, it is clear that this is generally complex in these kinds of R&D collaborations, although the projects are feasible. Also, the newness of the knowledge can be considered as being high because the subject of the collaboration is always related to the state-of-the-art technology. The tension between the sharing and protection of knowledge becomes very clear while considering the imitability characteristic of it. First of all, most knowledge that is shared should be possible to imitate extremely easily (in order to appropriately transfer it). To a certain extent, this is even the case for more tacit forms of knowledge, especially for people working in the same (technology) field. Because the actual sharing only takes place within the collaboration, some sort of natural protection mechanism is created. But still some kind of (illegal) appropriation stays possible, especially for product technologies such as software. Furthermore, in this specific collaboration the prototypes that were developed (as one of the main objectives) leave room for 'piracy', meaning that it can be imagined that others are able to 'steal' knowledge from them. This is also the case for external parties outside of the collaboration. But it is nevertheless necessary to use and show this knowledge in order to prove your achievements. Therefore, this issue is mainly dealt with by the establishment of trust (within the collaboration) and by common law (outside of the collaboration).

In conclusion, the goal for Philips of an R&D collaboration such as this one is to create a standard that (to a certain extent) ensures future development, to create and protect intellectual property (rights) and to educate their people for the similar reason, and to benefit from the developments of others by using an 'open innovation model'. Overall, this collaboration can be considered as a successful one and Philips expects to implement and commercialize this technology in a number of years, dependent on the actual development of the digital television technology.

5.10.2 Main Finding from the Philips Case

It is clear (from the Philips case) that standardization and inter-compatibility issues can play an important role in certain R&D collaboration. In this case knowledge (especially embodied in patents) *has to* be shared. Therefore, the possible protection of background knowledge, i.e. knowledge 'owned' by an individual collaborating partner, is limited. In this case, the sharing of intellectual property rights is established through a standardization body. Sharing of foreground and sideground knowledge has to be done on an open and free/reasonable basis in order to make the technology (commercially) successful and adopted. This is especially the case because there are different kinds of partners involved (i.e. in the case of Philips: content providers, infrastructure owners, storage medium manufacturers, etcetera), and therefore the resources, i.e. knowledge, are complementary. Postground knowledge will in this case go into the standardization body, because of the same reasons as foreground and sideground (through foreground) knowledge. And because of the ongoing (collaborative) projects new knowledge is continuously being developed and used, and therefore there is a gradual knowledge development in relation to the subject of the collaboration.

Table 39 provides an overview of the condition of the tension field as it can be identified from this case study. The *embodiment* takes an important role in Philips's R&D collaborations. Intellectual property rights have traditionally been important for the firm. Because of their focus on consumer electronics, among others, products take an important place as well. Both of these embodiments cause Philips to be careful for bringing background or sideground knowledge (embedded in these) into the collaboration. Therefore, the embodiment of knowledge appears to have an important role in the tension field of knowledge sharing and protection. Knowledge embedded in people, on the other hand, is shared much more openly, although with the common non-disclosure and confidentiality agreements. This is in fact one of the main reasons to collaborate in the first place. The embodiment appears to be a dynamic concept. Especially tacit forms of knowledge (i.e. know-how in people and routines) – although the more explicit ones also (intellectual property rights and technology), albeit to a less dynamic and more gradual extent – change over time, and moreover certain embodiments can influence each other (e.g. knowledge embodied in people is translated, in some way, into intellectual property rights).

Table 39. Tension field in Philips's collaboration

Dimensions	Measured degree
Knowledge characteristics	
- Complementarity	+
- Tacitness	+/–
- Codifibility	+
- Imitability	+
- Systematic nature	+
- Teachability	+
- Complexity	+
- Newness	·
- Specificity	·
Knowledge embodiment	
- IPR	+
- Technology	+
- Routines	+
- People	+
Relational dimension	
- Trust	+
- Commitment	+
- Geographical distance	–
- Cultural distance	–
- Technological distance	–
Collaboration characteristics	
- Explorative (vs. exploitative) nature	+
- Vertical (vs. horizontal) nature	+/–
- Number of partners	+
- Previous experience with partner	+
- Experience of partner	+
- Firm size	+
- University involvement	+
- Duration	+/–
Environmental dimension	
- Uncertainty	+
- Sector:	
- Private internalization	+
- Public standardization	+

The variety of partners and thereby also the complementarity of the knowledge caused the partners in this collaboration to set up some kind of layered scheme. This was reinforced by the partly horizontal collaboration, e.g. between Philips and Nokia that both aimed at eventually commercializing a 'MyTV Box'. Therefore, it can de argued that the *environmental dimension* is characterized by elements of both public standardization (in relation to the services and interoperability) and private internalization (in relation to the eventual commercializing of the technology). The degrees of knowledge exchange in relation to this layered strategy are given in Table 40

Licensing on background knowledge in this collaboration takes place as a joint licensing arrangement with a licensing authority as administrator. Other licensing is covered by general agreements and can be interpreted as granting on an 'ordinary' non-exclusive license with royalty-payment based on fair and reasonable terms. In case of co-development of a patent, a non-exclusive royalty-free license with sub-licensing right is generally granted.

Table 40. Knowledge exchange strategy in Philips's collaborations

	Degree of knowledge exchange		
Exchange strategies	*Internal – Core or close members*	*Internal – Outer members*	*External – Outside*
Layered exchange strategy	High	Moderate	Low to Moderate

5.11 TELIA: 'AUTOMATED SPOKEN DIALOGUE TECHNOLOGIES'[94]

5.11.1 Telia's Collaboration

The use of automated spoken dialogue technologies can have significant effect on how our society functions in the future, mostly on the level of the individual. It is considered to be a challenging technology and has received attention from industry and not the least from academia. It provides a very natural way to communicate and has already found it way in applications for elderly and disabled, and gaming applications, among others. The theoretical challenges behind the technology still hamper its wide-spread use, however. Of course the acceptance from the user side also needs to be developed.

In relation to these developments several European projects were set up, in addition to other developments, during the 'intelligent home hype'. Although this hype is already over, developments go on (although not to the same extent). The European Framework projects were especially suitable for the development of this technology because it brought together the knowledge and expertise from industry and universities, which found this to be a topic of interest. In a subsequent range of European Project, a fourth one was started in 2001. This project named D'Homme[95] addressed the theoretical challenges in language understanding and dialogue management for controlling and querying multiple networked from inside or outside the home (http://www.ling.gu.se/projekt/dhomme, 2004). This collaboration most specifically addressed the automated spoken dialogue application in 'Plug and Playable' (local) networks in which it is important that the network reconfigures itself (see e.g. Rayner, Boye, Lewin and Gorrell, 2003). The partners that had been previously collaborating – which were Netdecision (a start-up in the 'intelligent home boom'), SRI (a research centre) and some universities – formed this collaboration. It also included Telia[96] (as an industrial firm) that considered the Intelligent Home to be an important concept (and even fashionable at the time of the collaboration). Telia could help with some of the high-tech issues in this concept and had a prototype of an intelligent home that was

[94] NOTE: THIS DESCRIPTION/ANALYSIS STILL NEEDS CONFORMATION FROM THE INTERVIEWEE.

[95] D'Homme: Dialogues in the home machine environment (http://www.cordis.lu, 2004).

[96] In fact, it was Telia Research, which at that time was a direct subsidiary of Telia, that was involved in the collaboration. In 2003 Telia merged with the Finnish telecom operator Sonera to become TeliaSonera, Telia had been involved in several other collaborations, both European and other ones.

used in testing. The collaboration took place in 2001 (for one year) under the IST program of the Fifth Framework Programme. The partners are given in the table below.

Table 41. Partners in collaboration 'D'Homme'

Participants	Country
SRI International	UK
University of Edinburgh	UK
Netdecistions Ltd	UK
Universidad de Sevilla	Spain
Göteborg Universitet	Sweden
Telia Research AB	Sweden

One of the main considerations for Telia to go into this collaboration was to become part of the pool of knowledge that existed among the collaborating partners. Of the six partners in this collaboration, Telia mostly worked together with Netdecisions and focused on a 'simpler' network by using its own prototype room. This also complied with the nature of the collaboration, which was exploratory (theoretical) but also to make use of a demonstrator. In the end, two demonstrators were built that mostly provided a 'proof of concept'.

Regarding the *relationship* between the collaborating partners, it is considered to be invaluable to have a relationship that is based on friendship. Although most communication goes via e-mail, it is important to have actual meetings and to get to know each other. This is facilitated by the extensive travel budget provided by the European Commission. Because of this, the geographical distance is not considered to be a hampering issue. The technological distance is furthermore low which facilitates knowledge transfer. This was not considered to be of any problem, i.e. the danger of leakage of knowledge, partly due to the short time schedule and good scheme. The ease to use each other's knowledge was high and no learning curve was experienced.

The real collaboration is said to consist of identification of project paths and the exchange of results and ideas. Furthermore, it can be argued that one collaborated with people more than with organizations. This moreover that people collaborate with others regardless of their employer. It moreover emphasizes that a friendship-based relationship is crucial. Trust is furthermore an important characteristic of the relationship. The partners will therefore know (or assume) that each other partner will contribute to the collaboration. For this reason, inappropriate behavior could damage a good and trust-based relation. In order to reach consensus on information that is made public, an article is first circulated before it is published.

The *background knowledge* in this collaboration was mainly general knowledge in the field and also how to operate these electronic networks, which was rather explicit knowledge. Moreover, some special knowledge was required, e.g. in the case of the Telia prototype (or demonstrator) knowledge on the application of the Swedish language was required. Because this collaboration dealt with speech recognition it is easy to understand the (general) point but it is more difficult to understand the (exact) problem. The outcome of the collaboration was the development of a program code (i.e. *foreground knowledge*) as well as the establishment of more personal connections and even personal networks (which is considered to be an important asset of the firm. This collaboration also created some sort of image value for Telia due to the development of a number of demos which can establish a reputation in this field. *Postground knowledge* has furthermore been developed after the end of the collaboration. The agreement stated that this had to be shared on a reasonable basis, although it was shared (more or less informally) any. This was also due to the fact that this knowledge had no direct relation with any commercialization efforts. Because the technology is still rather immature, the protection of this knowledge is quite unimportant (publishing is more important) and external processes such as standardization are not relevant.

Because it can be hard to understand the problem in relation to speech recognition, know-how is an important *embodiment* of knowledge, in addition to general knowledge. This know-how can also be based on (statistical) data. Due to the importance of the use of a network it is important to learn the system. The subject of this collaboration, i.e. plug and play of speech in a network, also derived from an idea based on general knowledge and more tacit know-how.

As said before, the demonstrators (which are an important embodiment of knowledge) that were built mostly provided a proof of concept. In general this thus does not show the exact knowledge that is embedded in it, although sometimes the demonstrator is show on a more detailed level to external parties (e.g. to get them more involved).

Although Model Agreements exist (provided by the European Commission), this was not signed for this collaboration. Rather bilateral agreements were used, in particular for the collaboration (of Telia) with Netdecisions. This agreement stated that the parties could use each other's code and involve another one. They are not allowed to commercialize it, however. Although it worked out well in the end, there was some debate on the level of the lawyers. It was furthermore agreed that the partners had to notify each other if one wanted to apply for a patent, for which it would then be negotiated that the other got access on a fair and reasonable basis. (To be sure, there was no patent filed for this collaboration.) This agreement scheme complied with the general idea of this collaboration in which the partners adapted their own dialogue systems rather than attempting to build a single new system (due to exploratory nature and the short time frame of this collaboration and the existence of considerable knowledge on each site) (http://www.ling.gu.se/projekt/dhomme, 2004).

5.11.2 Main Findings from the Telia Case

Overall, this collaboration was considered to consist of an excellent mix of different partners. Trust on different levels proved to exist and be important. One the one hand there is personal and professional trust on the practitioners' level. And in addition a distinction can be made between trust among people involved and trust among the organizations in general. This latter case also refers to the strategic management level in which there are possibly three different levels (in the organization in general), namely the top-management, intermediate management and practitioners' level. In relation to collaborations the proactive or reactive attitude of management will be of interest.

As shown in Table 42, the main kinds of *knowledge embodiment* are technologies and knowledge embedded in people. Technologies in this case to a large extent refer to prototypes. The *environmental dimension* did not play such an important role because of the small scope of the collaboration. In relation to this, it was important work together with people that are competent and trustworthy. The explorative nature of the collaboration made it moreover possible set create an open sharing atmosphere within the collaboration. Maintaining a closed attitude to third parties remained important (reinforcing a relationship based on trust), the results were not always very 'visible' (even in the technology) and could quite easily be privately internalized.

Table 42. Tension field in Telia's collaboration

Dimensions	Measured degree
Knowledge characteristics	
- Complementarity	+
- Tacitness	+/–
- Codifibility	+
- Imitability	–
- Systematic nature	+
- Teachability	+/–
- Complexity	+
- Newness	·
- Specificity	+
Knowledge embodiment	
- IPR	–
- Technology	+
- Routines	·
- People	+
Relational dimension	
- Trust	+
- Commitment	+
- Geographical distance	–
- Cultural distance	·
- Technological distance	–
Collaboration characteristics	
- Explorative (vs. exploitative) nature	+
- Vertical (vs. horizontal) nature	+/–
- Number of partners	+
- Previous experience with partner	+
- Experience of partner	+
- Firm size	+
- University involvement	+
- Duration	–
Environmental dimension	
- Uncertainty	+
- Sector:	
- Private internalization	+
- Public standardization	–

As described above, this collaboration involved different kinds of partners that used the collaboration to pool some of their knowledge but still their own codification. Together with the importance of know-how and the short duration of the collaboration, a layered knowledge exchange strategy was adopted (Table 43). In the case of Telia, this basically meant a 'sub-collaboration' with Netdecisions.

Table 43. Knowledge exchange strategy in Telia's collaborations

	Degree of knowledge exchange		
Exchange strategies	*Internal – Core or close members*	*Internal – Outer members*	*External – Outside*
Layered exchange strategy	High	Moderate	Low

5.12 Discussion and Conclusions

The case studies, described above, are conducted to give insight in what the tension field of knowledge sharing and protection is and how firms can cope with it. One of the goals therefore was to test the model developed in Section 4.2 (Figure 19). From the case studies becomes clear that the dimensions identified as comprising the tension field are indeed the main element that determine the sharing and protection of knowledge. It is clear that in the case of R&D collaborations the *characteristics of the knowledge* have a central place in the tension field. In other words, the properties of knowledge are acknowledged to first of all determine the tension between the sharing and protection of knowledge. Furthermore, in R&D collaborations in particular the most important knowledge characteristics are complexity, complementarity and teachability. Knowledge in R&D collaborations is complex and moreover (typically) new due to its pre-competitive nature. Additionally, the *embodiment of knowledge* is considered to be an important dimension as well because it refers how exactly knowledge can be protected *and* shared, and it furthermore comprises the main competitive asset for the firm as well as the R&D collaboration. All the different kinds of embodiments described earlier in the study are identified in the case studies, to a certain extent. With regard to the *relational dimension*, trust is the major element. Many other kinds of relational elements are usually shaped in such a way that they foster the building of trust, or alternatively these other relational elements hamper trust (if they take the 'wrong' form). The same can be said to a large extent about the *collaboration characteristics* that are usually shaped in such a way that the sharing of knowledge is facilitated while the protection of knowledge is arranged in such a way that it does not hamper the innovative process. The general explorative nature of R&D collaborations moreover largely determines the high complexity of knowledge as discussed above. The *environmental dimension* is acknowledged to determine the risk and potential of the collaboration as well as the significance of standardization efforts.

In conducting the case studies, the framework developed in Section 4.3.2 (Figure 20) proved to be a useful 'tool' to identify different types of knowledge and knowledge transfer, thereby revealing the tension field more explicitly. It was moreover helpful to explore the strategies a firm can use to cope with the tension field. In this respect it is clear that the establishment of an open sharing atmosphere of some sort is the primary way to cope with the tension field. Moreover, the use of a layered collaboration scheme is adopted with an increasing number of partners quite rapidly. Because of the emphasis on 'open sharing', the protection of knowledge appeared to get less attention in some cases. There seems to be some kind of spectrum in this sense that ranged from 'open sharing' to 'restrictive protecting' that overlaps with the degree of explorative nature. In more restrictive collaborations, the role of licensing becomes more apparent although different licensing schemes can still be identified in more open arrangement. Moreover, the most open knowledge exchange strategy could be translated in some kind of licensing scheme.

As shown in Table 44, the two main knowledge exchange strategies that can be identified in the case studies are a 'private open exchange strategy' and a 'layered exchange strategy'. Therefore, the only propositions from Section 4.3.4 that can be tested are (respectively) proposition 2 and proposition 3. In the table, a certain condition is marked if it complies with the proposition. From this table can be concluded that the knowledge in R&D collaborations (in these case studies at least) is generally complex, codifiable and complementary, and has a varying degree of tacitness. This latter conclusion also means that all different embodiments are to a large extent present in every investigated R&D collaboration. Furthermore, trust and commitment are identified as being present and important in general and the technological distance appears to be low. Additionally, the firms tend to collaborate with others that have high amount of experience and private internalization is typically part of the collaboration strategy. The market uncertainty determines moreover the environmental dimension.

The main differences between the existence of the two strategies that can be identified from the case study results are the following. Most clearly, the number of partners explains the adoption of either strategy to a large extent and might even be the main consideration. With regard to the characteristics of knowledge, there seems to be some relation between new and specific knowledge and the adoption of a (private) open exchange strategy. The layered strategy on the other hand is especially present in the case of a wide variety of partners (i.e. a vertical *and* horizontal nature of the collaboration). The involvement of a university also is highly correlated to the adoption of a layered scheme, as was expected. The two small firms that were investigated have furthermore adopted a private open sharing strategy, although this is most probably related to the number of partners in their collaboration. However, it can be expected that small firms generally have a higher need for more direct appropriation of results and are not that interesting in collaborations that require significantly more management efforts. It can be said however that the tension field of knowledge sharing and protection becomes even more apparent for small firms, although adopting an open exchange strategy seems to be the best way to deal with it. A small firm needs the exchange of knowledge and thereby development of new knowledge through R&D collaborations in order to stay competitive. At the same time though there is a strong need to protect its knowledge to the outside world, to appropriate the results of the (collaborative) developments.

Other elements of the propositions that are not discussed above do not explain the adoption of a certain knowledge exchange strategy in this sample. They might not hold at all, or just to a minor extent. This means that this condition either does not affect the adoption of a certain strategy or that specific element is not part of the dimensions that comprise the tension field.

Elaborating on the question why the 'private open exchange strategy' and the 'closed exchange strategy' do not occur, an explanation may be found in the specific nature of R&D collaborations. The general complexity of knowledge in (explorative) R&D collaborations and the importance of tacit knowledge can explain why the closed exchange strategy is not adopted, as also stated in proposition 4 (Section 4.3.4). The non-adoption of the private open exchange strategy can be related to the very 'public' nature of this strategy in which it is difficult or uncertain to (quickly) appropriate the results of the R&D efforts. Clearly, the boundaries between the different strategies can be fuzzy and they might be overlapping in any case. The Ericsson collaboration moreover has a very strong relation to the public open exchange strategy as given in proposition 1 but still a layered scheme was used. Thus, because this strategy is also related to a high number of partners (among other things), a public open strategy might often highly relate to a layered strategy.

Table 44. Knowledge exchange strategies in case studies

Dimensions: Case:	Array	Eka Chemicals	Akzo Nobel	Lionix	Telia	KPN	Philips	Ericsson
Knowledge characteristics								
- Complementarity	+	+	+	+	+	+	+	+
- Tacitness	+/–	+/–	+/–	+	+/–	+/–	+/–	+/–
- Codifibility	+	+	+	+	+	+	+	+
- Imitability	+	+	+	+	–	–	+	+
- Systematic nature	+	.	+	.	+	+	+	+
- Teachability	–	–	+	+	+/–	–	+	+
- Complexity	+	+	+	+	+	+	+	+
- Newness	+	–	+/–	+	.	+	.	+
- Specificity	+	+	+	+	+	+	.	+/–
Knowledge embodiment								
- IPR	+	+	+	–	–	–	+	+
- Technology	+	+	+	+	+	+	+	+
- Routines	+/–	+	+	+	.	+	+	+
- People	+/–	+	+	+	+	+	+	+
Relational dimension								
- Trust	+	+	+	+	+	+	+	+
- Commitment	+	+	+	+	+	+	+	+
- Geographical distance	+	+	+	+	–	–	–	+
- Cultural distance	+	–	+	.	.	.	–	–
- Technological distance	–	+	–	–	–	+	–	–
Collaboration characteristics								
- Explorative nature	+	–	+	+	+	+	+	+
- Vertical (vs. horizontal) nature	–	+/–	–	+/–	+/–	+/–	+/–	+/–
- Number of partners	–	–	–	+/–	+	+	+	+
- Previous experience with partner	+	–	+	+/–	+	+	+	+
- Experience of partner	+	+	+	+	+	+	+	+
- Firm size	–	+	+	–	+	+	+	+
- University involvement	–	–	–	+	+	+	+	+
- Duration	+/–	+/–	+/–	+/–	–	+/–	+/–	+
Environmental dimension								
- Uncertainty	+	+	+	+	+	.	+	+
- Sector:								
- Private internalization	+	+	+	+	+	+	+	.
- Public standardization	–	–	–	+/–	–	–	+	+
Knowledge exchange – core members	Mod. - high	Mod. - high	High	Mod. - high	High	High	High	High
Knowledge exchange - outer members	-	-	-	-	Moderate	Moderate	Moderate	Mod. - high
Knowledge exchange - outside	Low	Low	Low	Moderate	Low	Low	Low-moderate	Moderate
Knowledge exchange strategy	***Open private***	***Open private***	***Open private***	***Open private***	***Layered***	***Layered***	***Layered***	***Layered***

6 Conclusions, Discussion and Suggestions for Further Research

In the efforts of this report to explore the tension field that arises when firms participate in R&D collaborations, several issues are discussed. First of all, the importance of knowledge sharing in the present economy is explained. The most important developments that give rise to the need for firms to share their knowledge are the ongoing globalization, the increased pace of innovation, the importance of technology in general, the multi-technology characteristic of products and technological diversification. In this sense, R&D collaborations are one possible form of knowledge sharing. R&D collaborations (and inter-firm collaborations in general) have gone through significant changes and have in general become of increasing importance.

R&D collaborations receive much attention from Academia, industry and policy makers because they are an important means to establish innovation and thereby growth for firms and for the economy at large. It is clear that the sharing of knowledge is at the heart of an R&D collaboration. But at the same time, firms participating in these collaborations have the need to protect their knowledge because it is their main competitive asset. An inherent tension between the sharing and protection of knowledge in R&D collaborations thus becomes apparent. Studies attempting to investigate how firms cope with this tension field point at the importance of governance mechanisms to maximize inter-firm learning (Mohr and Sengupta, 2002), the establishment of trust (Gulati, 1995) or relational capital in general (Kale, *et al.*, 2000) and defining the scope of the alliance (Oxley and Sampson, 2004). Still it is argued that the tension field has not been addressed that explicitly yet (McEvily, *et al.*, 2004). This study addresses this issue by posing the following research question: *"What is the tension field of knowledge sharing and protection in* R&D *collaborations, and how can firms cope with this tension field?"* In order to answer this question the perspective of both knowledge *sharing* and *protection* are explicitly addressed.

The two traditional perspectives that explain collaborative knowledge sharing are *transaction cost economics* and the *resource-based view*. The first perspective can be especially used to place collaboration among firms in the broader economic spectrum ranging from the market to the hierarchy. Collaboration is the preferred governance mechanism in the case of medium production and transaction costs. The resource-based view, on the other hand, takes the firm's perspective and tries to explain how it can achieve a certain competitive advantage. In this sense, collaboration is one way of doing this by exploiting resource complementarities. In relation to the resource-based view several other approaches have been developed, one of these being the *dynamic capabilities approach* that tries to determine how firms build and sustain a competitive advantage in dynamic markets with collaboration as one possible means. These views contribute to the overall understanding of the importance of (the characteristics of) a firm's resources. Another approach, which takes more of an intellectual capital approach, is the *knowledge-based view* that tries to explain how the knowledge base of a firm (in the present knowledge-based economy) can create a sustained competitive advantage. By doing this it explicitly recognizes the importance of the characteristics of this knowledge base, which also has an important effect on the possibilities to transfer and appropriate this knowledge, for example in R&D collaborations. The *technology-based view* takes an even more specific approach by looking at technology-based firms as a specific kind of knowledge-based firm with collaboration as one possible strategy to acquire and exploit this technology base. It therefore explicitly considers the specific characteristics of technology as a body of knowledge. The knowledge-based and technology-based views consequently increase the insights in the role of knowledge (or technology) in knowledge-based undertakings, such as R&D collaborations.

All these perspectives give different inputs for the relevant dimensions that are related to the sharing of knowledge in collaborations. From transaction cost economics, for example, one can derive some important *environmental* (i.e. uncertainty) and *relational* (i.e. geographical and technological distance, commitment and trust) characteristics that influence (and give the constraints for) the boundaries in which organizations can collaborate. Moreover, the *nature* (i.e. explorative or exploitative) of the collaboration has to be considered. The resource-based view as well as the dynamic capabilities approach, on the other hand, take a different perspective and focus more on the firms' (dynamic) resource bases and their characteristics, also in relation to each other in the case of collaboration. Therefore, the *complementary* of the collaborating firms' resources (i.e. knowledge) is an important characteristic that influences the knowledge sharing. Furthermore, important characteristics are *imitability*, *tacitness* (vs. explicitness), the *systematic nature* of knowledge, *teachability*, *codifibility*, *complexity*, *specificity* and *newness*. Also taking the knowledge-based and technology-based views into consideration, the importance of these characteristics becomes even more apparent. Besides the fact they go more into some of the characteristics mentioned above, they put an emphasis on the tacit nature of (technological) knowledge as well as on the characteristics of intellectual capital in general. Intellectual property and the embodiment of knowledge (e.g. in intellectual property rights) come to play an important role in this.

In addition to the earlier mentioned developments in the world economy in general and in (R&D) collaborations in particular, looking in more detail at the developments in R&D collaborations themselves reveal some important trends. R&D collaborations, for example, are becoming much more complex and international. Furthermore the number of partners increases, as does the involvement of partners from various backgrounds (e.g. universities). Because of this, the public initiatives for R&D collaboration have also expanded. Therefore, some more *collaboration characteristics*, in addition to the nature of the collaboration, appear to be important, i.e. number of partners, experience of and with partners, partner size, university involvement, duration. These changes also impact the legal framework in which R&D collaborations take place. One important consideration is the pre-competitive nature and possibly anti-competitive nature of R&D collaborations. Addressing the limits to collaborative knowledge sharing in R&D collaboration, firms will have take Article 81 of the EC Treaty (ex Article 85) and Article 82 of the EC Treaty (ex Article 86) into consideration because these (and specifically their interpretations) give the constraints for anti-competitive issues. In general however, (pre-competitive) R&D collaborations are subject to the Block Exemption in Article 81(3) of the EC Treaty, meaning that their outcome is not subject to the article and it therefore may be declared inapplicable. It is therefore important to investigate the potential tension between anti-competitive and pro-competitive arrangements (e.g. Shapiro, 2003).

In an R&D collaboration, a firm will have the need to protect its most valuable asset, i.e. its knowledge, which it puts into the collaboration. Therefore, it is important to explore the possibilities to protect this knowledge. In this sense, it is useful to consider knowledge as a form of intellectual property in which it shares some important characteristics with 'real' property but also significantly differs from it in some extent. The protection of knowledge or intellectual property can be characterized by some important trends. The propensity for firms to file patents increased significantly, which gave rise to a 'pro-patent era' in the 1980s. From this time onwards the role of patents in the economy changed tremendously. The development of the NMT system (i.e. a telephony system in Nordic European countries) and other related systems interestingly went through different phases of open and more protective knowledge exchange (Granstrand, 1993). The impact and outcomes of patents trigger an ongoing discussion about the costs and benefits of the patent system as a whole. Some scholars in fact argue that the patent system not always matches its main rationales, which are providing an incentive to innovate and commercialize innovations while at the same time making the innovation public (which in turn stimulates innovation). The possibility to protect knowledge (i.e. by intellectual property rights) is subject to ongoing discussion and change, however. The latter can be for example seen in the new kinds of intellectual property rights that emerge. Another interesting development is the increasing interest in the Open Source Model, which is finding its way (or interest at least) also outside of the software sector. Interestingly, open source-based models still use licensing arrangements, although this is generally not so well recognized. For example, a typical open source license can be characterized as royalty-free license with a grant-back provision and the right to sub-license. The increasing importance of licensing has moreover indicated the rise of a 'pro-licensing era' (Granstrand, 2004a).

When investigating the protection of knowledge in collaborations it becomes apparent that the specific characteristics of knowledge (and technology) have to be taken into explicit consideration. The embodiment of knowledge is furthermore a crucial issue to take into account to investigate which constraints and possibilities exist for a firm to protect the knowledge it shares in a collaboration. The four main embodiments of knowledge that can be identified for R&D collaborations are knowledge embodied in (a) intellectual property rights, (b) technologies, (c) people, and (d) routines. Whereas all of them can be considered as a form of knowledge, the first three forms of embodiment most specifically refer to technical knowledge. This distinction between technical and non-technical knowledge is extremely important in the case of R&D collaborations, especially because of the technological and complex character of R&D.

Taking the protection of knowledge a step further, it means the role of licensing and licensing strategies have to be considered. Three main considerations that have to be made refer to the exclusivity of the license, the right to sub-license, and the compensation that is used. Then, in addition to 'ordinary' licensing, the main possible forms of licensing are cross-licensing, joint licensing and grant-back licensing.

Concluding, the tension field of knowledge sharing and protection in R&D collaborations is a combination of different dimension in relation to the knowledge as subject of the collaboration, to the relationship between the partners, to the characteristics of the collaboration as a whole, and to the environmental characteristics influencing all these other dimensions (see Table 6). The properties of knowledge determine to a large extent the shape of this tension field, as can be seen in the model (Figure 19) developed in Section 4.2. In addition to knowledge itself, trust is a very important element in the tension field. It can balance the different interests of knowledge sharing and protection. While this becomes clear in this study it has been recognized before (e.g. Ring and Van der Ven, 1992; Gulati, 1995; Gulati and Singh, 1998). Moreover, it is argued that trust is the most efficient mechanism in governing economic transactions in general (Arrow, 1974).

In order to consider knowledge governance mechanisms in R&D collaboration, an R&D collaboration can be seen as a 'virtual entity' of which the existence is limited in time (i.e. by its start and end) and by the resources (i.e. knowledge) that are put into it and that it develops. The framework that is developed in relation to this is given in Figure 20. It is important in this respect to explicitly consider the transfer of knowledge. At the start of (or during) the collaboration, the partners (two or more) put in a certain amount of *background knowledge* into the collaboration. During the collaboration, i.e. inside the *virtual entity*, the partners collaboratively develop *foreground knowledge* by sharing their (background) knowledge. In addition, the different partners (typically) develop some knowledge in-house that is needed for and put into the collaboration (i.e. *sideground knowledge)*. Furthermore, *postground knowledge* might exist which is knowledge in relation to the subject of the collaboration but developed after it (i.e. after the end date at which the virtual entity ceased to exist). An important consideration that has to be made relates to the *environment* of the collaboration. For all these issues certain agreements have to be made in order to arrange the exact sharing and protection. Therefore, the role of different kinds of licenses becomes apparent although – and this is related to the pre-competitive nature of R&D collaboration – much of the knowledge sharing takes place in an open atmosphere without the use of a high degree of protection mechanisms.

The actual way in which the firms go about the sharing and protection of knowledge, i.e. how they cope with the tension field, is related to several issues. In this tension field the characteristics of knowledge take a central place. They influence the way in which partners in the collaboration can share their knowledge and how they can protect it. Furthermore, they influence what kind of relation the partner can have and how the knowledge can be embodied. In the case of R&D collaborations this respectively means that the relations generally have to be based on trust and commitment in order to utilize the full potential of the collaboration and that both the tacit and embedded kinds of embodiments are crucial for the success of the collaboration. Moreover, this embodiment determines the way in which a firm can protect its knowledge. This protection can in turn influence the way the relations between the different partners are set up. These relational dimensions again facilitate the actual sharing of knowledge, of which the outcome determines what the (foreground) knowledge looks like. This framework is yet again influenced by two (meta) characteristics, namely the general collaboration characteristics and the environmental dimensions.

In order to investigate in more detail what the different coping strategies entail, the developed framework shows that knowledge flow at distinct occasions. As discussed above, a certain degree of protectiveness (vs. openness) might exist in relation to the protective mechanisms used in R&D collaborations. A collaboration can also have its own 'sub-collaborations', meaning that a (limited) number of partners jointly work on a part of the collaboration's (broader) scope. The collaboration therefore has strong a 'project character'. For this reason, the 'personal factor' appears to play an important role in R&D collaborations. The actual knowledge sharing namely takes place by the *people* participating in the collaboration on behalf of the organization. And because of the importance of an open atmosphere, this 'personal factor' is crucial and therefore trust (as the basis of a good and open relationship) is essential. Commitment furthermore plays an important role in this. Because of this personal factor, the codification of knowledge can be an important mechanism in the case of technological distance between partners, for example if partners 'do not speak the same language'. Because of the importance of know-how (i.e. knowledge embodied in people) the people that participate in the actual collaboration are chosen on the basis of this criterion, among others. This again reinforces the people-orientated characteristic of R&D collaborations. Moreover, the 'real' collaboration, i.e. the actual knowledge sharing, takes place on a lower level in the organizational hierarchy whereas the formal decision-making and permissions come from the higher level, which is highly concerned with the protection of a firm's knowledge. Therefore, there appears to a 'hierarchical bridge' between the sharing and protection of knowledge. There is thus an intra-organizational barrier between knowledge sharing and protection which can decrease the tension if taken well but increase it (and thereby hamper good sharing and appropriation of knowledge) if it remains. This therefore can reinforce the tension field.

Overall, taking the concepts of *knowledge transfer*, *governance* of knowledge flows and *licensing* into consideration, some main coping strategies can be developed (as done in Section 4.3). This study develops four main coping strategies, namely a 'public open exchange strategy' a 'private open exchange strategy', a 'layered exchange strategy' and a 'closed exchange strategy'. The propositions that discuss in which conditions in the tension field lead to the adoption of a strategy are given in Section 4.3.4. In general it can be said that the knowledge characteristics are expected to play an essential role in the tension field. The complexity of knowledge is one of the most important characteristics and the presence of highly complex knowledge is expected to be related to the adoption of a more open strategy, as well as the tacitness of knowledge (i.e. knowledge embodiment). Therefore, more tacit knowledge is expected to relate to the adoption of an open exchange strategy, and the involvement of more explicit knowledge to the establishment of a closed strategy. This can be attributed to the ease to exchange explicit knowledge in a restrictive manner. The adoption of the layered exchange strategy is expected if all the embodiments are present which can create the need to set up 'sub-collaborations'. In an open exchange, the role of trust becomes apparent and highly determines the degree of open sharing. All of this is influenced by the characteristics of the collaboration and the collaborating firms.

The *case studies* conducted in this study (see Chapter 5) are used to investigate the tension field and coping strategies in general and therefore contribute to the insight as elaborated above. Additionally, they are used to test the propositions in order to see which strategies occur and what determines their adoption. In the case studies, the 'private open exchange strategy' and 'layered exchange strategy' were identified and therefore proposition 2 and proposition 3 were respectively identified and tested. From the analysis can be concluded that the knowledge in R&D collaborations is generally complex, codifiable and complementary, and furthermore has a varying degree of tacitness. Therefore, all different embodiments can be identified in the investigated R&D collaborations to a large extent as well. Trust and commitment are furthermore important elements. In general, the technological distance is low. Additionally, the firms tend to collaborate with others that have high amount of experience and private internalization is typically part of the collaboration strategy. The market uncertainty is generally high as well for R&D collaborations.

The main differences between the two strategies that can be identified from the case study results are the following. Most clearly, the number of partners explains the adoption of a strategy to a large extent and might even be the main consideration. With regard to the characteristics of knowledge, there is a relation between new and specific knowledge on the one hand and the adoption of a private open exchange strategy on the other hand. The adoption of the layered exchange strategy is related to a wide variety of partners (i.e. a vertical *and* horizontal nature of the collaboration). The involvement of a university is furthermore highly related to the adoption of a layered collaboration scheme. The two small firms that were investigated furthermore adopted a private open sharing strategy, which might be explained by the fact that small firms generally have a higher need for more direct appropriation of results and are not interested that much in collaborations that require significantly more management efforts.

The fact that the 'public open exchange strategy' and the 'closed exchange strategy' were not identified might be explained by the specific nature of R&D collaborations, which is generally explorative. The complexity of knowledge in R&D collaborations and the importance of tacit knowledge can explain why the closed exchange strategy was not identified. The very 'public' nature of the public open exchange strategy can moreover explain this strategy was not adopted. It is namely difficult or uncertain to (quickly) appropriate the results of the R&D efforts in this way which is often required for firms that participate in a collaboration to create (short-term or medium-term) value and/or lower (direct) transaction costs.

In sum, it can be argued that knowledge sharing through collaboration is becoming of increasing importance in the economy in general and for firms in particular. Still collaborating firms want to protect their knowledge because it is their main competitive asset. In this perspective technical knowledge highly determines innovation and economic growth. In order to cope with the increasing complexity and diversity of (technical) knowledge, firms specifically participate in R&D collaborations that have a pre-competitive and therefore mostly explorative nature. The dimensions that comprise the tension field (as a result of this study) make clear which elements determine certain outcomes in relation to the tension between knowledge sharing and protection. A firm can affect some of the dimensions by design or by management. The significance of the practitioners' level becomes apparent in this as well. In relation to coping strategies moreover this study develops four main exchange strategies, mainly based on open, closed and/or layered strategy considerations. The strategies incorporate the concepts of knowledge transfer, governance and licensing in some way. Propositions are developed that explain in which condition of the tension field a certain coping strategy can be expected. In relation to this, an open strategy is expected to be adopted in case of more tacit knowledge with an important role of trust, and a layered strategy is moreover expected to be adopted in the case of many partners and a less average trust-based relationship.

With regard to future research, it has to be considered that R&D collaborations are becoming of increasing importance and are expected to maintain this importance. This applies to firms as well as to the economy as a whole. Therefore, the competition law has to be investigated in order to foster and/or not to hamper the establishment of (pre-competitive) R&D collaborations.

Another issue of interest relates to the coping strategies developed in this study. It will be valuable to examine (theoretically and empirically) what the possibilities and effect are of 'open sharing' based models or strategies. More specifically, the 'Open Source characteristics' of R&D collaborations can be identified, for example referring to inter-compatibility issues and the relation to legal aspects (e.g. the 'clashes' between protected knowledge and open source knowledge when these two are combined). This new model of knowledge sharing could moreover lead to a new theory of innovation.

In relation to this, it might be possible to make a characterization of different kinds of partners in an R&D collaboration in order to explore the relational dimension in more detail, for example a distinction between 'friends' and 'foes' as Dahlander (2004) made for Open Source Software. In this sense, 'friends' might focus on value maximizing whereas the 'foes' try to establish cost minimizing in collaborations. Moreover, a more detailed identification of the 'personal factor' might give valuable insight in the importance of the practitioners' level at which the *actual* collaboration takes place. A next logical issue is to examine the 'gap' that might exist between the strategic management level and the practitioners' level. In fact, this gap seems to create a tension on its own causing an unstable equilibrium in the broader tension between knowledge sharing and protection, as also identified by Foray and Steinmueller (2003).

With regard to the framework developed in this study to investigate the different kinds of knowledge transfer, it has to be further examined what the concepts of 'sideground knowledge' and 'postground knowledge' exactly entail because there are no widely accepted definitions yet. The framework itself would benefit from some more elaboration as well in order to identify what its exact use is to investigate the tension field and possible coping strategies. While the collaboration is identified as some kind of 'virtual entity' this concept can be developed in more detail, for example by exploring the possible resources, processes, routines and relations of this entity, both within and outside its 'boundaries' (i.e. with the collaborating organizations *and* the rest of the market). In this sense, the dynamics of collaborations have to be investigated in more detail as well.

References

Aadne, J. H., G. von Krogh and J. Roos (1996) 'Representationism: The Traditional Approach to Cooperative Strategies'. In: von Krogh, G. and J. Roos (eds), *Managing Knowledge: Perspectives on Cooperation and Competition.* London: Sage Publications: 9-31.

Abramowicz, H., N. Niebert, W. Mohr, *et al.* (2004). The Wireless World Initiative: A Framework for Research on Systems Beyond 3g, Mobile Summit 2004. Ambient Networks.

Adler, P. S. (2002) 'Market, Hierarchy and Trust: The Knowledge Economy and the Future of Capitalism'. In: Choo, C. W. and N. Bontis (eds), *The Strategic Management of Intellectual Capital and Organizational Knowledge.* Oxford: Oxford University Press: 23-46.

Andersen, B. (2004) 'If 'Intellectual Property Rights' Is the Answer, What Is the Question? Revisiting the Patent Controversies', *Economics of Innovation and New Technology*, **13** (5): 417-442.

Arora, A., A. Fosfuri and A. Gambardella (2001). *Markets for Technology: The Economics of Innovation and Corporate Strategy.* Cambridge, MA: MIT Press.

Arora, A., A. Fosfuri and A. Gambardella (2003) 'Markets for Technology and Corporate Strategy'. In: Granstrand, O. (ed.), *Economics, Law and Intellectual Property.* Dordrecht: Kluwer Academic Publishers.

Array Printers (1996). Annual Report 1995.

Array Printers (2000). Annual Report 1999.

Array Printers (2001). Annual Report 2000.

Arrow, K. (1962) 'Economic Welfare and the Allocation of Resources for Invention'. In: National Bureau of Economic Research (ed.), *The Rate and Direction of Inventive Activity.* Princeton, NJ: Princeton University Press: 609-625.

Arrow, K. J. (1974). *The Limits of Organization.* New York: Norton.

Arthur, W. B. (1994). *Increasing Returns and Path Dependence in the Economy.* Ann Arbor, MI: The University of Michigan Press.

Badaracco, J. L. (1991). *The Knowledge Link: How Firms Compete through Strategic Alliances.* Boston, MA: Harvard Business School Press.

Bainbridge, D. I. (2002). *Intellectual Property. 5th Edition.* Harlow: Longman.

Bamford, J. and D. Ernst (2002) 'Managing an Alliance Portfolio', *McKinsey Quarterly* (3).

Barney, J. B. (1986) 'Strategic Factor Markets: Expectations, Luck, and Business Strategy', *Management Science*, **32** (1231-1241).

Barney, J. B. (1991) 'Firm Resources and Sustained Competitive Advantage', *Journal of Management*, **17**: 99-120.

Barney, J. B. and W. S. Hesterly (1996) 'Organizational Economics: Understanding the Relationship between Organization and Economic Analyis'. In: Clegg, S., C. Hardy and W. R. Nord (eds), *Handbook of Organization Studies.* Thousand Oaks, CA: Sage Publications: 115-147.

Beard, T. R. and D. L. Kaserman (2002) 'Patent Thicket, Cross-Licensing and, Antitrust', *Antitrust Bulletin*, **47** (2/3): 345-368.

Bednarek, M. and M. Ineichen (2004) 'Patent Pools as an Alternative to Patent Wars in Emerging Sectors', *Intellectual Property and Technology Law Journal*, **16** (7): 1-5.

Bekkers, R. (2004). The Macro-Economic Effects of Intensive Patenting Industries - Or: Why We Could Be All Better Off with Less Patenting. Position Statement for the Ieee Ets-04 Conference. May 24-26, 2004, Corsica.

Bekkers, R. N. A. (2001). The Development of European Mobile Telecommunications Standards: An Assessment of the Success of Gsm, Tetra, Ermes and Umts. Eindhoven, Department of Technology Management, Technische Universiteit Eindhoven.

Bessy, C. and E. Brousseau (1998) 'Technology Licensing Contracts Features and Diversity', *International Review of Law and Economics*, **18**: 451– 489.

Bleeke, J. and D. Ernst (1993). *Collaborating to Compete: Using Strategic Alliances and Acquisitions in the Global Marketplace*. New York: John Wiley & Sons.

Cantwell, J., A. Gambardella and O. Granstrand (2004) 'Technological and Corporate Diversification'. In: Cantwell, J., A. Gambardella and O. Granstrand (eds), *The Economics and Management of Technological Diversification*. London: Routledge: 1-17.

Chesbrough, H. W. (2003a) 'The Era of Open Innovation', *MIT Sloan Management Review*, **44** (3): 35–41.

Chesbrough, H. W. (2003b). *Open Innovation: The New Imperative for Creating and Profiting from Technology*. Boston, MA: Harvard Business School Press.

Choo, C. W. and N. Bontis, Eds. (2002). 'The Strategic Management of Intellectual Capital and Organizational Knowledge'. Oxford: Oxford University Press.

Christensen, C. M. and R. S. Rosenbloom (1995) 'Explaining the Attacker's Advantage: Technological Paradigms, Organizational Dynamics, and the Value Network', *Research Policy*, **24**: 233-257.

Coase, R. H. (1937) 'The Nature of the Firm', *Economica*, **4**: 386-405.

Cohen, W. M., A. Goto, A. Nagata, *et al.* (2003) 'R&D Information Flows and Patenting in Japan and the United States'. In: Granstrand, O. (ed.), *Economics, Law and Intellectual Property*. Dordrecht: Kluwer Academic Publishers: 123-154.

Contractor, F. J. and P. Lorange, Eds. (1988a). 'Cooperative Strategies in International Business'. Toronto: Lexicon Books.

Contractor, F. J. and P. Lorange (1988b) 'Why Should Firm Cooperate? The Strategy and Economics Basis for Cooperative Ventures.' In: Contractor, F. J. and P. Lorange (eds), *Cooperative Strategies in International Business*. Toronto: Lexicon Books.

Contractor, F. J. and W. Ra (2002) 'How Knowledge Attributes Influence Alliance Governance Choices: A Theory Development Note', *Journal of International Management*, **8**: 11-27.

Coriat, B. and F. Orsi (2002) 'Establishing a New Intellectual Property Rights Regime in the United States Origins, Content and Problems', *Research Policy*, **31**: 1491–1507.

Cowan, R., P. A. David and D. Foray (2000) 'The Explicit Economics of Knowledge Codification and Tacitness', *Industrial and Corporate Change*, **9** (2): 211-253.

Cyert, R. M. and J. G. March (1963). *A Behavioural Theory of the Firm.* Englewood Cliffs, NJ: Prentice-Hall.

Dahlander, L. (2004). Appropriating the Commons: Firms in Open Source Software. Gothenburg, Department of Industrial Dynamics, School of Technology Management and Economics, Chalmers University of Technology.

Das, T. K. and B.-S. Teng (2000) 'A Resource-Based Theory of Strategic Alliances', *Journal of Management*, **26** (1): 31-61.

Davis, L. (2004) 'Intellectual Property Rights, Strategy and Policy', *Economics of Innovation and New Technology*, **13** (5): 399-415.

Dodgson, M. (1991) 'Technology Learning, Technology Strategy and Competitive Pressures', *British Journal of Management*, **2**: 133-149.

Dodgson, M. (1993). *Technological Collaboration in Industry: Strategy, Policy and Internationalization in Innovation.* London: Routledge.

Doz, Y. L. and G. Hamel (1998). *Alliance Advantage: The Art of Creating Value through Partnering.* Boston, MA: Harvard Business School Press.

Dubois, P.-A. (2004) 'The Proposed Technology Transfer Block Exemption: How It Will Impact Technology Licensing', *Computer and Internet Lawyer*, **21** (4): 27-31.

Dyer, J. H. and H. Singh (1998) 'The Relational View: Cooperative Strategies and Sources of Interorganizational Competitive Advantage', *Academy of Management Review*, **23** (4): 660-679.

Edvinsson, L. (1997) 'Developing Intellectual Capital at Skandia', *Long Range Planning*, **30** (3): 366-373.

Edvinsson, L. and M. S. Malone (1997). *Intellectual Capital: Realizing Your Company's True Value by Finding Its Hidden Brainpower.* New York: HarperBusiness.

Eisenberg, R. S. (1996) 'Public Research and Private Development: Patents and Technology Transfer in Government Sponsored Research', *Virginia Law Review*, **82**: 1663-1727.

Eisenhardt, K. M. and J. A. Martin (2000) 'Dynamic Capabilities: What Are They?' *Strategic Management Journal*, **21** (10/11): 1105-1121.

European Commission (1999). Etan Working Paper: Strategic Dimensions of Intellectual Property Rights in the Context of S&T Policy. Brussels, European Commission.

European Commission (2001a) 'Commission Notice: Guidelines on the Applicability of Article 81 of the Ec Treaty to Horizontal Cooperation Agreements ', *Official Journal of the European Union*, **44** (C 03): 2-30.

European Commission (2001b). Ipr (Intellectual Property Rights) Aspects of Internet Collaborations. Brussels, European Commission.

European Commission (2002). Expert Group Report On: Role and Strategic Use of Iprs (Intellectual Property Rights) in International Research Collaborations. Brussels, European Commission.

European Commission (2004) 'Commission Notice: Guidelines on the Applicability of Article 81 of the Ec Treaty to Horizontal Cooperation Agreements ', *Official Journal of the European Union*, **44** (C 03): 2-30.

Foray, D. (2004). *Economics of Knowledge.* Cambridge, MA: MIT Press.

Foray, D. and W. E. Steinmueller (2003) 'On the Economics of R&D and Technological Collaborations: Insights and Results from the Project Colline', *Economics of Innovation and New Technology*, **12** (1): 77-91.

Foss, N. J., K. Husted, S. Michailova and T. Pedersen (2003). Governing Knowledge Processes: Theoretical Foundations and Research Opportunities. Copenhagen, The Center for Knowledge Governance, Department of Management, Copenhagen Business School.

Gallini, N. and S. Scotchmer (2002) 'Intellectual Property: When Is It the Best Incentive Mechanism?' In: Jaffe, A. B., J. Lerner and S. Stern (eds), *Innovation Policy and the Economy 2.* Cambridge, MA: MIT Press: 51-78.

Gerlach, M. L. (1992). *Alliance Capitalism: The Social Organization of Japanese Business.* Berkeley: University of California Press.

Giuri, P., J. Hagedoorn and M. Mariani (2004) 'Technological Diversification and Strategic Alliances'. In: Cantwell, J., A. Gambardella and O. Granstrand (eds), *The Economics and Management of Technological Diversification.* London: Routledge.

Gomes-Casseres, B. (1996). *The Alliance Revolution: The New Shape of Business Rivalry.* Cambrigde, MA: Harvard University Press.

Granovetter, M. (1985) 'Economic Action and Social Structure: A Theory of Embeddedness', *American Journal of Sociology*, **91**: 481-510.

Granstrand, O. (1993). The Evolution of Nordic Mobile Telephony. Working Paper. Gothenburg, Department of Industrial Management of Economics, Chalmers University of Technology.

Granstrand, O. (2000). *The Economics and Management of Intellectual Property: Towards Intellectual Capitalism.* Cheltenham: Edward Elgar Publishing.

Granstrand, O. (2003). Innovation and Intellectual Property. Working Paper. Gothenburg, Department of Industrial Management and Economics, Chalmers University of Technology.

Granstrand, O. (2004a) 'The Economics and Management of Technology Trade: Towards a Pro-Licensing Era?' *International Journal of Technology Management*, **27** (2,3): 209-240.

Granstrand, O. (2004b) 'Innovation and Intellectual Property Rights'. In: Fagerberg, J., D. C. Mowery and R. R. Nelson (eds), *The Oxford Handbook of Innovation.* New York: Oxford University Press.

Granstrand, O. (2004c) 'Multi-Technology Management'. In: Cantwell, J., A. Gambardella and O. Granstrand (eds), *The Economics and Management of Technological Diversification.* London: Routledge: 296-332.

Granstrand, O. and S. Lindmark (2002). Technology Collaborations in Corporate Innovation Systems. Gothenburg, Department of Industrial Management and Economics, Chalmers University of Technology.

Granstrand, O., P. Patel and K. Pavitt (1997) 'Multi-Technology Corporation: Why They Have Distributed Rather Than Distinctive Core Competences', *California Management Review*, **39** (4): 8-25.

Granstrand, O. and S. Sjölander (1990) 'Managing Innovation in Multi-Technology Corporations', *Research Policy*, **19**: 35-60.

Grant, R. M. (1996) 'Towards a Knowledge-Based Theory of the Firm', *Strategic Management Journal*, **17** (Winter): 109-122.

Grant, R. M. (2002) 'The Knowledge-Based View of the Firm'. In: Choo, C. W. and N. Bontis (eds), *The Strategic Management of Intellectual Capital and Organizational Knowledge*. New York: Oxford University Press: 133-148.

Grindley, P. C. and D. J. Teece (1997) 'Managing Intellectual Capital: Licensing and Cross-Licensing in Semiconductors and Electronics', *California Management Review*, **39** (2): 8-41.

Gulati, R. (1995) 'Does Familiarity Breed Trust? The Implications of Repeated Ties for Contractual Choices in Alliances', *Academy of Management Journal*, **38** (1): 85-112.

Gulati, R. and H. Singh (1998) 'The Architecture of Cooperation: Managing Coordination Costs and Appropriation Concerns in Strategic Alliances', *Administrative Science Quarterly*, **43** (4): 781-814.

Hagedoorn, J. (2002) 'Inter-Firm R&D Partnerships: An Overview of Major Trends and Patterns since 1960', *Research Policy*, **31**: 477-492.

Hagedoorn, J., A. N. Link and N. S. Vonortas (2000) 'Research Partnerships', *Research Policy*, **29**: 567-586.

Hagedoorn, J. and J. Schakenraad (1990) 'Inter-Firm Partnerships and Cooperative Strategies in Core Technologies'. In: Freeman, C. and L. Soete (eds), *New Explorations in the Economics of Technological Change*. London: Pinter.

Hagedoorn, J. and J. Schakenraad (1994) 'The Effect of Strategic Technology Alliances on Company Performance', *Strategic Management Journal*, **15**: 291-309.

Hamel, G. (1991) 'Competition for Competence and Inter-Partner Learning within International Strategic Alliances', *Strategic Management Journal*, **12**: 83-103.

Hamel, G., Y. Doz and C. Prahalad (1989) 'Collaborate with Your Competitors - and Win', *Harvard Business Review*: 133-139.

Harhoff, D., J. Henkel and E. von Hippel (2003) 'Profiting from Voluntary Information Spillovers: How Users Benefit by Freely Revealing Their Innovations', *Research Policy*, **32** (10): 1753-1769.

Harison, E. (2004). Designed for Innovation: The Structure of Ipr Regimes and the Evolution of Information Technologies. Paper Presented at the Druid Summer Conference 2004 on Industrial Dynamics, Innovation and Development. Elsinore, Denmark, June 14-16, 2004. Maastricht, MERIT, University of Maastricht.

Harison, E. and R. Cowan (2004) 'On Substitution of Intellectual Property and Free Disclosure: An Analysis of R&D Strategies in Software Technologies', *Economics of Innovation and New Technology*, **13** (5).

Henkel, J. (2004). Patterns of Free Revealing: Balancing Code Sharing and Protection in Commercial Open Source Development. Munich, Institute for Innovation Research, Technology Management and Entrepreneurship, University of Munich.

Hersey, K. (2004). Coming of Age: Technology Transfer in the Us. Paper Presented at the Cip Symposium, June 1-3, Gothenburg. Cambridge, MIT.

Hertzfeld, H. R., A. N. Link and N. S. Vonortas (2001). Intellectual Property Protection Mechanisms and Research Partnerships. Washington, D.C., Center for International Science and Technology Policy, Elliott School of International Affairs, George Washington University.

Hladik, K. J. (1985). *International Joint Ventures: An Economic Analysis of U.S.-Foreign Business Partnerships.* Lexington, MA: Lexington Books.

http://e2r.motlabs.com (2004). End-to-End Reconfigurability.

http://europa.eu.int (2004). The European Union Online, European Commission.

http://www.ambient-networks.org (2004). Ambient Networks.

http://www.bluetooth.com (2004). The Official Bluetooth Wireless Info Site.

http://www.cordis.lu (2004). Community Research and Development Information Service - Cordis, European Commission.

http://www.creativecommons.org (2004). Creative Commons.

http://www.extra.research.philips.com/euprojects/mytv (2004). The Mytv Project Public Homepage.

http://www.ist-mobilife.org (2004). Mobi Life.

http://www.ist-winner.org (2004). Winner.

http://www.ling.gu.se/projekt/dhomme (2004). D'homme.

http://www.tv-anytime.org (2004). Tv-Anytime Forum.

http://www.wireless-world-initiative.org (2004). Wireless World Initiative.

http://www.wto.org (2004). World Trade Organization.

Huber, G. P. (1991) 'Organizational Learning: The Contributing Processes and Literatures', *Organization Science*, **2**: 88-115.

Jaffe, A. B. (2000) 'The U.S. Patent System in Transition: Policy Innovation and the Innovation Process', *Research Policy*, **29**: 531-557.

Jorde, T. M. and D. J. Teece (1990) 'Innovation and Cooperation: Implications for Competition and Antitrust', *Journal of Economic Perspectives*, **4** (3): 75-96.

Kale, P., H. Singh and H. Perlmutter (2000) 'Learning and Protection of Proprietary Assets in Strategic Alliances: Building Relational Capital', *Strategic Management Journal*, **21**: 217-237.

Katz, M. L. and C. Shapiro (1985) 'Network Externalities, Competition, and Compatibility', *The American Economic Review*, **75**: 424-440.

Kaufer, E. (1989). *The Economics of the Patent System*. Chur: Harwood Academic Publishers.

Kogut, B. (1988) 'Joint Ventures: Theoretical and Empirical Perspectives', *Strategic Management Journal*, **9**: 319-332.

Kogut, B. and U. Zander (1992) 'Knowledge of the Firm, Combinative Capabilities, and the Replication of Technology', *Organization Science*, **3** (3): 383-397.

Kogut, B. and U. Zander (1993) 'Knowledge of the Firm and Evolutionary Theory of the Multinational Corporation', *Journal of International Business Studies*, **24**: 625-645.

Koopmans, T. C. (1957). *Three Essays on the State of Economic Science*. New York: McGraw-Hill.

Lee, L. C. and J. S. Davidson (1993). *Managing Intellectual Property Rights*. New York: John Wiley & Sons.

Lerner, J. (2000). 150 Years of Patent Protection. Nber Working Paper Series. Number: 7478.

Lerner, J. and J. Tirole (2002a). The Scope of Open Source Licensing. Nber Working Paper Series. Number: 9363.

Lerner, J. and J. Tirole (2002b) 'Some Simple Economics of Open Source', *The Journal of Industrial Economics*, **50** (2): 197-234.

Levin, R. C., A. K. Klevorick, R. R. Nelson and S. G. Winter (1987) 'Appropriating the Returns from Industrial R&D', *Brookings Papers on Economic Activity*, **14**: 551-561.

Levitt, B. and J. G. March (1988) 'Organizational Learning', *Annual Review of Sociology*, **14**: 319-340.

Machlup, F. M. (1980). *Knowledge: Its Creation, Distribution and Economic Significance*. Princeton, NJ: Princeton University Press.

Madhavan, R. and R. Grover (1996). From Embedded Knowledge to Embodied Knowledge: New Product Development as Knowledge Management. University Park, PA, Institute for the Study of Business Markets, The Pennsylvania State University.

Mansfield, E. (1986) 'Patents and Innovation: An Empirical Study', *Management Science*, **32** (2): 173-181.

March, J. G. (1991) 'Exploration and Exploitation in Organizational Learning', *Organization Science*, **2** (1): 71-87.

Mazzoleni, R. and R. R. Nelson (1998) 'The Benefits and Costs of Strong Patent Protection: A Contribution to the Current Debate', *Research Policy*, **27**: 273-284.

McEvily, S. K., K. M. Eisenhardt and J. E. Prescott (2004) 'The Global Acquisition, Leverage, and Protection of Technological Competencies', *Strategic Management Journal*, **25**: 713-722.

Megantz, R. C. (1996). *How to Licence Technology*. New York: John Wiley & Sons.

Mohr, J. J. and S. Sengupta (2002) 'Managing the Paradox of Inter-Firm Learning: The Role of Governance Mechanisms', *Journal of Business & Industrial Marketing*, **17** (4): 282-301.

Mowery, D. C. (1988) 'Collaborative Ventures between U.S. And Foreign Manufacturing Firms'. In: Mowery, D. C. (ed.), *International Collaborative Ventures in U.S. Manufacturing*. Cambridge, MA: Ballinger Publishing Company.

Mowery, D. C., J. E. Oxley and B. S. Silverman (1998) 'Technological Overlap and Interfirm Co-operation: Implications for the Resource-Based View of the Firm', *Research Policy*, **27**: 507-523.

Narula, R. and G. Duysters (2004) 'Globalisation and Trends in International R&D Alliances', *Journal of International Management*, **10**: 199-218.

Narula, R. and J. Hagedoorn (1999) 'Innovating through Strategic Alliances: Moving Towards International Partnerships and Contractual Agreements', *Technovation*, **19**: 283-294.

Nelson, R. R. (1959) 'The Economics of Invention: A Survey of the Literature', *The Journal of Business*, **April**: 101-127.

Nelson, R. R. and S. G. Winter (1982). *An Evolutionary Theory of Economic Change.* Cambrigde, MA: The Belknap Press of Harvard University Press.

Nonaka, I. (1994) 'A Dynamic Theory of Organizational Knowledge Creation', *Organization Science*, **5**: 14-37.

Nonaka, I. and H. Takeuchi (1995). *The Knowledge-Creating Company: How Japanese Companies Create the Dynamics of Innovation.* New York: Oxford University Press.

Nonaka, I. and D. J. Teece, Eds. (2001a). 'Managing Industrial Knowledge: Creation, Transfer and Utilization'. London: Sage Publications.

Nonaka, I. and D. J. Teece (2001b) 'Research Directions for Knowledge Management'. In: Nonaka, I. and D. J. Teece (eds), *Managing Industrial Knowledge: Creation, Transfer and Utilization.* London: Sage Publications.

Ordover, J. A. (1991) 'A Patent System for Both Diffusion and Exclusion', *Journal of Economic Perspectives*, **5** (1): 43-60.

Organisation for Economic Co-operation and Development (2002). *The Measurement of Scientific and Technological Activities: Proposed Standard Practice for Surveys on Research and Experimental Development: Frascati Manual 2002.* Paris: Organisation for Economic Co-operation and Development.

Osborn, R. N. and J. Hagedoorn (1997) 'The Institutionalization and Evolutionary Dynamics of Inter-Organizational Alliances and Networks', *Academy of Management Journal*, **40** (2): 261-278.

Oxley, J. E. and R. C. Sampson (2004) 'The Scope and Governance of International R&D Alliances', *Strategic Management Journal*, **25**: 723-749.

Parr, R. P. and P. H. Sullivan (1996). *Technology Licensing: Corporate Strategies for Maximizing Value.* New York: John Wiley & Sons.

Penrose, E. T. (1959). *The Theory of the Growth of the Firm.* Oxford: Basil Blackwell.

Peteraf, M. (1993) 'The Cornerstones of Competitive Advantage: A Resource-Based View', *Strategic Management Journal*, **14**: 179-191.

Pisano, G. P., M. V. Russo and D. J. Teece (1988) 'Joint Ventures and Collaborative Agreements in the Telecommunications Equipment Industry'. In: Mowery, D. C. (ed.), *International Collaborative Ventures in U.S. Manufacturing.* Cambridge, MA: Ballinger Publishing Company: 23-70.

Polanyi, M. (1958). *Personal Knowledge: Towards a Post-Critical Philosophy.* Chicago, IL: Routledge & Kegan Paul.

Polanyi, M. (1967). *The Tacit Dimension.* New York: Anchor Books.

Poltorak, A. I. and P. J. Lerner (2004). *Essentials of Licensing Intellectual Property.* Hoboken, NJ: John Wiley & Sons.

Prahalad, C. K. and G. Hamel (1990) 'The Core Competence of the Organization', *Harvard Business Review*, **(May-June)**: 79-90.

Raymond, E. S. (2001). *The Cathedral and the Bazaar: Musings on Linux and Open Source by an Accidental Revolutionary.* Sebastopol, CA: O'Reilly.

Rayner, M., J. Boye, I. Lewin and G. Gorrell (2003) 'Plug and Play Spoken Dialogue Processing'. In: Kuppevelt, J. v. and R. W. Smith (eds), *Current and New Directions in Discourse and Dialogue.* Dordrecht: Kluwer Academic Publishers.

Ring, P. S. and A. H. Van der Ven (1992) 'Structuring Cooperative Relationships between Organizations', *Strategic Management Journal*, **13**: 483-498.

Rivette, K. and D. Kline (1999). *Rembrandts in the Attic: Unlocking the Hidden Value of Patents.* Boston, MA: Harvard Business School Press.

Rogers, E. M. (1995). *Diffusion of Innovations.* New York: The Free Press.

Roos, J., G. Roos, L. Edvinsson and N. C. Dragonetti (1997). *Intellectual Capital: Navigating the New Business Landscape.* Basingstoke: Macmillan.

Rosenberg, N. (1994) 'Science - Technology - Economy Interactions'. In: Granstrand, O. (ed.), *Economics of Technology.* Amsterdam: North-Holland: 323-337.

Rumelt, R. P. (1984) 'Towards a Strategic Theory of the Firm'. In: Lamb, R. B. (ed.), *Competitive Strategic Management.* Englewood Cliffs, NJ: Prentice-Hall: 566-570.

Scherer, F. M. (1980). *Industrial Market Structure and Economic Performance.* Chicago, IL: Rand McNally.

Schildt, H. A., M. V. J. Maula and T. Keil (2003). Explorative and Exploitative Learning from External Corporate Ventures. Espoo, Institute of Strategy and International Business, Department of Industrial Engineering and Management, Helsinki University of Technology.

Schumpeter, J. A. (1934). *The Theory of Economic Development: An Inquiry into Profits, Capital, Credit, Interest, and the Business Cycle.* Cambridge, MA: Harvard University Press.

Shapiro, C. (2001) 'Navigating the Patent Thicket: Cross Licenses, Patent Pools, and Standard Setting'. In: Jaffe, A. B., J. Lerner and S. Stern (eds), *Innovation Policy and the Economy 1.* Cambridge, MA: MIT Press: 119-150.

Shapiro, C. (2003) 'Antitrust Limits to Patent Settlements', *The RAND Journal of Economics*, **34** (2): 391-411.

Shapiro, C. and H. R. Varian (1999). *Information Rules: A Strategic Guide to the Network Economy.* Boston, MA: Harvard Business School Press.

Sherry, E. F. and D. J. Teece (2004) 'Royalties, Evolving Patent Rights, and the Value of Innovation', *Research Policy*, **33**: 179-191.

Shurmer, M. and G. Lea (1995) 'Telecommunications Standardization and Intellectual Property Rights: A Fundamental Dilemma?' *StandardView*, **3** (2): 50-59.

Simon, H. A. (1991) 'Bounded Rationality and Organisational Learning', *Organization Science*, **2**: 125-134.

Stiglitz, J. (1999). Scan Globally, Reinvent Locally: Knowledge Infrastructure and the Localization of Knowledge. Keynote Address First Global Development Network Conference. December 1999. Bonn.

Stokes, D. E. (1997). *Pasteur's Quadrant: Basic Science and Technological Innovation.* Washington, D.C.: Brookings Institution Press.

Sullivan, P. H. (2000). *Value-Driven Intellectual Capital: How to Convert Intangible Corporate Assets into Market Value.* New York: John Wiley & Sons.

Sveiby, K. E. (1997a) 'The Intangible Asset Monitor', *Journal of Human Resource Costing and Accounting*, **2** (1): 73-97.

Sveiby, K. E. (1997b). *The New Organizational Wealth: Managing and Measuring Knowledge-Based Assets.* San Francisco: Berrett-Koehler.

Teece, D. J. (1981) 'The Market for Know-How and the Efficient International Transfer of Technology', *The Annuals of the Academy of Political and Social Science* (458): 81-96.

Teece, D. J. (1986) 'Profiting from Technological Innovation: Implications for Integration, Collaboration, Licensing and Public Policy', *Research Policy*, **15**: 285-305.

Teece, D. J. (1998) 'Capturing Value from Knowledge Assets: The New Economy, Markets for Know-How, and Intangible Assets', *California Management Review*, **40** (3): 55-79.

Teece, D. J. (2000). *Managing Intellectual Capital: Organizational, Strategic, and Policy Dimensions.* Oxford: Oxford University Press.

Teece, D. J. and G. Pisano (1994) 'The Dynamic Capabilities of Firms: An Introduction', *Industrial and Corporate Change*, **3** (3): 537-555.

Teece, D. J., G. Pisano and A. Shuen (1997) 'Dynamic Capabilities and Strategic Management', *Strategic Management Journal*, **18**: 509-533.

Tsang, E., W.K. (2000) 'Transaction Cost and Resource-Based Explanations of Joint Ventures: A Comparison and Synthesis', *Organization Studies*, **21** (1): 215-242.

Vanhaverbeke, W., B. Beerkens and G. Duysters (2003). Explorative and Exploitative Learning Strategies in Technology-Based Alliance Networks. Eindhoven, Eindhoven Centre for Innovation Studies, Department of Technology Management, Eindhoven University of Technology.

Verspagen, B. (2003) 'Intellectual Property Rights in the World Economy'. In: Granstrand, O. (ed.), *Economics, Law and Intellectual Property.* Dordrecht: Kluwer Academic Publishers.

Verspagen, B. and G. Duysters (2004) 'The Small Worlds of Strategic Technology Alliances', *Technovation*, **24**: 563-571.

von Hippel, E. (1988). *The Sources of Innovation.* New York: Oxford University Press.

von Hippel, E. (forthcoming). *Democratizing Innovation.* Cambridge, MA: MIT Press.

von Hippel, E. and G. von Krogh (2003) 'Open Source Software and the "Private-Collective" Innovation Model: Issues for Organization Science', *Organization Science*, **14** (2): 209-223.

Wernerfelt, B. (1984) 'A Resource-Based View of the Firm', *Strategic Management Journal*, **5**: 171-180.

Williamson, O. E. (1975a) 'The Economics of Governance: Framework and Implications', *Journal of Theoretical Economics*, **140**: 195-223.

Williamson, O. E. (1975b). *Markets and Hierarchies: Analysis and Antitrust Implications*. New York: Free Press.

Williamson, O. E. (1981) 'The Economics of Organizations: The Transaction Cost Approach', *American Journal of Sociology*, **87** (3): 548-577.

Williamson, O. E. (1985). *The Economic Institutions of Capitalism: Firms, Markets, Relational Contracting*. New York: Free Press.

Williamson, O. E. (1991a) 'Comparative Economic Organization - the Analysis of Discrete Structural Alternatives', *Administrative Science Quarterly*, **36** (4): 269-296.

Williamson, O. E. (1991b) 'Strategizing, Economizing, and Economic Organization', *Strategic Management Journal*, **12**: 95-74.

Williamson, O. E. (1996). *The Mechanisms of Governance*. New York: Oxford University Press.

Williamson, O. E. (1999) 'Strategy Research: Governance and Competence Perspectives', *Strategic Management Journal*, **20**: 1087-1108.

Winter, S. G. (1987) 'Knowledge and Competence as Strategic Assets'. In: Teece, D. J. (ed.), *The Competitive Challenge: Strategies for Industrial Innovation and Renewal*. Cambridge, MA: Ballinger: 159-184.

Winter, S. G. (2003) 'Understanding Dynamic Capabilities', *Strategic Management Journal*, **24** (10): 991-995.

WIPO (2001). *Wipo Intellectual Property Handbook: Policy, Law and Use*. Geneva: World Intellectual Property Organization.

Yin, R. K. (2003). *Case Study Research: Design and Methods*. Thousand Oaks: Sage Publications.

Zollo, M. and S. G. Winter (2002) 'Deliberate Learning and the Evolution of Dynamic Capabilities', *Organization Science*, **13**: 339-351.

Appendix A: Semi-Structured Interviews

Overview of semi-structured interviews, conducted at an early stage of the study.

Firm	Country	Interviewee	Function of interviewee	Date of Interview
ASML	Netherlands	Judon Stoeldraijer	Project leader some of the R&D collaborations	4 March 2004
Lionix	Netherlands	Rene Heideman	Technical director and co-founder; project leader of R&D collaboration	11 March 2004
Philips	Netherlands	John Bell	Corporate alliance manager	28 January 2004
ABB	Sweden	Thomas Edström	Project leader of some of the collaborations with universities	11 March 2004
Acreo	Sweden	Walter Margulis	Senior scientist; project leader of R&D collaboration	23 March 2004
Eka Chemicals	Sweden	Maria Norell	Intellectual property manager	10 March 2004
Ericsson	Sweden	Tage Lövgren	Responsible for consortium agreements in FP6[97] and other collaborations at the licensing and patent development department	26 March 2004
Volvo	Sweden	Håkan Löfgren	Research coordinator	29 March 2004

Note: All interviews were conducted by phone, except for the one with Maria Norell, which was conducted at Chalmers University of Technology in Gothenburg, Sweden. The interviews took approximately one hour (on average).

[97] Sixth Framework Programme of the European Commission.

Appendix B: Case Study Interviews

This table gives an overview of the different case studies that were conducted for this study. It gives the name and country of the firm, the name of the interviewee and his/her function within both the firm and the collaboration, and the date and location of the interview. The interview took on average between two and three hours.

Firm	Name of interviewee	Function within firm	Name and function of interviewee	Date and location interview
Akzo-Nobel, Netherlands	Jan Many, Ph.D.	Venture leader innovation unit	Project leader of collaboration	10 August 2004 Arnhem, Netherlands
KPN (later: TNO), Netherlands	Erik Fledderus, Ph.D., Prof.	Senior Strategist	Project leader of collaboration	12 August 2004 Eindhoven, Netherlands
Lionix, Netherlands	Rene Heideman, Ph.D.	Chief Technical Officer	Technical manager of collaboration	20 October 2004 Phone interview
Philips, Netherlands	Ronald Tol, Ph.D.	Technology manager	Project leader of collaboration	11 August 2004 Eindhoven, Netherlands
Array, Sweden	Ove Larson, M.Sc.	(Ex-) President	Top-management involvement	11 November 2004 Gothenburg, Sweden
Eka Chemicals, Sweden	Inger Jansson, Ph.D.	Head and R&D manager of the Colloidal Silica group	Member of collaboration's steering group	9 September 2004 Gothenburg, Sweden
Ericsson, Sweden	Henrik Abramowicz, M.Sc	Director Beyond 3G, IP Networks	IP Networks Project coordinator of collaboration	11 October 2004 Stockholm, Sweden
Telia, Sweden	Johan Boye, Ph.D.	Researcher Voice Technologies[98]	Representative of Telia	11 October 2004 Stockholm, Sweden

98 At the R&D department of TeliaSonera, Sweden.

Appendix C: Case Study Protocol

Part 1: Background and characteristics of the collaboration.

- Can you give an overview of the collaboration in question; i.e. can you tell in your own words about the drivers, the main features and the functioning of the collaboration? For example:
    - Environmental (market) dimensions, such as the sector setting, needs and uncertainty.
    - Main motives to establish this collaboration.
    - Duration, number of partners, etc.
    - Research (exploration) and/or Development (exploitation).

Part 2: Characteristics of your firm in relation to the partners.

- What can you say about the collaborating partners and your relation to them?
    - Reasons for the choice of these partners.
    - Relation to partners in the value chain (e.g. horizontal or vertical).
    - Relational characteristics, such as geographical and technological distance, commitment, trust, frequency of collaboration.
    - Complementarity of resources (i.e. knowledge).

Part 3: Appropriability of partner's resources (i.e. knowledge).

- How was the sharing of knowledge established?
    - Ease to use the partner's resources, i.e. knowledge.
    - Embodiment of the knowledge, i.e. IPR, technology, people, routines (rules/instructions/culture).
    - Characteristics of the resources (i.e. knowledge), such as complexity, imitability, teachability, newness.
    - Agreements in relation to the sharing of different kinds of knowledge (e.g. accessibility to knowledge during and after the collaboration).
    - Role of intellectual property rights (e.g. patents and trade secrets) in different stages of the collaboration.
    - Influence of external processes, such as standardization and competition law.

This protocol was sent to the interviewees before the interview was conducted, as well as a short abstract of the study and the goal of the interview. In addition to this protocol, other material was used during the interview, most particularly the framework given Figure 20. To be sure, this scheme was used as a guideline to (semi-) structure the interview.