R&D Cooperation - Propensity to Cooperate and to Succeed

Study of Austrian, German and Swiss High-Technology Firms from an Absorptive Capacity Perspective.

Dissertation

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Abstract

In the past ten to twenty years it has become popular in the research-intense high-technology industries to bundle R&D effort by undertaking R&D in cooperations. Firms conducting R&D in cooperations gain access to external knowledge. In order to successfully explore and exploit external knowledge, absorptive capacity is considered to be an essential factor. Previous studies have researched the effects of absorptive capacity in the field of R&D cooperations mainly at firm-level, and thus provided implications for policy makers. Little attention has been paid to studies at project-level that allow understanding the absorption mechanisms at the project-level.

This study aims at closing this gap and, therefore, focuses on two aspects of R&D cooperation management at project-level: (1) formation and initiation of R&D cooperations and (2) explaining the success determinants of an established R&D cooperation. First, the results show that companies with a higher scientific linkage have a higher propensity to be engaged in R&D cooperations. Second, the results clearly indicate that an R&D cooperation is more successful if (a) a firm was previously engaged in cooperations and (b) did not formalize this experience too strictly into rules and procedures thus minimizing bureaucratic efforts in the cooperation. The results furthermore show that (c) a commitment to good project management increases the propensity for a successful R&D cooperation.

This study was conducted by means of a standardized online questionnaire. The results were obtained through a regression analysis including the responses of 81 R&D managers from Austrian, German and Swiss high-technology firms.

Kurzfassung

In den letzten beiden Jahrzehnten haben F&E-Kooperationen speziell in der forschungsintensiven Hoch-Technologie-Industrie an Bedeutung gewonnen. Die Teilnahme an F&E-Kooperationen erlaubt es Unternehmen, externes Wissen in den eigenen F&E-Prozess zu integrieren. Diese Integration von Wissen wird als 'absorptive capacity' bezeichnet. Der Forschungsfokus von absorptive capacity konzentrierte sich in den vergangenen Jahren hauptsächlich auf die Industrieebene, individuellen F&E-Kooperationsprojekten wurde dabei kaum Aufmerksamkeit geschenkt. Die bisherigen wissenschaftlichen Arbeiten auf diesem Gebiet lieferten daher vor allem volkswirtschaftliche Empfehlungen, jedoch keine Erkenntnisse um einzelne F&E-Kooperationsprojekte effektiver und effizienter zu steuern.

Die vorliegende Arbeit betrachtet, erstens, die Kooperationsneigung in F&E-Projekten und, zweitens, die Erfolgsaussichten von F&E-Kooperationsprojekten jeweils in Hinblick auf unternehmensspezifische Merkmale. Die Ergebnisse zeigen, dass die Kooperationsneigung mit der wissenschaftlichen Vernetzung des Unternehmens zunimmt. Die Erfolgsaussicht von F&E-Kooperationsprojekten erhöht sich wenn das Unternehmen (a) bereits Kooperationserfahrung aufweist, (b) wenn diese Kooperationserfahrung nicht zu stark in Regeln und Mechanismen verankert wurde und (c) systematisch Projekt-Management-Methoden angewendet werden.

Diese Ergebnisse wurden anhand der logistischen Regression ermittelt. Als Stichprobe diente der Rücklauf von 81 F&E Managern, welche in deutschen, österreichischen und schweizer Hoch-Technologie-Unternehmen beschäftigt sind.

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Contents

Chapter 1

Introduction

This first chapter introduces the identified research gap and the objectives of this study. Section 1.1 describes the research problem and its relevance. Section 1.2 addresses the identified gap and presents the research questions. Section 1.3 outlines the structure of this paper and the research process on which this study is based.

1.1 Research Problem and Relevancy

To stay competitive, enterprises invest money in their R&D projects to explore and exploit new knowledge leading to new products or services. Open innovation approaches state that it has become increasingly important to access external knowledge leading to better performance of a firm's own R&D activities (Chesbrough, 2003; Gassmann, 2006). A special form of sourcing external technology is cooperating on R&D (e.g. Hagedoorn and Schakenraad, 1994; Nicholls-Nixon and Woo, 2003; Bauer, Gangl and Marchner, 2008). In the past 20 years it has become popular to conduct R&D projects in cooperations (Hagedoorn, 2002). The advantages of cooperative R&D can be seen in the achieved economy of scale, shared risk of R&D, and avoidance of duplicated R&D efforts (Okamuro, 2007; Hagedoorn, 2002).

Especially in the research-intense high-technology industries it has become popular to bundle the R&D efforts, thus allowing a more efficient exploitation and exploration of new knowledge (Hagedoorn, 2002; Miotti and Sachwald, 2003; Rothaermel and Deeds, 2004). To integrate external knowledge into the internal knowledge pool it is essential that the firm has the capability to absorb this knowledge. Capabilities to absorb new knowledge are known as absorptive capacity (Cohen and Levinthal, 1990).

Previous studies operationalized the concept of absorptive capacity in the context of management of R&D cooperations mainly with R&D intensity (R&D expenditure as a proportion from sales). However, there are only few studies which operationalize absorptive capacity with non-financial measures (Lane and Lubatkin, 1998; Heimeriks and Duysters, 2007). Zahra and George (2002, p. 199) argue that "there is a clear need to capture the individual capabilities that constitute a firm's ACAP [absorptive capacity]." This study aims to fill this gap by defining absorptive capacity as a richer concept, including the findings of alliance capability and project management research.

1.2 Objectives and Addressed Research Gap

This study focuses on absorptive capacity and aims to explain (1) the difference between firms' R&D cooperation activities and (2) the likeliness of success of an R&D cooperation. The first objective of this study is to identify capabilities which determine the propensity to cooperate on R&D (see also Figure 1.1 for an illustration).

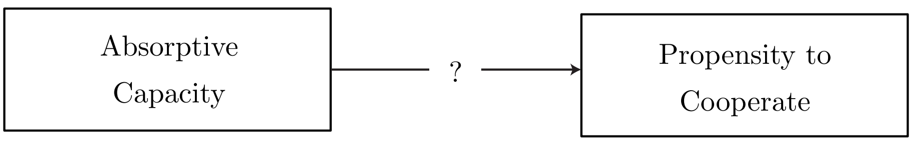

Figure 1.1: Research Question 1

In the existing literature some studies explain the propensity to cooperate with function specific indicators, such as the existence of an alliance function (e.g. Kale, Dyer and Singh, 2002), an R&D department (e.g. Miotti and Sachwald, 2003; Zhang, Baden-Fuller and Mangematin, 2007) or a gatekeeper (e.g. Fritsch and Lukas, 2001). However, little attention has been paid beyond the scope of the function specific indicators, e.g. by focusing on the processes and routines which are covered by these functions. Kale and Singh (2009) demonstrate that in addition to a dedicated alliance function the absorption of knowledge is further improved with codified tools to manage cooperations.

The two function specific indicators existing R&D department and gatekeeper focus on the capability to relate external knowledge to one's own knowledge base. Firms which systematically search for external knowledge sources (e.g. publications) are considered to have a higher scientific linkage and, hence, are more likely to identify external knowledge which could be useful for creating new opportunities in the R&D process (e.g. Fontana, Geuna and Matt, 2006). This study integrated these process oriented aspects into the absorptive capacity view and seeks to answer the following question (**Research Question 1**):

> *To what extent does absorptive capacity influence the propensity to engage in R&D cooperations?*

The second objective of this paper is to identify capabilities which determine the likeliness of success in an R&D cooperation. See also Figure 1.2 for an illustration of the second objective.

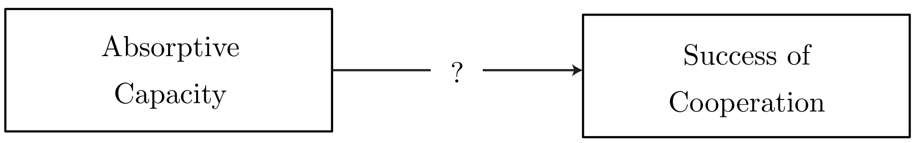

Figure 1.2: Research Question 2

According to Tsai (2009), little research has been conducted discussing absorptive capacity and innovation performance in the field of cooperation activities. However, there is some literature that explains innovation performance from an alliance capability perspective. A study conducted by Rothaermel and Deeds (2006) investigates alliance capabilities, indicating that alliance capability has a positive impact on the new product development process. Alliance capability studies (Kale et al., 2002; Rothaermel and Deeds, 2006; Rothaermel and Boeker, 2008) focus on firm-level data but lack understanding at project-level. Only few studies have been carried out to measure the success of R&D cooperations at project-level and to explain it from a capability perspective (Curran, Niedergassel, Picker and Leker, 2009). Furthermore, Kale and Singh (2009) argue that project management capabilities are required in the post-formation phase of a cooperation in order to allow for successful cooperations. Research suggests that project management capabilities also influence the absorption mechanism of a firm (Jugdev and Mathur, 2006; Curran et al., 2009); hence they are included in this study.

To sum up, this study investigates the success of R&D cooperations from an absorptive capacity perspective including previous research on (a) scientific linkage, (b) alliance capability and (c) project management. Thus, **Research Question 2** is proposed:

> *To what extent does absorptive capacity influence the success of R&D cooperation projects?*

1.3 Document Structure

The structure of this document follows the research process illustrated in Figure 1.3. The above stated research questions were derived from an extensive literature review.

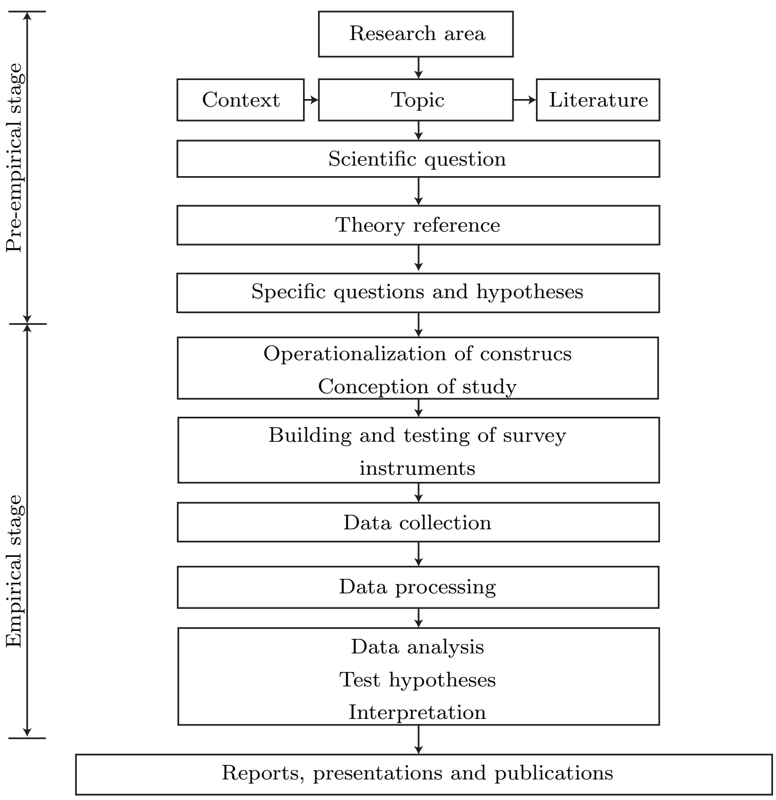

Figure 1.3: Followed research process of this work, derived from Punch (2005, p. 40). Adapted illustration taken from Kohlbacher (2009, p. 5)

This work is embedded in the broader field of strategic management. Chapter 2 therefore discusses strategic management theories which are used to explain the management of R&D cooperations. The management of R&D cooperation is investigated from an absorptive capacity perspective. The concept of absorptive capacity is discussed in Chapter 2 and is related to the recently developed concept of open innovation. Additionally, Chapter 2 discusses key concepts of R&D and innovation management.

Chapter 3 reviews previously conducted studies in the field of R&D cooperation management which research (a) the propensity to cooperate on R&D and (b) the likeliness of success in an R&D cooperation. In addition, hypotheses are derived according to the research questions and the identified gaps in literature. The formulated hypotheses are operationalized and tested in an empirical study. The operationalization of the variables and the process of data collection are discussed in Chapter 4. Furthermore, Chapter 4 discusses the process of data collection.

Chapter 5 shows how the data was processed and presents the results of the empirical study including the hypotheses tests. Chapter 6 concludes this paper with a summary of the conducted study, shows its limitations and suggests avenues for further research.

Chapter 2

Literature Review

This chapter addresses the theoretical framework of this study. Strategic management theories are discussed in Section 2.1 focusing on theories which explain cooperation management. A special emphasis is put on the resource-based view in which this study is embedded. Additionally, Section 2.1 discusses theories used to explain the management of R&D cooperations. In Section 2.2 basic terms of the R&D and innovation process will be defined. The concept of open innovation will be discussed in Section 2.3. Section 2.4 focuses on absorptive capacity. Section 2.5 combines the concept of open innovation with the concept of absorptive capacity.

2.1 Strategic Management Theories

This study focuses on absorptive capacity in the context of R&D cooperation management. The analysis of capabilities is embedded in the resource-based view. Therefore, in Section 2.1.1 and Section 2.1.2 the resource-based view and the theory of dynamic capabilities will be discussed consecutively. Other theories also used to explain the management of R&D cooperations are addressed in Section 2.1.3 (industrial organization) and Section 2.1.4 (transaction cost economics). The latter two theories focus on the external perspective of the firm.

2.1.1 Resource-based View

Edith Penrose was the first who discussed the concept of resources in the late 1960s[1] (Penrose, 1959, p. 24) (Carpenter, 2008, pp. 96). “Firms differ in fundamental ways because each firm possesses a unique set of resources” (Collis, 2004, p. 30). Most researchers focus on the external influences explaining the competitive advantage[2] of a firm (Porter, 1980; Porter, 1985; Barney, 1991). For the analysis of factors external to the firm Porter (1980) developed the five-forces and the generic strategy framework. These frameworks focus on the external environment with the steps (a) scanning this external environment systematically, (b) choosing a strategy[3] and (c) acquiring relevant resources to create or sustain competitive advantage over competitors (Porter, 1980). Porter’s frameworks implicitly assume homogeneity in the distribution of strategic resources within an industry. Furthermore, it is implicitly assumed that if there is an unequal balance of resources in an industry then this imbalance will be “very short lived because the resources [. . .] are highly mobile [. . . and . . .] can be bought and sold in factor markets” (Barney, 1991, p. 100).

Barney (1991), on the other hand, argues that the two assumptions about resources (homogeneity and short-lived imbalance) are invalid due to not perfectly mobile resources. Furthermore, he notes that the strategic resources can be distributed heterogeneously within an industry, and that this heterogeneity can last long (Wernerfelt, 1984; Barney, 1991). These two assumptions lead to the framework of the resource-based view, defining certain resources as a source of sustained competitive advantage leading to above average rents (Barney, 1991).

[1] The influence of Edith Penrose’s work is seen differently among scholars. Some view it as little. For a discussion see also Rugman and Verbeke (2002).

[2] Competitive advantage is defined by Carpenter (2008, p. 34): “A firm’s ability to create value in a way that its rivals cannot.” The essential question in strategic management is how firms gain and sustain a competitive advantage over other firms (Teece, Pisano and Shuen, 1997). For a review see also Rumelt, Schendel and Teece (1994).

[3] Ansoff (1976) sees the way to reach a goal as strategy, whereas Chandler (1963) sees the goal itself and the way to reach the goal as strategy. For a discussion if only the ’means’ (way) or the ’means and ends’ (way and goal) are considered to be strategy see also Venkatraman (1989). In the remainder of this work strategy is seen as ’means’ (way) as used by Ansoff (1976) and Venkatraman (1989).

Definition of Resources and Capabilities

"By a resource is meant anything which could be thought of as a strength or weakness of a given firm. More formally, a firm's resources at a given time could be defined as those (tangible and intangible) assets which are tied semipermanently to the firm" (Wernerfelt, 1984, p. 172). However, Barney (1991, p. 101) defines resources in more depth as "all assets, capabilities, organizational processes, firm attributes, information, knowledge, etc. controlled by a firm that enable the firm to conceive of and implement strategies that improve its efficiency and effectiveness [. . .]". Example of resources can be financial or physical assets (e.g. property, plant and equipment; physical technology used in a firm), human (e.g. training; experience), or organizational (e.g. informal and formal planning; coordinating system) (Barney, 1991; Amit and Schoemaker, 1993).

Amit and Schoemaker (1993) distinguish between resources and capabilities. Resources are tradable and non-specific to firms. Capabilities, on the other hand, deploy resources and improve their productivity. Capabilities are specific to firms, either tangible or intangible but not tradable, e.g. the knowledge transfer in the firm. This view and categorization is widely adopted in the resource-based theory (Amit and Schoemaker, 1993; Teece et al., 1997; Makadok, 2001; Winter, 2003; Hoopes, Madsen and Walker, 2003).

For example, the Intel Corporation holds patents for their microprocessors. These patents are considered a strategic resource. This resource can be traded and sold to other companies. However, the ability to develop new generations of microprocessors is a capability, which cannot be traded and is, therefore, the firm's competitive advantage over competitors (Makadok, 2001). Capabilities are seen as the ability to manage resources and to utilize the full potential of a given resource (Hedman, 2002, pp. 80) (Amit and Schoemaker, 1993). Teece et al. (1997, p. 529) argue that: "Capabilities cannot easily be bought; they must be built."

Capabilities originate from the accumulated experience in a firm, which is transferred into mechanisms and, furthermore, into codified routines. The mechanisms and the routines are seen as capabilities (Zollo and Winter, 2002). The developed capabilities then influence the performance of the firm[4] (Heimeriks and Duys-

[4]Heimeriks and Duysters (2007) showed a correlation for alliance capabilities and alliance performance.

ters, 2007). See Figure 2.1 for an illustration.

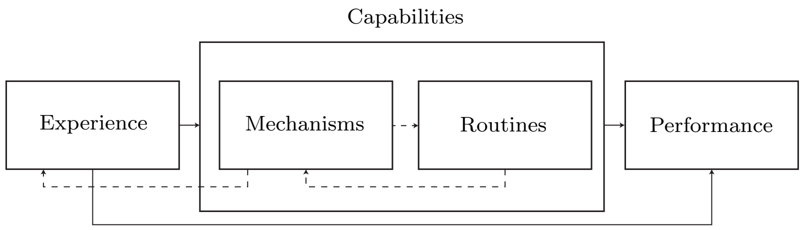

Figure 2.1: Capability development process (Heimeriks and Duysters, 2007, p. 28)

2.1.2 Dynamic Capabilities

The resource-based view is a rather static view of the firm, where a competitive advantage is identified with a set of resources or capabilities. The concept of dynamic capabilities reacts to a dynamic market environment (Eisenhardt and Martin, 2000), where it is necessary to adapt or generate new resources or capabilities to stay competitive[5]. The dynamic capability view combines the resource-based view with the learning perspective in a firm (Coombs and Bierly, 2006). The competitive advantage is seen in the dynamic capability perspective in specific and identifiable processes (e.g. product development, alliance management, project management) (Teece et al., 1997; Eisenhardt and Martin, 2000). Teece et al. (1997, p. 516) define dynamic capabilities as "the firm's ability to integrate, build, and reconfigure internal and external competences to address rapidly changing environments." The competitive advantage of the firm lies not in the capabilities itself, but in the way capabilities recreate and configure resources (Eisenhardt and Martin, 2000). Dynamic capabilities are seen – in contrast to other resources - as homogeneous in an industry and can be duplicated. Nevertheless, the creation and the characteristics of the dynamic capabilities are specific to each firm and depend strongly on their evolutionary path. However, similarities exist across firms, which can be extracted and seen as best practice for a specific industry (Eisenhardt and Martin, 2000). More precisely, the "dynamic capabilities can be duplicated across firms, their value for competitive advantage lies in the resource configurations that they create, not

[5]R&D cooperations are seen as one way to generate new resources or capabilities in a firm (Hagedoorn, Link and Vonortas, 2000; Heimeriks and Duysters, 2007).

in the capabilities themselves" (Eisenhardt and Martin, 2000, p. 1117). However, a "long-term competitive advantage is infrequently achieved in dynamic markets" (Eisenhardt and Martin, 2000, p. 1117) and requires a continuous improvement of a firm's own dynamic capabilities to stay competitive (Teece et al., 1997).

This study aims to identify best practices in successful firms which can be developed by competing firms to achieve competitive parity. These capabilities also belong to the learning mechanisms of the firm enhancing its absorptive capacity. The concept of absorptive capacity is discussed in Section 2.4. This study is embedded in the resource-based view and the dynamic capability theory.

2.1.3 Industrial Organization

The theoretical framework of industrial organization looks at a specific industry and seeks to answer the question how firms interact with each other in this industry. The industrial organization theory is part of microeconomics[6]. According to the industrial organization theory firms within the same industry compete with similar products on a given market and, therefore, compete for the same customer. Product differentiation allows a firm to attract specific customers in the market. If the product differentiation is patent protected then competitors can even be locked out of the market. Game theory models are used to model the behavior of firms distinguishing two types of models: (1) tournament models and (2) non-tournament models (Shy, 1996, pp. 11) (Cabral, 2000, pp. 3).

First, tournament models look at the timing when the innovation was created and patented. The patent allows the winner of the patent race to produce and sell the product monopolistically, thus creating monopolistic returns for the winner (winner takes it all). The tournament models investigate the number of firms which enter the race and how the total R&D expenditures are distributed among the firms. In the case of cooperation the risks of R&D are pooled among the cooperating firms and the R&D costs are shared.

Second, in the case of non-tournament models a patent is not considered to

[6]However, it is debatable whether industrial organization falls within the category of strategic management. Hagedoorn et al. (2000, p. 570) argue that "industrial organization approaches have undoubtedly drawn on strategic management." Following this argumentation, the section of industrial organization is placed within the section of the strategic management theories.

bring monopolistic returns to the patenting firm. Firms are aiming for incremental improvements of the products or trying to achieve a cost reduction. The focus of non-tournament models lies on the maximization of the return for the whole industry[7] (Shy, 1996, pp. 11) (Cabral, 2000, pp. 3) (Hagedoorn et al., 2000). "The expectation of market failure has driven the analyses, and it is reflected in under-investment and duplication of non-cooperative R&D effort in non-tournament models and the over-investment in R&D in tournament models" (Hagedoorn et al., 2000, p. 573). It has been empirically proven that firms in industries with high spillover are more likely to engage in R&D cooperations than in industries with low spillover. However, in the case of high spillover it is still necessary to invest in own R&D capacity allowing the absorption of external knowledge, i.e. absorptive capacity (e.g. Cohen and Levinthal, 1990; Veugelers, 1997). The issue of absorptive capacity will be further discussed in Section 2.4. This study focuses on firm capabilities and does not use the industrial organization theory as a theoretical framework.

2.1.4 Transaction Cost Economics

The origin of the transaction cost economics is contributed to the seminal articles of Coase. Coase (1937) states that market transactions are not free of charge. Firms which source external technology are required to identify potential trading partners, negotiate on a contract and agree on this contract. These costs are called transaction costs. Dahlman (1979) lists the following types of transaction costs:

1. Search and information costs.
2. Bargaining and decision costs.
3. Policing and enforcement costs.

First, search and information costs are required to identify a specific good or service which fulfills the requirements of the buyer. Travel or consulting costs are examples for the first cost type. Second, bargaining and decision costs imply the cost to agree on a price and on a contract. The first two types of costs are called ex-ante costs, since these costs occur before a contract is signed. Third, policing and enforcement costs are called ex-post costs because these costs occur after the

[7] In the tournament model the return of the winner equals the return of the industry.

contract was signed. This cost type includes the costs to fulfill the contract and also includes the costs of appropriate measures (e.g. at court) if the contract is not fulfilled (Dahlman, 1979) (Picot, Reichwald and Wigand, 2001, pp. 50).

Williamson developed the framework of transaction cost economics further. He states that the costs of the transaction depend on the following items (Williamson, 1981): (a) frequency, (b) specificity, (c) uncertainty, (d) limited rationality and (e) opportunistic behavior.

The specificity influences the transaction costs concerning the organizational form of the transactions. Two extreme positions exist considering the specificity and the transaction costs: (1) build the technology within the firm or (2) source the technology externally (see also Figure 2.2 for an illustration). In additon to these extreme positions there is also (3) a hybrid form where the technology is developed in a cooperation.

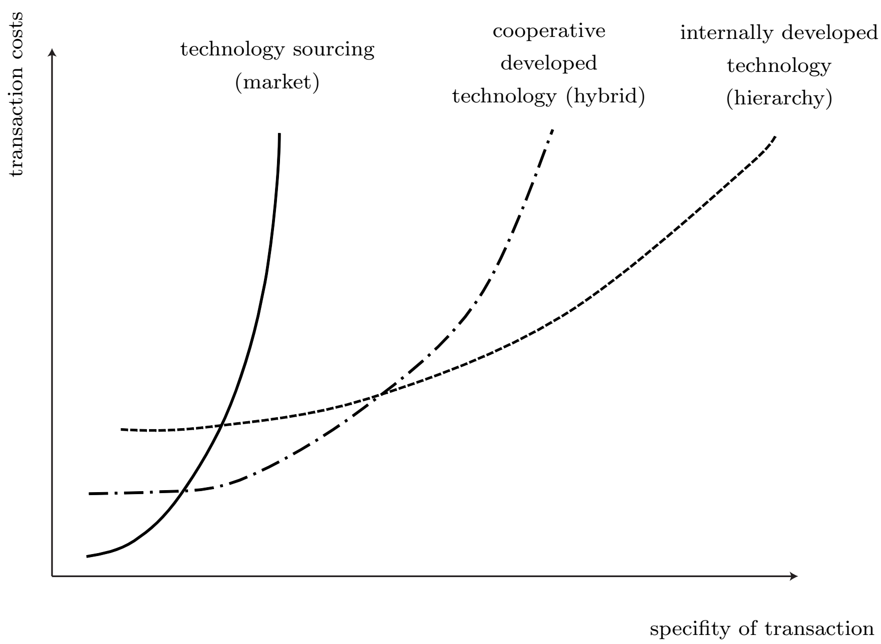

Figure 2.2: The influence of factor specificity on the transaction costs. Translated from Picot et al. (2001, p. 55)

First, a high range of specificity can be covered in the case of technology developed inside the firm (hierarchy[8]). Compared to the other two forms this allows

[8]The term is derived from the hierarchical organization structure in a firm.

the highest specificity and lowest transaction cost. Transaction costs in this case are the coordination costs within the firm. Second, the transaction costs get rather high in areas of low specificity in the case of external technology sourcing. However, the transaction costs can be lower than in the case of internal development due to the expertise of the supplier in this field (Picot et al., 2001, pp. 54). Third, the hybrid case describes lower transaction costs in areas of low specificity compared to the hierarchy case. However, with an increase of specificity the transaction costs will get higher as in the hierarchy case. “Transaction costs increase steeply when contracts are incomplete, that is, when they do not fully specify the actions of each party in every contingency” (Hagedoorn et al., 2000, p. 571). Especially in the case of R&D cooperations not every detail can be listed in the contract due to the uncertainty character of research. Therefore, only few studies exist which use the transaction cost economics to explain R&D cooperations (Hagedoorn et al., 2000; Lai and Chang, 2010). The study of Lai and Chang (2010) is an exception. Their study uses the transaction cost perspective to explain equity based joint ventures, which are seen as a special case of hierarchical technology development. Therefore, this study does not use the transaction cost model as a theoretical framework.

2.2 R&D and Innovation Management

The following two sections provide a definition for the term 'research and experimental development'. Furthermore, the innovation process and its evolution is discussed.

2.2.1 Research and Experimental Development

The most widely adopted definition of research and experimental development is the one from OECD's Frascati manual. The most recent version of this manual is from 2002 and has seen three revisions since the first version from 1963 (Howells, 2008). In order to be consistent with the research in this field, this paper follows the definition of OECD (2002, p. 30)[9]:

> Research and experimental development (R&D) comprise creative work

[9]For an overview of other definitions of R&D see, for example, Brockhoff (1992)

> undertaken on a systematic basis in order to increase the stock of knowledge, including knowledge of man, culture and society, and the use of this stock of knowledge to devise new applications.

The OECD, furthermore, categorizes the research and experimental development into three categories:

1. Basic research
2. Applied research
3. Experimental development

First, "basic research is experimental or theoretical work undertaken primarily to acquire new knowledge of the underlying foundation of phenomena and observable facts, without any particular application or use in view" (OECD, 2002, p. 30). Second, "applied research is also original investigation undertaken in order to acquire new knowledge. It is, however, directed primarily towards a specific practical aim or objective " (OECD, 2002, p. 30). Third, "experimental development is systematic work, drawing on existing knowledge gained from research and/or practical experience, which is directed to producing new materials, products or devices, to installing new processes, systems and services, or to improving substantially those already produced or installed " (OECD, 2002, p. 30).

The goal of the OECD Frascati manual is to make R&D expenditures comparable among different firms and in particular among different countries. Therefore, a clear separation of R&D activities from related activities is presented. "The basic criterion for distinguishing R&D from related activities is the presence in R&D of an appreciable element of novelty and the resolution of scientific and/or technological uncertainty, i.e. when the solution to a problem is not readily apparent to someone familiar with the basic stock of common knowledge and techniques for the area concerned"(OECD, 2002, p. 34). Table 2.1 lists an overview of activities which fall into the category of R&D and which are included and which need to be excluded.

2.2.2 Evolution of the Innovation Process

The main objectives of an R&D process is to generate new knowledge by spending money on ideas. If the new knowledge can be patented then a new invention has been

Item	Treatment	Remarks
Prototypes	Include in R&D	As long as the primary objective is to make further improvements.
Pilot plant	Include in R&D	As long as the primary purpose is R&D.
Industrial design and drawing	Divide	Include design required during R&D. Exclude design for production process.
Industrial engineering and tooling up	Divide	Include "feedback" R&D and tooling up industrial engineering associated with development of new products and new processes. Exclude for production processes.
Trial production	Divide	Include if production implies full-scale testing and subsequent further design and engineering. Exclude all other associated activities.
After-sales service and trouble-shooting	Exclude	Except "feedback" R&D.
Patent and license work	Exclude	All administrative and legal work connected with patents and licenses (except patent work directly connected with R&D projects).
Routine tests	Exclude	Even if undertaken by R&D staff.
Data collection	Exclude	Except when an integral part of R&D.
Public inspection control, enforcement of standards, regulations	Exclude	

Table 2.1: Classification of R&D and non-R&D activities OECD (2002, p. 41)

made. Joseph A. Schumpeter sees the invention as the first step in his innovation triplet, which comprises (1) invention, (2) innovation and (3) diffusion (Wohinz, 2003, pp. 107).

Ad (2), innovation is the economic application of inventions thus bringing monetary returns to the company by introducing, for example, new products to the market. However, not every output from the R&D process can be patented but still can create innovative opportunities. This innovative opportunity can be: process innovation, social innovation, business model innovation, etc. Ad (3), the diffusion step in Schumpeter's triplet is when the new knowledge spreads across the intended markets (Brockhoff, 1992, pp. 28) (Wohinz, 2003, pp. 107).

Rothwell (1994) and Nobelius (2004) describe the evolution of the innovation process in their papers. Rothwell (1994) identified five generations of innovation processes. The first generation started in the 1950s and ended in the mid-1960s. This generation was characterized by rapid industrial growth allowing to sell products easily on the market. An increase in R&D spendings showed a direct link to the output of the innovation process resulting in successful products (technology-push). However, in the mid 1960s there was a higher competition on the market and not every product found a customer. Therefore, it was necessary to focus on the customer, which led to the second-generation of the innovation process. In this generation, ideas generated after an extensive market research were transfered into products (market-pull). This phase lasted till the early-70s. The third-generation of innovation management (early 1970s - mid 1980s) combined both models. The idea generation looked at the market needs (market-pull) and, additionally, ideas from the research department were used to generate new technology (technology-push) thus leading to new products or services (Rothwell, 1994; Nobelius, 2004). The idea generation is seen as the central part of the innovation process. Thom (1992) introduced a framework which describes the idea generation and realization process (see Figure 2.3).

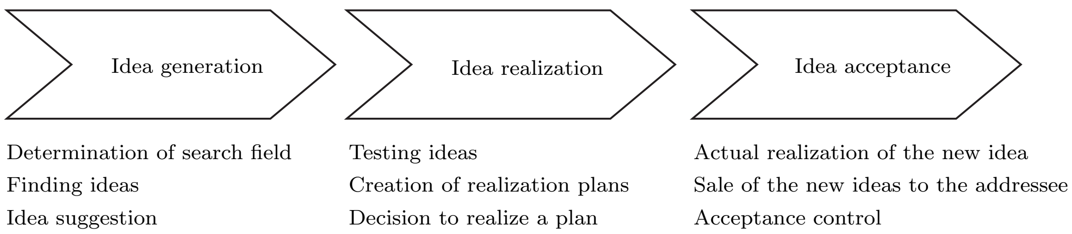

Figure 2.3: Innovation process Thom (1992, p. 53). Translation by Brem (2008, p. 76)

The idea generation activity can also cover various departments in the firm to reach a higher quantity and acceptance of the generated ideas. The integration of various departments characterizes the fourth-generation innovation process (early 1980s - early 1990s). The marketing department starts to identify or to develop a market need according to the market-pull strategy. Parallel to this activity the R&D department starts to work on the generated ideas and integrates the product development department into the project at an early stage. To allow an early market launch, suppliers and the manufacturing departments are integrated in the innovation process. The integration of partners external to the firm (suppliers) in the innovation progress enabled a higher pace in the development process (Rothwell, 1994; Nobelius, 2004). Furthermore, Rothwell (1994) proposed the fifth-innovation process; i.e. that knowledge external to the firm is “a significant factor in successful innovation.” Christensen (2006, p. 40) sees the description of the fifth-innovation process as one of the cornerstones of open innovation together with the concept of absorptive capacity. The concept of open innovation is discussed in the next section, the concept of absorptive capacity in Section 2.4.

2.3 Open Innovation

The concept of open innovation was brought to a broader audience by Chesbrough with his seminal book on open innovation in 2003. The open innovation approach of Chesbrough consists of two elements: (1) inbound innovation and (2) outbound innovation.

First, according to the open innovation approach, not only ideas created within a company should be used in the innovation process but also ideas external to the firm. Second, technology which is not used in a company should be externalized. This externalization allows firms to earn royalties for technology which is licensed to other firms. “Open innovation is the use of purposive inflows and outflows of knowledge to accelerate internal innovation, and expand the markets for external use of innovation, respectively. Open innovation is a paradigm that assumes that firms can and should use external ideas as well as internal ideas, and internal and external paths to market, as they look to advance their technology” (Chesbrough and Crowther, 2006, p. 1). Chesbrough (2003) speaks of inbound innovation if external ideas and external technology is integrated into the knowledge stock of a firm. Externalizing knowledge is termed outbound innovation (Chesbrough, 2003). Gassmann and Enkel (2006) introduce a third category[10] (coupled process), which explicitly represents the collaboration activities between two firms where new knowledge is

[10]Gassmann and Enkel (2006) use the term ’outside-in’ process for inbound innovation and the term ’inside-out’ process for outbound innovation.

created together.

Figure 2.4 illustrates the original concept of Chesbrough, where the traditional innovation process can be seen as funnel. In closed innovation environments, research projects are initiated from the own technology base, promising projects are put forward stepwise until they either can be transferred into the development phase or have to be canceled.

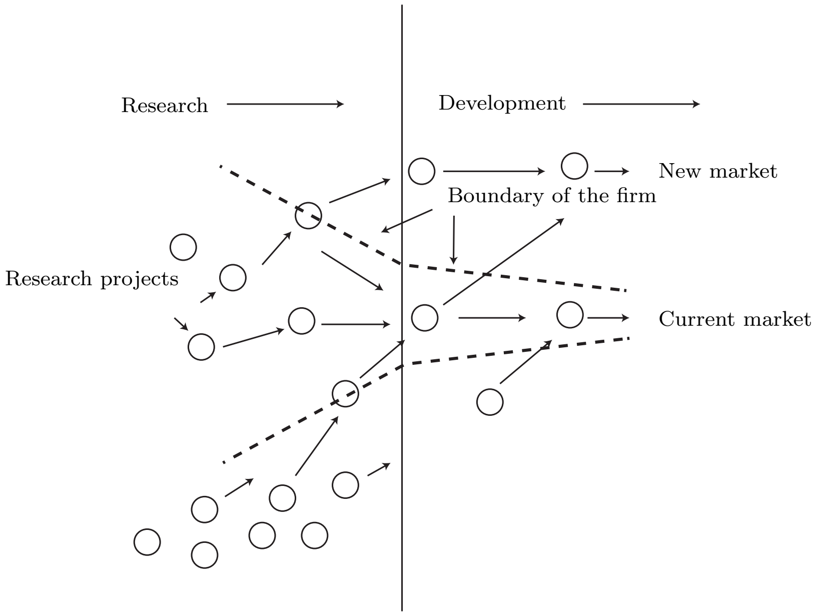

Figure 2.4: Concept of open innovation, illustrated by Chesbrough (2003, p. xxv)

However, in an open innovation environment the funnel is considered permeable and thus enabling inbound and outbound innovation. In the case of inbound innovations technology is not only used from the own technology base, but also by scanning and including external technology bases (e.g. through collaboration with other firms, universities, etc.), to start new projects. Furthermore, it is also illustrated that outside technology can be licensed to speed up the development process thus allowing faster delivery of the product/service to the current market. In the case of outbound innovations ideas not fitting the own business model are licensed to other firms. Another way of profiting from technology not fitting the own business model is by spinning-off technology into a new firm trying to establish a new market (Chesbrough, 2003; Chesbrough and Crowther, 2006).

Nevertheless, to enable open innovation it is necessary to have knowledge about the industry and the underlying science base to allow the identification of external knowledge. Therefore, it is necessary to invest in own R&D to allow the absorption of relevant external knowledge (Spithoven, Clarysse and Knockaert, 2010). The absorption of external knowledge is known in the literature as absorptive capacity and is discussed in the next section.

2.4 Absorptive Capacity

Absorptive capacity was brought to a broader audience from Cohen and Levinthal (1989) with their seminal paper describing the learning capacity of an organization. This paper founded the research stream of absorptive capacity together with the consecutive work a year later by the same authors (Cohen and Levinthal, 1990). Absorptive capacity is seen as the "ability of a firm to recognize the value of new, external information, assimilate it, and apply it to commercial ends" (Cohen and Levinthal, 1990, p. 128). Their understanding of absorptive capacity is influenced by two factors: external and internal to the firm. The external factors are discussed in Section 2.4.1 and the internal factors in Section 2.4.2. The evolution of the model is discussed in Section 2.4.3.

2.4.1 External Factors of Absorptive Capacity

Lane, Koka and Pathak (2006) identified six external factors implied in the model by Cohen and Levinthal (1989; 1990). The factors outside the firms are shown in Figure 2.5. These external factors influence the variable R&D spending, which is used as a proxy for absorptive capacity.

The first factor, scope of technological opportunities, describes the positive influence from the available knowledge base outside the firm and the technological performance. The higher the available knowledge, the easier it is to get access to this knowledge thus allowing a higher absorptive capacity. Second, a positive influence exists between the spillover in an industry and the absorptive capacity. If the spillover in an industry is high, then the propensity to protect intellectual property is low (also known as low appropriability). Therefore, the motivation to understand the knowledge in a non-protected environment is higher than in the case of a protected

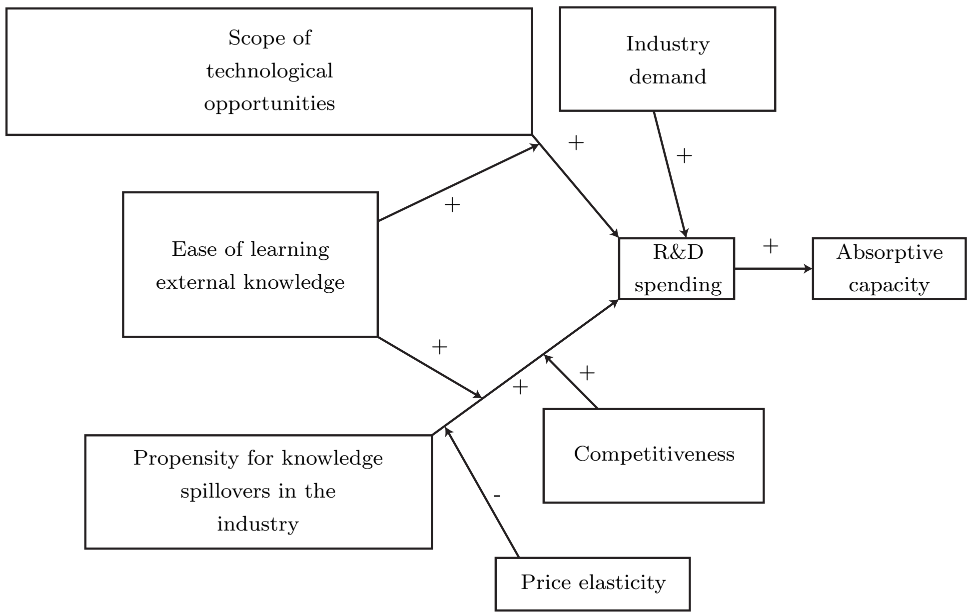

Figure 2.5: External factors of absorptive capacity implied in the model of Cohen and Levinthal (1989; 1990), illustrated by Lane et al. (2006, p. 837)

environment, which leads to higher R&D investment hence allowing better absorption of this knowledge. Third, the ease of acquiring external knowledge, mediates the effect between the two above stated factors and the absorptive capacity. This means that the ease of learning increases the effect of technological opportunities and decreases the likeliness of protection. Fourth, with a growing industry demand and a higher income elasticity the likeliness to spend more on R&D increases due to a higher motivation to invest in this growing industry segment. Fifth, another positive mediation effect is found with the competitiveness in an industry. This factor mediates between the factors spillover and R&D spending. Sixth and finally, price elasticity, mediates but negatively between spillover in an industry and the R&D spending. This means that with a growing demand the price of the goods falls and, therefore, it becomes less attractive to invest in absorptive capacity. The influence of these six factors on the absorptive capacity (operationalized with R&D spending) were tested and confirmed in an empirical study (Cohen and Levinthal, 1989; Cohen and Levinthal, 1990).

In addition to external factors of absorptive capacity Cohen and Levinthal identified firm specific internal factors of absorptive capacity, which are discussed in the next section.

2.4.2 Internal Factors of Absorptive Capacity

The internal factors influencing the absorptive capacity were introduced in the paper of Cohen and Levinthal (1990). The internal process and learning perspective of an organization represent the internal factors of absorptive capacity. Cohen and Levinthal describe absorptive capacity as a three stage process: (1) recognizing the value of new knowledge, (2) assimilating the new knowledge and (3) applying the knowledge for commercial needs leading to new innovations and higher innovative performance (see also Figure 2.6 for an illustration).

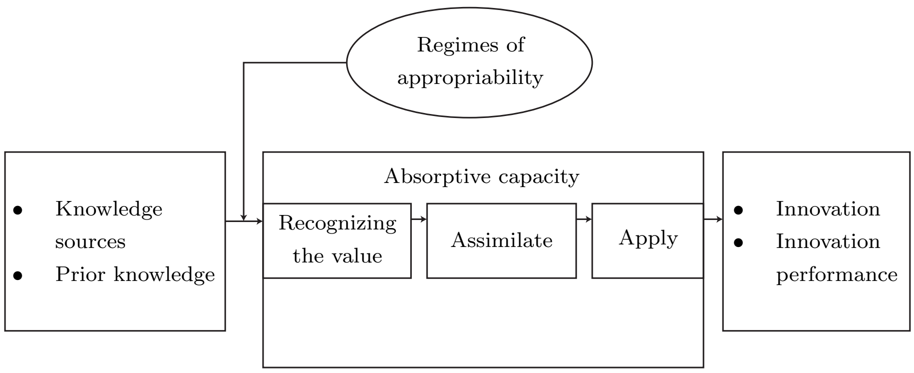

Figure 2.6: Internal factors of absorptive capacity implied in the model of Cohen and Levinthal (1989; 1990), illustrated by Todorova and Durisin (2007, p. 775)

The first factor, valuation of new knowledge is explained with the individual absorptive capacity. Each individual is more likely to accumulate new knowledge if they can relate the new knowledge to knowledge they already know. Furthermore, the acquired knowledge can be recalled easier if the new knowledge can be connected to prior knowledge. This line of reasoning applies also for the organizational absorptive capacity. New knowledge can be absorbed and valued more efficiently if a knowledge base in the firm exists where the new knowledge can be related to. "[W]ithout prior knowledge, organizations are not able to evaluate the new information and, thus, fail to absorb it" (Todorova and Durisin, 2007, p. 777). Therefore, firms invest in their R&D activities to understand new available knowledge. "[F]irms may conduct basic research less for particular results than to be able to provide themselves with the general background knowledge" (Cohen and Levinthal, 1990, p. 148) thus allowing to absorb new knowledge more efficiently (Cohen and Levinthal, 1990).

Second, the assimilation of new knowledge is the next process step after the valuation of external knowledge. Assimilation describes the process where new knowledge is embedded into the current cognitive structure of the firm by putting it in a new context in a way that the new knowledge, third, can be applied to commercial ends thus leading to better innovative performance in the firm (Cohen and Levinthal, 1990).

2.4.3 Evolution of Absorptive Capacity

The concept of absorptive capacity evolved in the past twenty years[11]. The model from Cohen and Levinthal (1989; 1990) was influenced by the Industrial Organizational literature, where it was used over the years. However, in this research stream the absorptive capacity was seen as a static resource and not as process or capability. This non-process and capability perspective is also represented in the operationalization of the construct, where absorptive capacity was measured with spendings on R&D. "R&D spending can be justified as a proxy [...], this measure is still problematic, since it treats absorptive capacity as a static resource and not as a process or capability" (Lane et al., 2006, p. 838). However, the use of this proxy stayed in line with prior industrial organization research, using static measures for process-oriented constructs (Lane et al., 2006). Therefore, the construct of absorptive capacity was further refined by different scholars and is discussed below.

Model by Van den Bosch, Volberda and de Boer (1999)

Van den Bosch et al. (1999), for example, proposed a refined conceptual framework on absorptive capacity. The concept includes the three main categories: (1) knowledge absorption, (2) organizational form, and (3) the combinative capabilities. These three categories are considered to determine the process perspective of absorptive capacity (see Figure 2.7 for an illustration of the model). First, the knowledge absorption is categorized into exploration and exploitation as discussed

[11] Lane et al. (2006) give a literature review of the used concepts and derives a reconceptualization of the absorptive capacity model.

by March (1991). Basic research, for example, has its focus on exploration of new knowledge. On the other hand, development primary focuses on the exploitation of knowledge by recombining available knowledge and by transferring it to marketability (Rothaermel and Deeds, 2004).

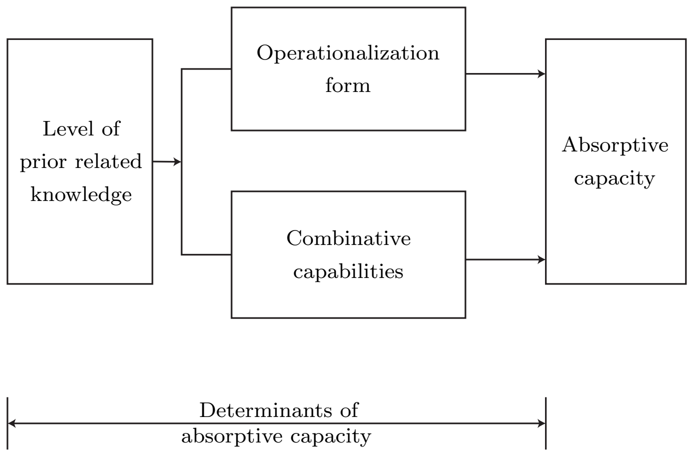

Figure 2.7: Absorptive capacity model from Van den Bosch et al. (1999, p. 554)

Second, the organizational form is essential in the perception of new knowledge. The perception of the knowledge was investigated in the organizational forms: (a) functional, (b) divisional, and (c) matrix. The matrix organizational form is considered to have a positive impact on the absorptive capacity, whereas the divisional form is considered having a moderate impact and the functional form having a negative impact on the absorptive capacity. The positive effect of the matrix organization is attributed to the interlinks in the matrix structure, which supports communication flows over functional and/or divisional boundaries. This allows an easier transfer of available information within an organization. Third, the combinative capabilities describe the combination of the absorptive capacity of individuals resulting in organizational absorptive capacity. The combinative capability consists of: (a) systems capabilities, (b) coordination capabilities, (c) socialization capabilities. Systems capability represents the degree of systematization in an organization (e.g. procedures, manuals, etc.). The higher the degree of systematization in an organization the lower the flexibility in knowledge creation becomes, thus leading to a negative influence on absorptive capacity. The coordination capability refers to the coordination effort to establish a relationship between the individual team members thus allowing a good team performance. This includes the training of the employees to gain a common understanding in project management skills, for example (Van den Bosch et al., 1999). The socialization capability shows the homogeneity in terms of culture in an organization. The more homogeneous the individuals are in an organization the lower is the absorptive capability due to shared believes, which prevent people, for example, from seeing changes in an industry and, therefore, leaving “little room for absorbing outside sources of knowledge” (Van den Bosch et al., 1999, p. 557).

Model by Zahra and George (2002)

Another model has been proposed by Zahra and George (2002). They evaluate previously conducted studies using absorptive capacity as construct and propose a refined model of absorptive capacity. The model is illustrated in Figure 2.8. The three process stages of the original model by Cohen and Levinthal (1990) are replaced by a four stage model including the steps (1) acquisition, (2) assimilation, (3) transformation, and (4) exploitation (Zahra and George, 2002; Todorova and Durisin, 2007).

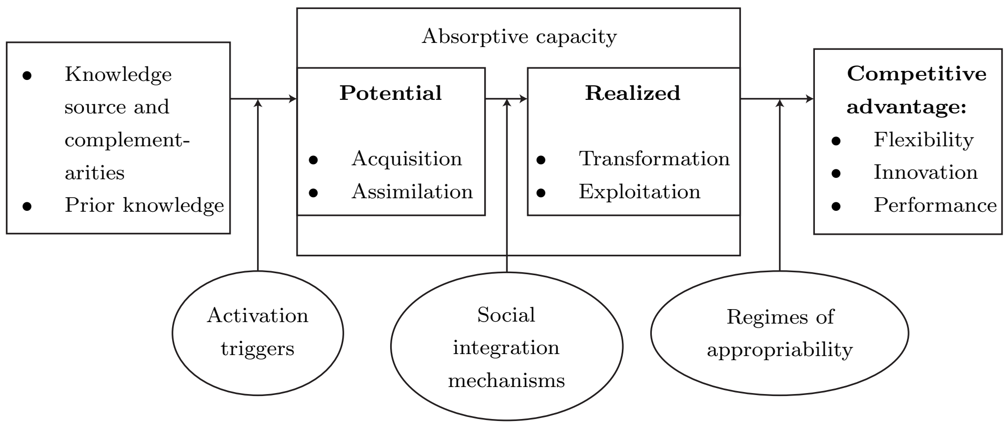

Figure 2.8: Absorptive capacity model from Zahra and George (2002), illustrated by Todorova and Durisin (2007, p. 775)

The first process step, the acquisition of knowledge includes the sub-steps of identification and acquiring external knowledge. The quality of the acquisition process depends on the intensity and speed of the search process for external knowledge. The quality of this process step is, furthermore, dependent on the strategic direction of the search space, which is determined with prior knowledge in the firm. It is essential to know where to look for, which is only possible with a basic understanding of the desired knowledge search field. Second, the assimilation of knowledge can only occur in a firm if the newly acquired knowledge is understood and can be interpreted and learned accordingly. These two process steps are grouped together and termed potential absorptive capacity. They need to be fulfilled so that the potential absorptive capacity can be transferred into a realized absorptive capacity with the steps transformation and exploitation. Therefore, the third process step of absorptive capacity is the transformation stage, where the new knowledge is internalized and converted to be, fourth, exploited in a firm. Exploitation means using the acquired knowledge and implementing it for commercial use, hence leading to competitive advantage of a firm (Zahra and George, 2002). The antecedent of the absorptive capacity is the same compared to the original model (knowledge source and prior knowledge). However, the model explicitly contributes to the resource-based view with the output dimension of competitive advantage (Zahra and George, 2002).

Three moderating factors are proposed in the model and are illustrated in Figure 2.8. First, the activation triggers have a positive moderation effect between the antecedent and the potential absorptive capacity. The activation triggers can be found either internally (e.g. in case of a crisis in the firm) or externally (e.g. radical innovation in the market, technology change) to the firm. Second, the social integration mechanisms moderate between the potential absorptive capacity and the realized absorptive capacity. This means that the relevant information (knowledge) needs to be shared among the individual members in a firm to enable the transfer from potential to a realized absorptive capacity. Third, the regimes of appropriability moderate the influence between realized absorptive capacity and the competitive advantage. Strong regimes of appropriability mean that the intellectual property rights (IPR) protection is high in the industry thus having only low spillover in this industry. This means that other firms cannot easily imitate the technology, products or services, which have been intellectually protected. Therefore, strong regimes of appropriability are considered to have a positive moderating relationship between the realized absorptive capacity and competitive advantage. However, weak regimes of appropriability are only considered to moderate the effect between realized absorptive and competitive advantage positively if firms can isolate the knowledge assets successfully against competitors (Zahra and George, 2002; Todorova and Durisin, 2007).

Model by Todorova and Durisin (2007)

The model by Zahra and George (2002) received critiques from Todorova and Durisin (2007), who claim that the model lacks an explicit concept of value recognition in the domain of absorptive capacity. The concept of value recognition is, therefore, included in their model before the process steps of acquisition of knowledge. Another point of critique is that according to Zahra and George the process steps of assimilation and transformation are not seen as consecutive steps but rather interdependent steps. Due to the lack of a clear separation between the individual process steps, the concepts of potential and realized absorptive capacity are no valid concepts. Todorova and Durisin (2007) base their criticism on an empirical study conducted by Jansen, Van den Bosch and Volberda (2005), where the four process steps of Zahra and George (2002) are operationalized individually. A confirmatory factor analysis showed that those four process steps are individual factors and cannot be combined into the two categories of potential and realized absorptive capacity. A novel approach in the model by Todorova and Durisin (2007) introduces the concept of power relationships between the firm and partners. Therefore, this model is explicitly supporting cooperation agreements. The power relationship has a positive moderation effect at two places of the model. First, there is a positive moderating effect between the antecedents of absorptive capacity. This moderating effect is caused by an enlarged search space when a firm has close links to other partners. Second, there is also a positive moderation effect between the process step of exploitation and the competitive advantage due to usability improvement when cooperating with customers, thus leading to higher customer value (Todorova and Durisin, 2007).

Model by Lane, Koka and Pathak (2006)

The model by Lane et al. (2006) also refocuses on the original process perspective of Cohen and Levinthal (1990), which includes (a) recognition and understanding of new external knowledge, seen as exploratory learning, (b) the assimilation of valuable external knowledge, seen as transformative learning, (c) the application of assimilated external knowledge, seen as exploitative learning. The novel approach in their model is the use of the learning triplet exploration-transformation-exploitation as synonym for the process steps used in Cohen and Levinthal's (1990) model.

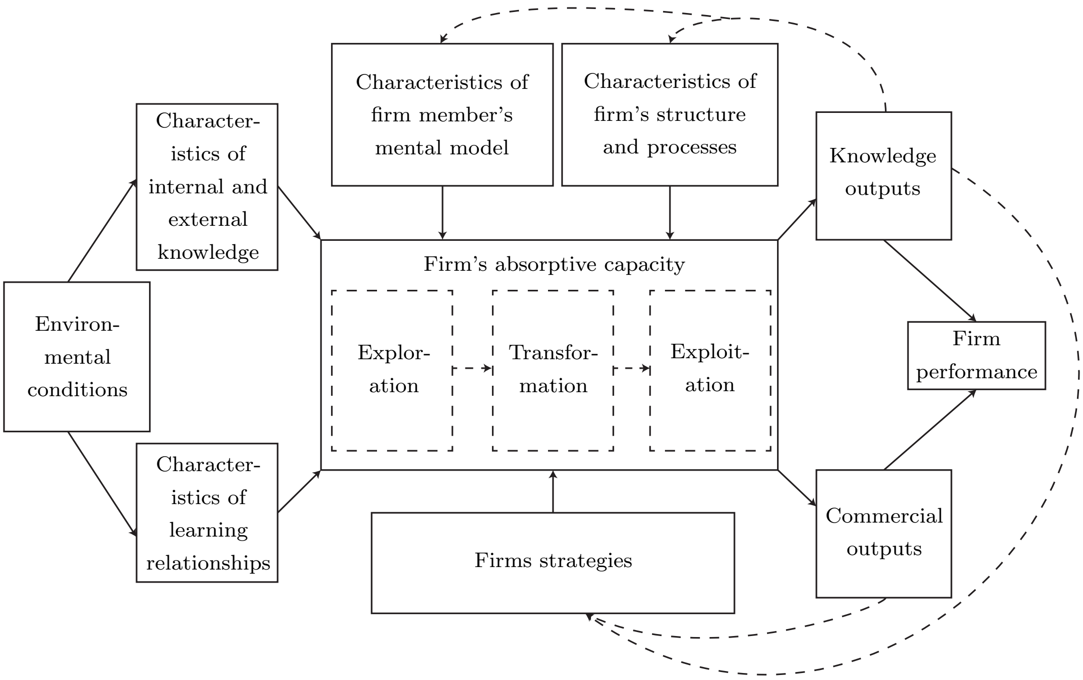

Figure 2.9: Absorptive capacity model by Lane et al. (2006, p. 856)

The model by Lane et al. (2006) consists of four parts. The first part was just described and is shown in the middle of the figure. The second part, the antecedent of the model (on the left side), describes the incentives to invest in absorptive capacity. Positive drivers are (a) knowing which information is available externally and (b) the ease of learning and knowledge transfer. The third part, the internal drivers are threefold: (a) the strategy of the firm determines the focus of the knowledge search and has an impact on the valuation of the found knowledge; (b) the mental models of the individuals are also seen as a driver for the creativity of the absorptive capacity; (c) the organizational structure affects the driver for efficiency and effectiveness of assimilation and application. The fourth part, the output dimension is illustrated on the right side of the figure. The output is subdivided into (a) commercial and (b) knowledge output, which in turn influences the firm's performance. Lane et al. (2006) state that in previous studies the focus was mainly on innovation-related performance, which was mainly operationalized with the R&D intensity. However, in their model the commercial model is further subdivided into products, services, and intellectual properties and not only into R&D input related measures. Furthermore, the knowledge output is also represented with the dimensions of e.g. scientific and technical knowledge (Lane et al., 2006).

2.4.4 The Funnel Perspective of Absorptive Capacity

Similar to the concept of open innovation, absorptive capacity can also be seen as funnel. See Figure 2.10 for an illustration. The funnel of absorptive capacity is already implied in the models from Cohen and Levinthal (1989; 1990), Lane and Lubatkin (1998) and Van den Bosch et al. (1999) and has been described in Lane et al. (2006). New knowledge is searched outside the boarders of the firm, represented by the wider opening of the funnel. The input of this search process is condensed by relating the new knowledge to available knowledge thus assimilating the new knowledge and, furthermore, exploiting it commercially. The model of Zahra and George (2002), however, focuses on the efficiency perspective in the process of absorptive capacity and not on the valuation of external knowledge. In their model the input-output relationship is emphasized with their introduced concept of potential and realized absorptive capacity, which can be seen as efficiency pipeline (Lane et al., 2006). The following section will discuss the relationship between the funnel perspective of the absorptive capacity model and the funnel used in the open innovation model.

2.5 Combination of Open Innovation and Absorptive Capacity

The funnel from open innovation consists of the inbound and the outbound process (see also Section 2.3 for a description). The inbound process is similar to the funnel perspective of absorptive capacity, where external knowledge is integrated into the own innovation process. However, the outbound perspective (e.g. licensing of not used technology to other firms, supporting technology spin-offs, etc.) is not part of the absorptive capacity model. The origin of the absorptive capacity research lies in the field of industrial organization and is rather academic, hence being criticized

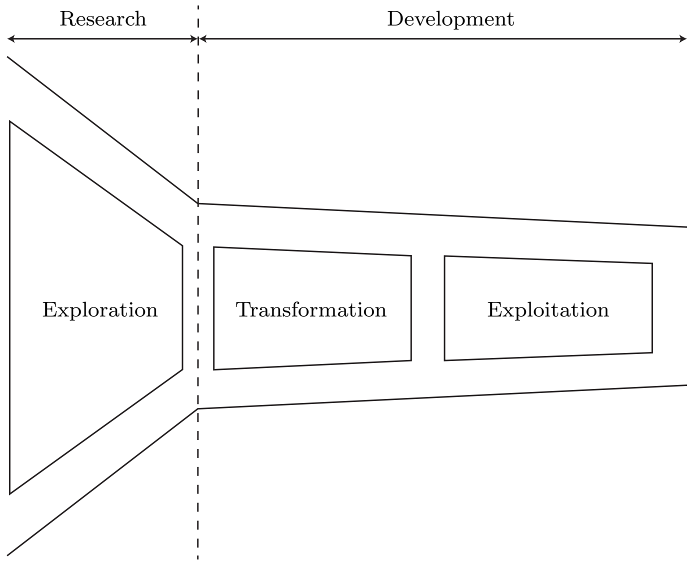

Figure 2.10: Funnel representation of absorptive capacity

for not being applicable from managers to steer a firm. On the other side, open innovation originates from a practical oriented research, with the drawback that it is only loosely connected to established theories in the field (Vanhaverbeke, Cloodt and van de Vrande, 2007).

Hardly any studies exist which connect the concepts of absorptive capacity and open innovation despite their conceptual similarities. Exceptions are the work by Vanhaverbeke et al. (2007) and Spithoven et al. (2010). Vanhaverbeke et al. (2007) is a conceptual paper which connects the two concepts and discusses the underlying theories (e.g. transaction cost view, resource-based view, organizational learning theory). Spithoven et al. (2010) is an empirical study, where the absorptive capacity is investigated and related to the open innovation process of small firms in the non-high technology industries. The industries were chosen because open innovation has not yet been that widely adopted by them. A result of their study is that absorptive capacity is required in a firm to enable the use of open innovation. This means that firms with lower absorptive capacity have a lower probability to adopt open innovation mechanisms (Spithoven et al., 2010).

To sum up, the concepts of open innovation and absorptive capacity focus both on externally available knowledge which can be integrated into the R&D or innovation process. R&D cooperation projects are one way to acquire external knowledge and transfer it into new product or service ideas. The next section focuses, therefore, on the management of R&D cooperation projects and looks at them from a capability and absorptive capacity perspective.

Chapter 3

Management of R&D Cooperations

This chapter presents the model and the hypotheses of this study. First, in Section 3.1 terms used in this study are defined. Second, in Section 3.2 arguments for R&D cooperations are provided and classified according to the strategic management theories. Third, the absorptive capacity funnel is revisited in Section 3.3 and the proposed determinants to manage R&D cooperations are shown. Fourth, the hypotheses regarding the propensity to cooperate on R&D are motivated and discussed in Section 3.4, aiming to answer the following research question:

> *To what extent does absorptive capacity influence the propensity to engage in R&D cooperations?*

Fifth, the hypotheses focusing on the success of R&D cooperations are motivated and formulated in Section 3.5, trying to answer the second research question:

> *To what extent does absorptive capacity influence the success of R&D cooperation projects?*

Finally, Section 3.6 gives an overview of the proposed hypotheses and presents the measurement models.

3.1 Definitions

This section discusses key terms used in this work. See below a list where the individual definitions are given:

- Research and Experimental Development – Section 2.2.1
- Project – Section 3.1.1
- R&D Cooperation and R&D Alliances – Section 3.1.2

3.1.1 Project

In the field of project management the term 'project' is defined in different ways. Two definitions, one by the International Organization for Standardization and one by the Project Management Institute are listed below:

- "unique process [. . .], consisting of a set of coordinated and controlled activities with start and finish dates undertaken to achieve an objective conforming to specific requirements [. . .], including constraints of time, cost and resources" (ISO 9000, 2005, p. 31).
- "a temporary endeavor undertaken to create a unique product, service or result" (PMBOK, 2004, p. 5).

To conclude, a project is described as a temporary endeavor with a defined start and finish, where a specified goal needs to be accomplished. The goal is unique and the process to reach the goal underlies certain constraints (time, cost and resources) (ISO 9000, 2005; PMBOK, 2004).

3.1.2 R&D Cooperation and R&D Alliance

In the scientific literature the terms 'cooperation' and 'alliance' are used synonymously (Hagedoorn et al., 2000). However, Hagedoorn et al. (2000) use the term

'R&D partnerships' and put it in the context of R&D cooperations and R&D alliances. Furthermore, they present a definition by the Council of Competitiveness of R&D partnerships[12]:

> "Partnerships are defined ... as cooperative arrangements engaging companies, universities, and government agencies and laboratories in various combinations to pool resources in pursuit of a shared R&D objective."

This definition focuses on a cooperative arrangement. Recently, the term 'R&D cooperation' has been used in literature more frequently than the terms 'R&D alliances' and 'R&D partnerships' (e.g. Arranz and de Arroyabe, 2008; Okamuro, 2007). Therefore, the term 'R&D cooperation' is used throughout this study. However, the capability to form and manage a cooperation or an alliance is described in literature mainly as 'alliance capability', therefore, the term 'alliance capability' will be used in this study (e.g. Hoffmann and Schlosser, 2001; Rothaermel and Deeds, 2006). To sum up, for this study R&D cooperations are defined as a collaborative project done in a partnership with at least one other legal independent entity conducting R&D together. This includes informal and contractual agreements.

3.2 Motivation for Cooperative R&D

Sourcing external technology decreases time-to-market and lowers the risk of R&D projects (e.g. Hagedoorn et al., 2000). "Technology sourcing is a multidimensional construct. It refers to the firm's approach to developing new technological capabilities, both in terms of the use of in-house R&D and through the use of external technology sourcing 'linkages' (Auster, 1990) or 'strategic technology alliances' (Hagedoorn and Schakenraad, 1994), such as R&D contracts, licenses, joint ventures, minority equity investments, and acquisitions" (Nicholls-Nixon and Woo, 2003, p. 652). Therefore, one way of sourcing external knowledge is cooperating (Gassmann, 2006). Literature categorizes the types of partners mainly into four categories: (a) supplier,

[12] Council on Competitiveness, 1996. Endless Frontier, Limited Resources: U.S. R&D Policy for Competitiveness. Council on Competitiveness, Washington. Cited in Hagedoorn et al. (2000, p. 568).

(b) competitor, (c) customer and (d) research organization (including universities). A cooperation with suppliers and customers is seen as a cooperation along the value chain and called vertical cooperation. A cooperation with a competitor is called horizontal cooperation and is not as frequent as other types of cooperations, however, "[i]n many instances, firms cooperate in some aspects of business and compete in others" (Carpenter, 2008, p. 34).

Hagedoorn et al. (2000) review the literature of R&D cooperations and provide a categorization according to the theories for an engagement in R&D cooperations. These theories are (1) the resource-based view, (2) industrial organization and (3) transaction cost. Table 3.1 presents this compilation.

Question	Resource-based view[13]	Industrial organization	Transaction costs
Incentives to form a research partnership	Share R&D costs Pool risks	Share R&D costs Pool risks	Minimize cost of transactions involving intangible assets (technical knowledge)
	Pool risks	Pool risks	Circumvent incomplete contracts
	Economies of scale and scope	Economies of scale and scope	Avoid opportunistic market behavior
	Co-opt competition Improve competitive position	Co-opt competition Accelerate return on investments	Avoid high costs of internalizing the activity
	Coordinate value chains with coalition partners	Access complementary resources Decelerate rate of innovation	
	Increase efficiency, synergy, power through network Access complementary resources to exploit own resources Use collaboration as learning vehicle to accumulate and deploy new skills and capabilities Learn from partners; transfer technology Create new investment options	Increase market power	
Expected results of research partnerships			
Partners	Successfully meet incentives Interdependency	Successfully meet incentives Interdependency Increase R&D efficiency Increase flow of information Increase overall R&D expenditures	Successfully meet incentives
Industry, society	Industry competitiveness	Increase overall R&D expenditures when spillovers are high Increase social welfare Subsidize on certain occasions	Better resource allocation

Table 3.1: Arguments for cooperative R&D. Taken from Hagedoorn et al. (2000, p. 575)

[13]In the original table this category is referred to as strategic management. The resource-based view is a sub-category of strategic management. However, Hagedoorn et al. (2000, p. 570) state

The arguments for conducting R&D in cooperations are similar in the resource-based view and in the industrial organization theory. Shared R&D costs and risk pooling are arguments shared by both theories. Ad (1), the resource-based view looks at the performance of the individual firm. Firm's performance can improve through an increased development speed and through the exchange of knowledge within the cooperation (Hagedoorn et al., 2000). However, to transfer knowledge it is essential that the firm has the capability to absorb this knowledge (Cohen and Levinthal, 1990). Ad (2), the industrial organization theory focuses on an interaction effect between firms in a given industry. Besides the above mentioned arguments, the industrial organization theory, further points out that an industry can increase the competitive position by increasing the R&D investments in case of high spillover (non-tournament model – see also Section 2.1.3). Ad (3), the transaction cost economics focuses on the costs of transactions, which are required to establish and maintain an R&D cooperation. However, the outcome in an R&D process is uncertain by definition, therefore it is hard to fully specify a defined output in the starting phase of an R&D project. "Transaction costs increase steeply when contracts are incomplete, that is, when they do not fully specify the actions of each party in every contingency. Intangible assets, including technical knowledge, are a primary cause of incomplete contracts" (Hagedoorn et al., 2000, p. 571). Therefore, the transaction cost theory is not suitable to describe R&D cooperations "[e]xcept for the case of a joint venture[. Otherwise] the transaction-cost theory is hardly noticed" (Yasuda, 2005, p. 768).

This study, however, focuses on the capabilities and the improvement of individual firms, therefore the resource-based view is chosen as theoretical framework. The next sections motivate the model and the hypotheses of this study.

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that every categorization is individual and say further that "the transaction cost and industrial organization approaches have undoubtedly drawn on strategic management to support various arguments." Following this argumentation, the categorization discussed in Chapter 2.1 concerning the triplet of transaction cost, industrial organization and resources based view as sub-categories of strategic management will be adopted in this section.

3.3 Model for the Study

This section gives a preview of the hypotheses of this study. As already stated, this study focuses on the effectiveness and the efficiency of R&D cooperations. Figure 3.1 illustrates the model of this study.

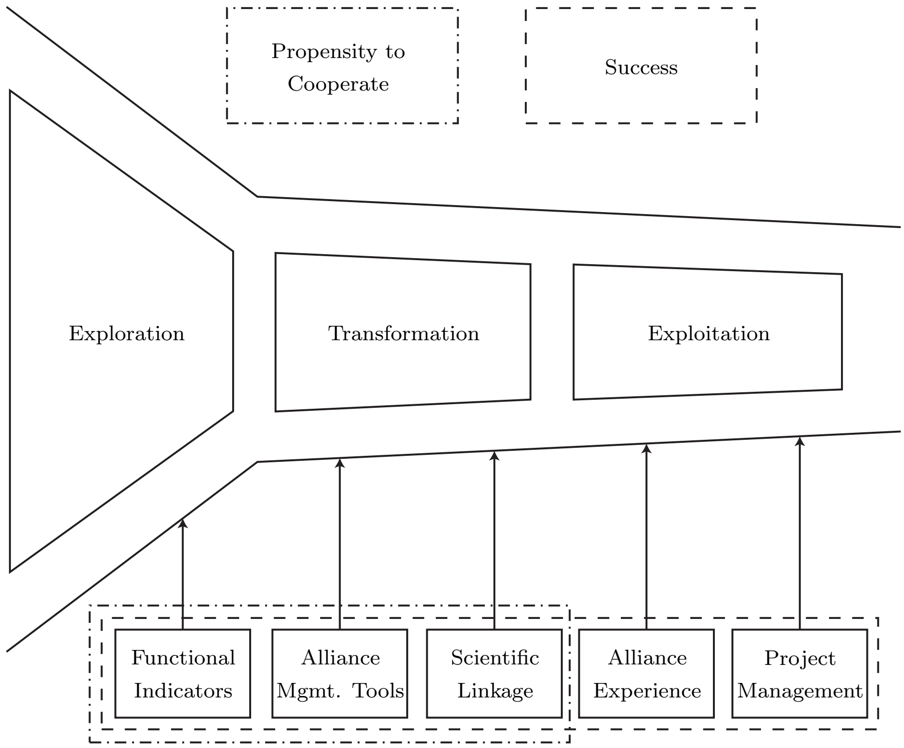

Figure 3.1: Empirical model for the study

The starting point of this model is the illustration of the absorptive capacity funnel in Section 2.5. The open search space (exploratory learning) represents the search for external partners to form an R&D cooperation. It is considered that (a) functional indicators, (b) alliance capability and (c) scientific linkage enhance the effective search for cooperation partners and, therefore, the propensity to engage in R&D cooperations. The efficiency perspective of the absorptive capacity consists of transformative and exploitative learning. In this study, the efficiency and the success of R&D cooperations is proposed to enhance with the following capabilities: (a) functional indicators, (b) alliance experience, (c) alliance capability, (d) scientific linkage and (e) project management capability.

3.4 Propensity to Cooperate on R&D

One aspect of the open innovation approach is to investigate external sources of knowledge in order to improve the own innovation process (Chesbrough, 2003; Gassmann, 2006). As already stated earlier, "[o]utside sources of knowledge are often critical to the innovation process" (Cohen and Levinthal, 1990, p. 128). One way to source external knowledge is by entering cooperation agreements thus enhancing the innovative capability (Hagedoorn and Schakenraad, 1994; Nicholls-Nixon and Woo, 2003). "Although many studies have observed the impact of alliance on innovation performance [. . .] few have examined how the alliances are formed" (Zhang et al., 2007, p. 519). In this study capabilities of a firm which possibly predict the propensity to cooperate on R&D are analyzed[14]. Empirical studies from the past ten years are reviewed that discuss the propensity to cooperate (see Section 3.4.1). Therefore, hypotheses will be motivated and formulated in the following sections:

- Section 3.4.2 – Function Specific Indicators
- Section 3.4.3 – Alliance Capability
- Section 3.4.4 – Scientific Linkage

3.4.1 Previous Studies

This section discusses recent studies which focus on the establishment of R&D cooperations. See Table 3.2 for an overview. The table discusses, in addition to the author(s) of the paper, the sample used in the study both in terms of quantity and origin[15] of the data. Furthermore, the table shows the level of analysis (industry-level, firm-level or project-level) and the research focus. In this section the individual studies are summarized and discussed.

Study by Bayona, Garcia-Marco and Huerta (2001)

The work by Bayona et al. (2001) investigates the motivations of firms for conducting R&D in cooperations. The findings indicate that the complexity of technology

[14] For a motivation of the research question see also Section 1.2.

[15] The Community Innovation Survey (CIS) is a standardized survey regarding the innovation activities in countries of the European Union, Norway and Iceland (Arranz and de Arroyabe, 2008).

Author	Sample	Data	Level	Research Focus
Bayona et al. (2001)	1,652	(DB)	(F)	sharing risk, market information, flexibility, quality
Fritsch and Lukas (2001)	1,800	(Q)	(F)	firms characteristic, gatekeeper
Sakakibara (2002)	312	(DB)	(I, F)	industry and firm characteristic, rate of cooperation
Hagedoorn (2002)	–	(DB)	(I)	alliance formation (past 40 years)
Miotti and Sachwald (2003)	2,378	(CIS)	(I, F)	firm characteristics, absorptive capability
Fontana et al. (2006)	255	(Q)	(F)	search strategies
Zhang et al. (2007)	2,647	(DB)	(F)	centrality R&D department, breadth of knowledge
Rothaermel and Boeker (2008)	32,332	(DB)	(F)	dyadic alliances, complementarity of knowledge
Arranz and de Arroyabe (2008)	1,652	(CIS)	(F)	types of cooperation
Lai and Chang (2010)	58	(Q)	(F)	governance structure

Abbreviations: Questionnaire (Q), Existing Database (DB), Community Innovation Survey (CIS), Industry-level (I), Firm-level (F), Project-level (P)

Table 3.2: Propensity to cooperate on R&D

and the uncertainty in the innovation process motivates firms to engage in R&D cooperations. Furthermore, large firms are more likely to participate in R&D cooperations than small firms. The motives of small firms to engage in cooperations differ from those of large firms: Small firms note that they want to get access to the knowledge of the market, whereas this is not considered as relevant for big firms. This study also shows that absorptive capacity has a positive influence on the likeliness to cooperate. The study was done by evaluating data from a survey of 1652 Spanish manufacturing firms.

Study by Fritsch and Lukas (2001)

Fritsch and Lukas (2001) investigate the type of cooperation (suppliers, customers, competitors, research organizations) and the motivation to cooperate on R&D. The results show that the firms that are engaged in cooperations have a set of characteristics which separate them from non-cooperating firms. The bigger the firm, the likelier it is that the firm is engaged in an R&D cooperation. A high share of R&D also improves the likeliness that firms are engaged in R&D cooperations. Furthermore, it is found that the presence of a 'gatekeeper'[16] in an organization improves the propensity to be involved in cooperating activities. The hypotheses are tested by looking at different sub-samples according to the engaged cooperations . The results were obtained by analyzing standardized questionnaires from 1800 manufacturing companies from Germany.

Study by Sakakibara (2002)

Sakakibara (2002) investigates industry and firm characteristics of 312 firms. The study shows a firm's rate of participation in R&D consortia. The findings indicate that the likeliness to be engaged in R&D cooperations increases in weak industries and in industries with low regimes of appropriability[17]. A prior engagement in a cooperation focusing on products development influences the propensity for R&D cooperation as positively as a past participation in a large scale R&D consortia does. The results are based on an analysis of Japanese governmental funded research consortia which were conducted in a period spanning almost 25 years.

Study by Hagedoorn (2002)

Hagedoorn (2002) provides an overview of R&D partnerships between the years 1960 - 1998. He reports that in the analyzed 40 years there was a shift from engaging in equity based partnerships (joint ventures) to contractual based partnerships. An explanation of this effect is that R&D partnerships are mainly conducted in the high-technology industries with a rather high-paced industry clock speed. To allow more flexibility in the partnership short-term contractual agreements are preferred over long-term equity based joint ventures. The results were optained by analyzing the data from the MERIT-CATI database.

[16] A 'gatekeeper' is a person who scans the environment for new technological development which can be integrated in a firm's R&D or innovation process (Rothwell and Dogson, 1991).

[17] Low patent protection and, therefore, high spillover in an industry (See also Section 2.4.1).

Study by Miotti and Sachwald (2003)

The work of Miotti and Sachwald (2003) investigates the propensity to cooperate on R&D and looks at the relative efficiency of the conducted R&D cooperations. The propensity to cooperate increases with the size of a firm and if R&D is conducted permanently in the firm. Furthermore, the propensity will increase with a higher relative R&D intensity compared to other firms and if firms receive governmental funding for their research activities. An industry effect was also identified. If a company is nearer to the technological frontier then the likeliness to cooperate on R&D increases. The relative efficiency of the R&D cooperations is measured with the patenting activities and the share of innovative products in the turnover of a firm. It has been found that firm size, market share, permanent R&D and the engagement in R&D cooperations have a positive influence on both mentioned success dimensions. Furthermore, it is shown that vertical cooperations have a positive influence on the propensity to introduce new products on the market. Cooperations with research organizations show a positive influence on patenting activities. The results were obtained by analyzing responses from the second French community innovation survey (CIS-2) where 2378 firms were included.

Study by Fontana, Geuna and Matt (2006)

The study by Fontana et al. (2006) investigates the propensity and the extent of collaborative R&D projects between public research organizations and industrial partners. The study focuses on the aspects of *searching*, *screening* and *signalling*. The construct *searching* represents the openness of a firm to develop products or processes in collaboration with external partners. The construct *screening* indicates the ability of a firm to find knowledge in publications. The construct *signalling* shows if a firm uses patents to protect their knowledge. The findings show that the propensity to cooperate with a research organization increases with the size of the firm. The propensity, furthermore, increases with the capability to look for external knowledge in publications (*screening*). The propensity decreases, however, if the firm uses patents to protect their knowledge (*signalling*). No relationship was found between the construct *searching* and the propensity to patent. The study was conducted in seven EU countries by means of a standardized questionnaire. The sample consisted of 255 firms. The study has no industry focus, but the sample is chosen to represent the low-, medium- and high technology industries.

Study by Zhang, Baden-Fuller and Mangematin (2007)

The study by Zhang et al. (2007) looks at the breadth of knowledge in a firm and the centrality of the R&D department. The results show a positive relationship between the two mentioned factors and the propensity to engage in R&D cooperations. The breath of knowledge is measured with the categorization of the patent classes, where a firm holds and files its patents. The R&D department is considered more central if a strong central R&D department exists compared to decentralized R&D departments in the divisions of the firm. In addition to the above stated findings, it is identified that bigger firms have a higher probability to engage in R&D cooperations. However, R&D intensity shows no effect on likeliness to engage in R&D cooperations. These results were obtained by interpreting a public available database on R&D cooperations in the pharmaceutical industry analyzing 2647 firms.

Study by Rothaermel and Boeker (2008)

The work of Rothaermel and Boeker (2008) investigates the benefits of alliances in the field of biotechnological and pharmaceutical firms. The benefit of the alliance between those two type of firms is, on the one side that the biotechnological firms ally with pharmaceutical firms to bring a potential product to the market. On the other side, the benefit for the pharmaceutical firm is to get access to newly explored knowledge which can be commercialized. The findings indicate that the likeliness to ally increases when the two partners have a complementary knowledge base. Furthermore, firm specific characteristics, such as firm size and patents in the field of biotechnology are also good indicators for predicting the propensity to enter such an R&D cooperation. These firm specific characteristics are even better predictors than technology based ones such as patent cross-citation or patent common citations. The results are based on the investigation of the dyad between 59 pharmaceutical and 548 biotechnology firms, which are engaged in human *in-vivo*[18] therapeutics, leading to a total of 32,332 pharmaceutical and biotechnology dyads.

[18] "[H]uman therapeutics that are placed inside the human body" (Rothaermel and Boeker, 2008, p. 53).

Study by Arranz and de Arroyabe (2008)

Arranz and de Arroyabe (2008) look at the motivation and the success for cooperating on R&D by the type of partners (supplier, clients, competitors, research organizations). It has been found that firms cooperate vertically (suppliers and customers) to create new products or to enter new markets. Horizontal cooperations (competitors) are mainly conducted in the high-technology industries, and to a lesser degree in the mid- and low-technology industries. The cooperation with research organizations is sought in case of limited knowledge in the target field. Furthermore, it has been found that the main motivation to work with a U.S. partner is to get access to technology and complementary knowledge. Partnerships with firms within the European Union, in contrast, target at cost reduction. The results were obtained by analyzing the Spanish Community Innovation Survey including the data of 1652 firms.

Study by Lai and Chang (2010)

The study by Lai and Chang (2010) focuses on the propensity to ally for R&D in respect to the governance structure (equity vs. non-equity based alliances). The findings show that the uncertainty of the project is a main determinant for the governance structure of the alliance. The higher the uncertainty, the more likely it is that an equity based alliance is entered. However, no relationship has been found between the governance structure and the success of R&D cooperations. The findings are obtained by analyzing the responses from 58 managers in the Taiwan's machinery industry via a standardized questionnaire.

Summary of the Studies

Table 3.3 provides an overview of the discussed studies regarding the used variables and the propensity to cooperate. The table is structured according to: (1) firm demographics, (2) function specific indicators and (3) scientific linkage. The table lists the investigated variables which have a positive influence on the propensity to cooperate. First, the demographic characteristic indicates that most of the studies show a positive influence of the firm size on the propensity to cooperate. Furthermore, it has been found that the firms differ in their propensity to cooperate according to their industry classification. Second, function specific indicators, such as (a) an existing R&D department, (b) an alliance function and (c) a gatekeeper enhance the propensity to cooperate on R&D. Third, two studies have found out that the breadth of knowledge of a firm and the search for publication also enhances the propensity to cooperate.

The next sections will develop the hypotheses of this study. These hypotheses are derived from the discussed studies in respect to answer Research Question 1.

	Bayona et al. (2001)	Fritsch and Lukas (2001)	Sakakibara (2002)	Hagedoorn (2002)	Miotti and Sachwald (2003)	Fontana et al. (2006)	Zhang et al. (2007)	Rothaermel and Boeker (2008)	Arranz and de Arroyabe (2008)	Lai and Chang (2010)
controls										
firm size	+	+			+	+	+	+	+	
part of a group of companies						+				
industry		+	+	+	+			+		
function specific indicators										
R&D department	+				+					
alliance function										+
gatekeeper		+								
scientific linkage										
search for publication						+				
breadth of knowledge							+			

Table 3.3: Firm characteristics enhancing the propensity to cooperate on R&D

3.4.2 Function Specific Indicators

Cohen and Levinthal (1989; 1990) used R&D expenditure divided by sales as a proxy for the absorptive capacity. However, for a deeper understanding of the underlying capabilities non-metric measures are suggested to determine absorptive capacity more suitably (Lane and Lubatkin, 1998; Heimeriks and Duysters, 2007). Function specific indicators have been used to determine absorptive capacity such as the existence of an R&D department or a gatekeeper scanning for new developments. A positive relationship between these function specific indicators are found enhancing the propensity to cooperate (e.g. Fritsch and Lukas, 2001; Miotti and Sachwald, 2003; Zhang et al., 2007). It has been further found that a dedicated alliance function also increases the propensity to cooperate (e.g. Kale et al., 2002; Kale and Singh, 2007). Therefore, the following hypothesis is developed:

> *Hypothesis 1: Function specific measures such as (a) existing R&D department, (b) alliance function and (c) technological gatekeeper enhance the probability to engage in R&D cooperations.*

3.4.3 Alliance Capability

One aspect of absorptive capacity is the alliance capability[19] (Heimeriks and Duysters, 2007). Alliance capability is defined as "how effectively the firm is able to capture, share, and disseminate the alliance management know-how associated with prior experience" (Kale et al., 2002, p. 750). Alliance capability is, therefore, seen as the capability to select a cooperation partner and to manage a cooperation effectively (Kale et al., 2002; Draulans, deMan and Volberda, 2003; Kale and Singh, 2007; Heimeriks and Duysters, 2007).

Building up alliance capability requires alliance management tools to simplify the partner selection process (Hoang and Rothaermel, 2005; Heimeriks and Duysters, 2007). These tools are usually developed at firm level by a dedicated alliance function (see also Hypothesis 1b) or an alliance department (e.g. De-Man, 2005; Heimeriks and Duysters, 2007). The tools are used by other departments to ease the management process of a cooperation. These management tools are, for example, a standardized cooperation process, standardized organizational routines or manuals (e.g. Reuer, Zollo and Singh, 2002; Das and Kumar, 2007). It is expected that organizations with a built up alliance management capability at firm-level are more likely to be engaged in R&D cooperation. The above mentioned studies focus on non-R&D specific cooperations. Additionally, alliance research is still at the be-

[19]The discussed studies in Table 3.3 did not focus on the influence of alliance capability on the propensity to cooperate, hence alliance capability is not reported in there.

ginning as Kale and Singh (2007, p. 983) state: "Academic research that investigates how firms have greater alliance success and alliance capability is fairly recent." The following hypothesis is derived by combining the research on alliance capability with the research on R&D cooperations:

> *Hypothesis 2: The use of alliance management tools enhances the probability to engage in R&D cooperations.*

3.4.4 Scientific Linkage

Hypotheses 1b and 2 (alliance function and alliance capability) focus on the knowledge to form and manage R&D cooperations. Hypothesis 1a and 1c (existing R&D department and technology gatekeeper) focus on the capability to relate external available knowledge to the own knowledge base thus having the ability to know potential partners for a cooperation. Firms which screen their environment systematically for external knowledge sources (e.g. publications) are more likely to engage in R&D cooperation than firms which do not (e.g. Fontana et al., 2006). The illustration in Figure 2.10 shows the funnel of absorptive capacity.

The wider end of the funnel represents the search space of a firm representing the identification of external knowledge. A wide search space requires a broad internal knowledge base allowing to estimate the value of external knowledge (Lane et al., 2006). Therefore, it is considered as relevant to invest in own R&D infrastructure to keep or develop a wide search space[20]. The search for external knowledge is a determinant for engaging and managing successful R&D cooperations (Borgatti and Cross, 2003; Laursen and Salter, 2006; Lane et al., 2006). Firms can be classified into two categories regarding their knowledge search strategies. First, there are firms which mainly look for knowledge that is similar to the knowledge in the own knowledge base thus allowing efficient cooperation formation and successful cooperation management (Cohen and Levinthal, 1990; Lane and Lubatkin, 1998; Van den Bosch et al., 1999; Fabrizio, 2009; Volberda, Foss and Lyles, 2010). Second, there are firms which look for knowledge that is complementary to the knowledge in the firm (Shenkar and Li, 1999; Vanhaverbeke et al., 2007). Gaining access to comple-

[20] Cooperations are considered as complementarity resource rather than a substitute for an own R&D department (e.g. Veugelers, 1997; Lichtenthaler and Ernst, 2007).

mentary knowledge can be difficult due to limited experience in these areas and, therefore, not knowing where to look for. This difficulty is expressed by Plato as the Meno paradox. "The Meno paradox states that either one knows what she or he is looking for and hence does not need to search for it, or one does not know what she or he is looking for and hence cannot find anything" (Shenkar and Li, 1999, p. 135). However, the limited experience can be overcome with close links to potential knowledge sources (Shenkar and Li, 1999; Owen-Smith and Powell, 2004; Vanhaverbeke et al., 2007). These knowledge sources can be scientists outside the firm, for example (Zucker, Darby and Armstrong, 2002; Laursen and Salter, 2006; Fabrizio, 2009). This suggests that (a) firms which screen their environment systematically for external knowledge sources and (b) firms which have a good network to scientific partners have a better scientific linkage. This scientific linkage is considered to enhance the propensity to engage in R&D cooperations, which leads to the following hypothesis:

> *Hypothesis 3: Scientific linkage increases the probability to cooperate on R&D.*

3.5 Success of R&D Cooperations

In addition to investigating the propensity to cooperate, this study also looks at capabilities which could possibly predict the success of R&D cooperation projects. For a motivation of the research question see also Section 1.2. Therefore, empirical studies from the past ten years are reviewed in Section 3.5.1, which discuss the success of R&D cooperations. Additionally, hypotheses will be motivated and formulated in the following sections:

- Section 3.5.2 – Functional Indicators
- Section 3.5.3 – Alliance Experience and Capability
- Section 3.5.4 – Scientific Linkage
- Section 3.5.5 – Project Management Capability

3.5.1 Previous Studies

This section reviews recent studies which focus on the success of R&D cooperations. See Table 3.4 for an overview. The table discusses, in addition to the author(s) of the paper, the sample which was used in the study, both in terms of quantity and origin. Furthermore, the table shows which focus the individual studies have (industry-level, firm-level or project-level). In this section the individual studies will be discussed in more depth, and finally the hypotheses for determining the success of R&D cooperations will be developed in the next sections.

Study by Bizan (2003)

Bizan (2003) investigated four factors determining the success of R&D projects. The four factors are: (a) size of project, (b) size of firm, (c) relationship to co-operating firm, (d) complementarity of knowledge. The success of the project is sub-categorized into the following three success dimensions (a) technical, (b) commercial, (c) financial. The key findings indicate that the likeliness for technical and commercial success increases if the cooperating firms are related through ownership. Furthermore, the likeliness for technical success increases if the cooperating firms posses complementary abilities. The findings were obtained by analyzing 142 cooperative R&D projects of Israeli firms which were governmentally sponsored.

Study by Miotti and Sachwald (2003)

See Section 3.4.1 for a summary of this study. The study discusses both the propensity to cooperate and the success of R&D cooperations.

Study by Mora-Valentin, Montoro-Sanchez and Guerras-Martin (2004)

The study conducted by Mora-Valentin et al. (2004) investigates determinants for the success of R&D cooperations in respect of contextual and organizational factors. The contextual factors include, for example, previous links, the partners' reputation and definition of project objectives. The findings show that the contextual factors mainly influence the cooperation agreement in the initial formation phase and in the early stages of the cooperation. As for the evolution of the cooperation, the

Author	Sample	Data	Level	Research Focus
Bizan (2003)	142	(DB)	(F)	size, complementarity, relatedness
Miotti and Sachwald (2003)	2,378	(CIS)	(I, F)	firm characteristics, absorptive capability
Mora-Valentin et al. (2004)	800	(Q)	(P)	contextual and organization factors
Rothaermel and Deeds (2004)	325	(DB)	(F,P)	exploration vs. exploitation
Belderbos et al. (2004)	2,056	(DB)	(F)	type of partner
Hoang and Rothaermel (2005)	292	(DB)	(F,P)	alliance experience
Belderbos et al. (2006)	2,053	(CIS)	(F)	complementarities in R&D cooperations
Rothaermel and Deeds (2006)	325	(DB)	(F)	alliance capability/experience
Okamuro (2007)	237	(Q)	(F,P)	firm, industry and project characteristics
Aschhoff and Schmidt (2008)	699	(CIS)	(F)	type of partner
Arranz and de Arroyabe (2008)	1,652	(CIS)	(F)	types of cooperation
Tsai (2009)	753	(DB)	(F)	absorptive capacity
Curran et al. (2009)	84	(Q)	(P)	project leadership
Cloodt (2009)	3,124	(DB)	(P)	positional embeddedness
Lai and Chang (2010)	58	(Q)	(F)	governance structure

Abbreviations: Questionnaire (Q), Existing Database (DB), Community Innovation Survey (CIS), Industry-level (I), Firm-level (F), Project-level (P)

Table 3.4: Previous studies investigating the success of R&D cooperations

organizational factors were identified as being critical (e.g. commitment, communication, trust). The results were derived by means of a standardized questionnaire investigating 800 cooperative projects of Spanish firms and research organizations.

Study by Rothaermel and Deeds (2004)

Rothaermel and Deeds (2004) investigate the relationship between exploration and exploitation alliances in the biotechnology and pharmaceutical industries. It was found that biotechnology firms are more likely to engage in exploration alliances than exploitation alliances. Pharmaceutical firms, on the other hand, are more likely to engage in exploitation alliances than in exploration alliances. These findings support the observation that biotechnology firms have their focus on the 'R'-part of the R&D process and pharmaceutical firms have their focus on the 'D'-part of the R&D process. Furthermore, the results show that there is a consecutive correlation between (a) the number of exploration alliances and the number of products in development, (b) the number of products in development and the number of exploitation alliances, and (c) the number of exploitation alliances and the number of products on the market. The firm size also supports the above described effects positively. The results were obtained by investigating 2565 alliances in 325 firms from the biotechnology and pharmaceutical industry.

Study by Belderbos, Carree and Lokshin (2004)

Belderbos et al. (2004) investigate the influence of different types of cooperation partners (supplier, competitor, customer, research organizations) on a firm's success. Firm's success is measured with labor productivity and innovation productivity (sales of new products to the market). The findings show that if firms cooperate with competitors or suppliers the likeliness increases for incremental innovation. Firms cooperating with customers and universities have a higher likeliness to generate radical innovations compared to firms without this type of cooperation. Furthermore, cooperations with universities and competitors result in a higher propensity to bring products to new markets. The study used data of the Dutch Community Innovation Survey. The response of over 2000 firms was investigated.

Study by Hoang and Rothaermel (2005)

Hoang and Rothaermel's (2005) study focuses on the influence of previous alliance experience and the success of R&D cooperations. The study focuses on the biotechnology and pharmaceutical industries. The results show that in the case of biotechnology firms previous alliance experience has a positive effect on the success of R&D projects; however, not in the case of pharmaceutical firms. Furthermore, it has been found that in the case of a dyadic alliance experience the probability of higher success rate decreases with the numbers of alliances done together. These findings are interpreted (a) with the rather high alliance experience of pharmaceutical firms compared to that of biotechnology firms. Biotechnology firms are improving their alliance management capability with each single alliance they participate in but (b) reach a saturation effect. However, the results show that better predictors than the alliance experience are project specific indicators as patent protection (higher if protected) and the stage at which the project was entered. The success is higher if the cooperation was entered at a later stage. Entering the cooperation in the exploitation stage results in a higher success rate than already entering in the exploration stage. The study evaluated a database about dyadic partnerships of pharmaceutical firm's and their biotechnology partners, i.e. 292 biotechnology projects were evaluated involving 30 pharmaceutical and 145 independent biotechnology partners.

Study by Belderbos, Carree and Lokshin (2006)

Belderbos et al. (2006) investigate the determinants of a firms productivity growth. The determinants are different cooperation types (competitors, suppliers, customers, research organizations). It is found that cooperations with competitors or suppliers individually improve the productivity of a firm. Another result shows that if firms cooperate with competitors, customers and universities in parallel the productivity enhances further due to the complementarities each partner brings into the cooperation. The cooperation with a customer is considered to enhance the market acceptance, whereas cooperation with the competitor and the university improves the ability to improve a firm's innovation capability. The results of this study were obtained by analyzing the Dutch Community Innovation Survey. 2053 firms were evaluated with 627 firms engaged in cooporations.

Study by Rothaermel and Deeds (2006)

Rothaermel and Deeds (2006) investigate the relationship between (1) alliance type, (2) alliance management experience, (3) alliance management capability and the innovative performance of a firm in terms of newly developed products. The study investigates biotechnology firms. First, the alliance types are categorized into (a) upstream, (b) horizontal and (c) downstream alliances. Upstream alliances are conducted with universities and research organizations focusing on the research phase. Horizontal alliances take place in early stages of commercialization with another biotechnology firm as partner. Downstream alliances are conducted in cooperation with pharmaceutical firms to bring a product to the market. Second, the alliance management experience is measured with the total managed alliances and with the alliance years. Alliance years is the cumulative sum of the alliance duration in the individual alliance projects. Third, alliance management capability is the number of alliances which can be managed in parallel efficiently. The results show that more downstream alliances can be managed in parallel than horizontal alliances. Additionally, the efficient parallel management of horizontal alliances outnumbers the parallel management of upstream alliances. The effect of a lower number of efficiently managed upstream alliances comes from the higher uncertainty involved in the research phase compared to the other cooperation types. Furthermore, the results indicate that firms with more alliance experience have a higher output in respect to newly developed products. The results were obtained by analyzing 325 global biotechnology firms taken from an alliance database.

Study by Okamuro (2007)

Okamuro (2007) investigates the technological and the commercial success of collaborative R&D projects in respect of firm-, industry- and project-specific indicators. The results show that the technological success is enhanced with (a) higher R&D input, cooperating with (b) a larger company (c) in a different industry, and (d) that the firm is already familiar with the cooperation partner. The likeliness of commercial success increases with (a) higher R&D input, (b) higher number of cooperation partners in the project, (c) cooperation with customers and (d) having already worked together in an R&D project. The study was conducted by means of a survey of Japanese manufacturing sector targeting SME's, including 237 firms in the analysis.

Study by Aschhoff and Schmidt (2008)

Aschhoff and Schmidt (2008) investigate the influence of different R&D cooperation types (competitors, suppliers, customers, research organizations) on the performance of the firm. Three types of performance increases have been identified: (a) cost reduction due to process improvement, increase of sales share due to (b) product imitation (product novel for the firm) and (c) market novelty. It has been found that cooperations with competitors have a higher probability to result in cost reduction than other types of cooperations. Cooperations with research organization have a higher likeliness to result in market novelties and, therefore, contribute to a sales increase. The study used German CIS data, analyzing 699 firms.

Study by Arranz and de Arroyabe (2008)

See Section 3.4.1 for a summary of this study. The study discusses both the propensity to cooperate and the success of R&D cooperations.

Study by Tsai (2009)

Tsai (2009) investigates the moderation effect between the absorptive capacity of a firm and the innovative sales productivity in respect to different cooperation partners (suppliers, customers, competitors, research organizations). It has been found that absorptive capacity positively moderates the impact if firms cooperate with suppliers and competitors. Furthermore, absorptive capacity moderates positively in the case of a cooperation with a research organization when working on marginal product improvements. However, the moderation effect is negative in the case of a cooperation with a research organization when working on new products or improving existing products. The effect is also negative in the case of a cooperation with a customer. The results were obtained by analyzing the Taiwanese Technological Innovation Survey database, including 753 firms in the Taiwanese manufacturing industry.

Study by Curran, Niedergassel, Picker and Leker (2009)

The study of Curran et al. (2009) focuses on project leaderships skills in cooperative R&D projects. It has been identified that the degree of trust among the team members and the administrative activity of the project leader plays a key role of being a successful project. However, upper management support or the risk associated with the project are not significant compared to a strong project leader. The results were derived by means of a standardized questionnaire sent to German firms in the chemical, pharmaceutical and biotechnology industry. The sample included 84 cooperative R&D projects.

Study by Cloodt (2009)

Cloodt (2009) investigates the number of R&D cooperations, positional embeddedness and the innovative performance of a firm. Positional embeddedness describes how central the firm is included in a network in their field of expertise. The results show that the more a firm is involved in R&D cooperations the higher its innovative performance is. The results show that this is also true for the other way around, meaning that firms with higher innovative performance are more likely to engage in R&D cooperations. Furthermore, firms with higher positional embeddedness are more likely to have increased their innovative performance and the likeliness to engage in R&D cooperations than firms with lower positional embeddedness. Besides, firms with a higher involvement in R&D cooperations are also more likely to have higher positional embeddedness. These two above identified circular relationships are described as the so-called Matthew effect, "referring to the situation in which already innovative companies constantly increase their innovative performance even further by increasing their level of R&D partnership formation and positional embeddedness" (Cloodt, 2009, p. 20). The results were obtained by analyzing the MERIT-CATI database. The focus of the study was the high-technology industry, where 3124 partnerships of 1697 firms were analyzed.

Study by Lai and Chang (2010)

See Section 3.4.1 for a summary of this study. The study discusses both the propensity to cooperate and the success of R&D cooperations.

Summary of the Studies

Table 3.5 gives an overview of the investigated studies regarding the likeliness of success. The factors influencing the likeliness of success are grouped according to the following structure: (1) firm demographics, (2) function specific indicators, (3) alliance experience, (4) scientific linkage and (5) the project management capability.

	Bizan (2003)	Miotti and Sachwald (2003)	Mora-Valentin et al. (2004)	Hoang and Rothaermel (2005)	Belderbos et al. (2006)	Rothaermel and Deeds (2006)	Okamuro (2007)	Aschhoff and Schmidt (2008)	Arranz and de Arroyabe (2008)	Tsai (2009)	Curran et al. (2009)	Cloodt (2009)
controls												
size of the firm	+				+	+	+	+		+		+
group					+							
industry					+		+	+		+	+	
function specific indicators												
R&D department								+				
alliance function				+								
alliance capability												
experience			+	+		+						+
experience R&D							+					
alliance years						+						+
scientific linkage												
linkage to outside scientists										+		
network to pot. knowledge sources										+		+
search for knowledge		+							+			
project management capability											+	
commitment to schedule	+			+			+					
commitment to budget	+											

Table 3.5: Overview of previous studies and the success of R&D cooperations

All studies show a positive effect on the likeliness of success in an R&D cooperation. First, most studies show an influence of the firm size and the success of an R&D cooperation. Furthermore, the industry affiliation of a firm serves also as determinant to predict the success of an R&D cooperation. Second, two studies have found out that function specific indicators, i.e. (a) an existing R&D department and (b) an alliance function also contribute to have an effect on the success of a cooperation. Third, a previous engagement in cooperations also enhances the success of an R&D cooperation. Fourth, some studies investigated the influence of scientific linkage and the success of R&D cooperations. These studies found out that (a) the link to potential knowledge sources and (b) the active search for new knowledge contributes positively to the success of an R&D cooperation. Fifth and finally, three studies investigated the influence of the project management capability and the success of a cooperation. These three studies found a positive relationship between the project management capability and the success of R&D cooperation.

In the following sections, the remaining hypotheses of this study are developed. These hypotheses are derived from the discussed studies in respect to answer Research Question 2.

3.5.2 Function Specific Indicators

According to the hypotheses stated in Section 3.4.2, function specific indicators, such as (a) an existing R&D department, (b) an alliance function or (c) a gatekeeper, enhance the propensity to cooperate. Furthermore, findings in previous studies show that these factors also influence the success of cooperations. First, the influence of an existing R&D department on the success of an R&D cooperation was investigated previously (e.g. Aschhoff and Schmidt, 2008; Bayona et al., 2001; Miotti and Sachwald, 2003). Second, the influence of an existing alliance function was investigated by a couple of researchers but not specifically in the field of R&D cooperations.

Table 3.6 shows studies where a positive influence between a dedicated alliance function in a firm and the success of cooperations was found. Third, an existing gatekeeper also enhances the likeliness for success in an R&D cooperation (e.g. Van den Bosch et al., 1999; Fritsch and Lukas, 2001). Consequently, the following hypothesis is formulated:

> *Hypothesis 4: Function specific measures such as (a) existing R&D department, (b) alliance function, (c) technological gatekeeper have a positive influence on the success of R&D cooperations.*

	Anand and Khanna (2000)	Deeds and Hill (1996)	De-Man (2005)	Douma et al. (2000)	Draulans et al. (2003)	Dyer et al. (2001)	Heimeriks and Duysters (2007)	Hoang and Rothaermel (2005)	Kale et al. (2001)	Serrat (2009)
alliance functions					+	+	+		+	
alliance experience	+	+	+	+			+	+	+	
alliance management tools					+		+		+	+

Table 3.6: Relationship of alliance capability and success

3.5.3 Alliance Capability

Hypothesis 4b states that an existing alliance function contributes to the success of an R&D cooperation. This alliance function can be seen as one part of the alliance capability (e.g. Heimeriks and Duysters, 2007). Table 3.6 gives an overview of the influence of individual aspects of alliance capability on the success of non-R&D cooperations[21]. In addition to the influence of the alliance function, alliance experience is identified as determinant for successful R&D cooperations. Alliance experience is defined "as the lessons learned, as well as the know-how generated through a firm's former alliances" (Heimeriks and Duysters, 2007, p. 29). This definition goes in line with previous research (e.g. Kale et al., 2002; Kale and Singh, 2007). Furthermore, "building on the experience curve literature [...], we suggest that a firm's alliance management capability is built through repeated engagements in alliances over time" (Rothaermel and Deeds, 2006, p. 438). Zollo and Winter (2002) see experience as a requirement to form a capability (see also Figure 2.1). Therefore, the following hypothesis is formulated:

> *Hypothesis 5: Alliance experience has a positive influence on the success of R&D cooperations.*

[21]The study by Rothaermel and Deeds (2006) is one of the few exceptions which combine the research on alliance capability research with the research on R&D cooperations.

The hypotheses formulated in Section 3.4.3 alliance capability increases the propensity to cooperate. For example, Kale et al. (2002) show that alliance capability has a positive impact on stock market performance. Rothaermel and Deeds (2006) show that alliance capability is built over time as path dependent process by participating in alliances thus increasing performance of the cooperation. This is also stated in a later study, in which alliance capability is said to improve with learning-by-doing (Rothaermel and Boeker, 2008). Additionally, as is shown in Table 3.6, alliance management tools and alliance capability also increase the likeliness of success. The mentioned factors focus on non-R&D specific cooperations. The alliance experience needs to be transferred into mechanisms and routines to gain better performance with alliances (Heimeriks and Duysters, 2007). Draulans et al. (2003) show also a positive relationship between the use of alliance management tools and the alliance success. The findings from non-R&D cooperations is transferred into the scope of R&D cooperation leading to the following hypothesis:

> *Hypothesis 6: The use of alliance management tools has a positive influence on the success of R&D cooperations.*

3.5.4 Scientific Linkage

As stated in Section 3.4.4, scientific linkage is considered to have a positive influence on the propensity to cooperate. Additionally, researchers found out the scientific linkage also has a positive influence on the success of R&D cooperations. “A primary factor influencing a firm’s ability to develop technology-based competencies via a cooperative venture is the potential to learn from that relationship” (Hagedoorn et al., 2000, p. 572). New knowledge can be absorbed and valued more efficiently if a knowledge base in the firm exists where the new knowledge can be related to (see also Section 2.4.2). However, if the new knowledge cannot be related to prior knowledge it is essential to know where additional information can be found. These sources can be: (a) searching in published material or (b) asking scientists external to the firm. It has been shown that an efficient search strategy in a firm has a positive influence on the success of cooperations (e.g. Zahra and George, 2002; Laursen and Salter, 2006; Lane et al., 2006; Spithoven et al., 2010). Furthermore, an efficient network also enhances the probability of success (e.g. Zucker et al., 2002; Laursen and Salter, 2006; Fabrizio, 2009). The concept of scientific knowledge combines both aspects hence the following hypothesis is proposed:

> *Hypothesis 7: Scientific linkage has a positive influence on the success of R&D cooperations.*

3.5.5 Project Management Capability

The aim of this study is to relate capabilities at firm-level with the success of R&D cooperations at project-level. It has been found that project management capability has a positive influence on the likeliness of success (e.g. Kwak and Ibbs, 2002; Andersen and Jessen, 2003). To isolate the effects of project management this study includes hypotheses regarding the project management capability. Therefore, project management capability is measured twofold: (a) project management efficiency and (b) the knowledge transfer in project management.

Jugdev, Mathur and Fung (2007) have found a positive relationship between project management capability and the project success. In their study they relate the tangible and intangible project management assets to the degree of achieved competitive advantage[22]. They found that only intangible assets (tacit knowledge) are responsible for sustained competitive advantage. In line with the identified influence of tacit knowledge other scholars have found a positive relationship between the project manager's personality and the success of projects (Dvir, Sadeh and Malach-Pines, 2006; Curran et al., 2009). However, little attention has been paid to the project management capability in the field of R&D cooperations so far (Curran et al., 2009). One aspect of project management maturity is how efficient the project management is in a firm. A proxy to measure project management efficiency is the iron triangle of project management (Atkinson, 1999). This iron triangle consists of time, cost and quality; however, "the most common result measures are cost and schedule"(Atkinson, 1999, p. 339). Additionally, to reach a commitment on budget and time, adequate tools and mechanisms are required constituting project management efficiency in this study (Andersen and Jessen, 2003; Grant and Pennypacker, 2006). Furthermore, in order to sustain project management capability over

[22]Competitive advantage is categorized into: (a) competitive parity, (b) temporary competitive advantage and (c) sustained competitive advantage. See also Section 2.1.1 for a discussion.

time it is essential to have an efficient knowledge transfer in the project management learning process (Jugdev et al., 2007), which leads to the two following hypotheses:

Hypothesis 8a: Commitment to project management efficiency has a positive influence on the success of R&D cooperations.

Hypothesis 8b: The capability of knowledge transfer in project management has a positive influence on the success of R&D cooperations.

3.6 Summary of Model and Hypotheses of the Study

This section shows the measurement models of the study and restates the formulated hypotheses. The measurement model for the propensity to cooperate is illustrated in Figure 3.2. The measurement model to explain the success of R&D cooperations is illustrated in Figure 3.3.

3.6.1 Propensity to Cooperate on R&D

Hypothesis 1: Function specific measures such as (a) existing R&D department, (b) alliance function and (c) technological gatekeeper enhance the probability to engage in R&D cooperations.

Hypothesis 2: The use of alliance management tools enhance the probability to engage in R&D cooperations.

Hypothesis 3: Scientific linkage increases the probability to cooperate on R&D.

3.6.2 Influence on the Success of R&D Cooperations

Hypothesis 4: Function specific measures such as (a) existing R&D department, (b) alliance function, (c) technological gatekeeper have a positive influence on the success of R&D cooperations.

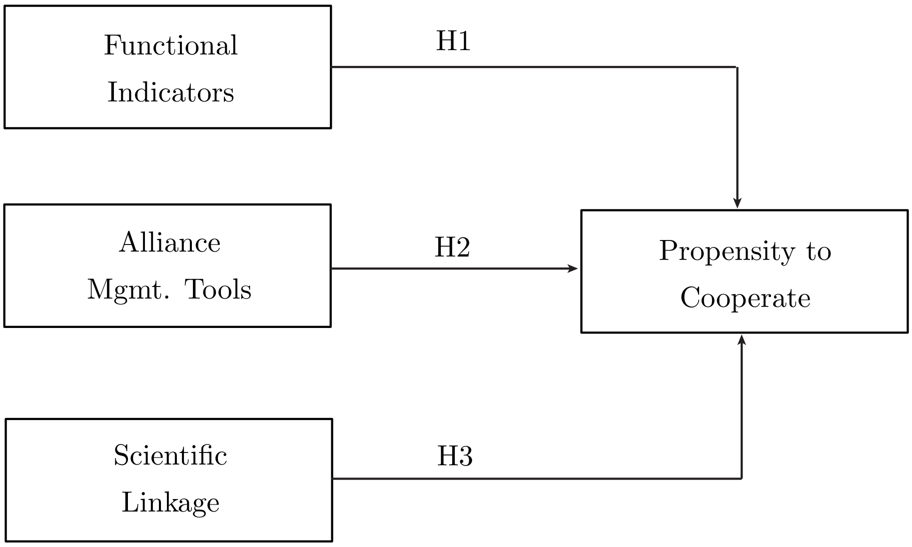

Figure 3.2: Measurement model analyzing the propensity to cooperate on R&D

Hypothesis 5: Alliance experience has a positive influence on the success of R&D cooperations.

Hypothesis 6: The use of alliance management tools has a positive influence on the success of R&D cooperations.

Hypothesis 7: Scientific linkage has a positive influence on the success of R&D cooperations.

Hypothesis 8a: Project management maturity has a positive influence on the success of R&D cooperations.

Hypothesis 8b: The capability of knowledge transfer in project management has a positive influence on the success of R&D cooperations.

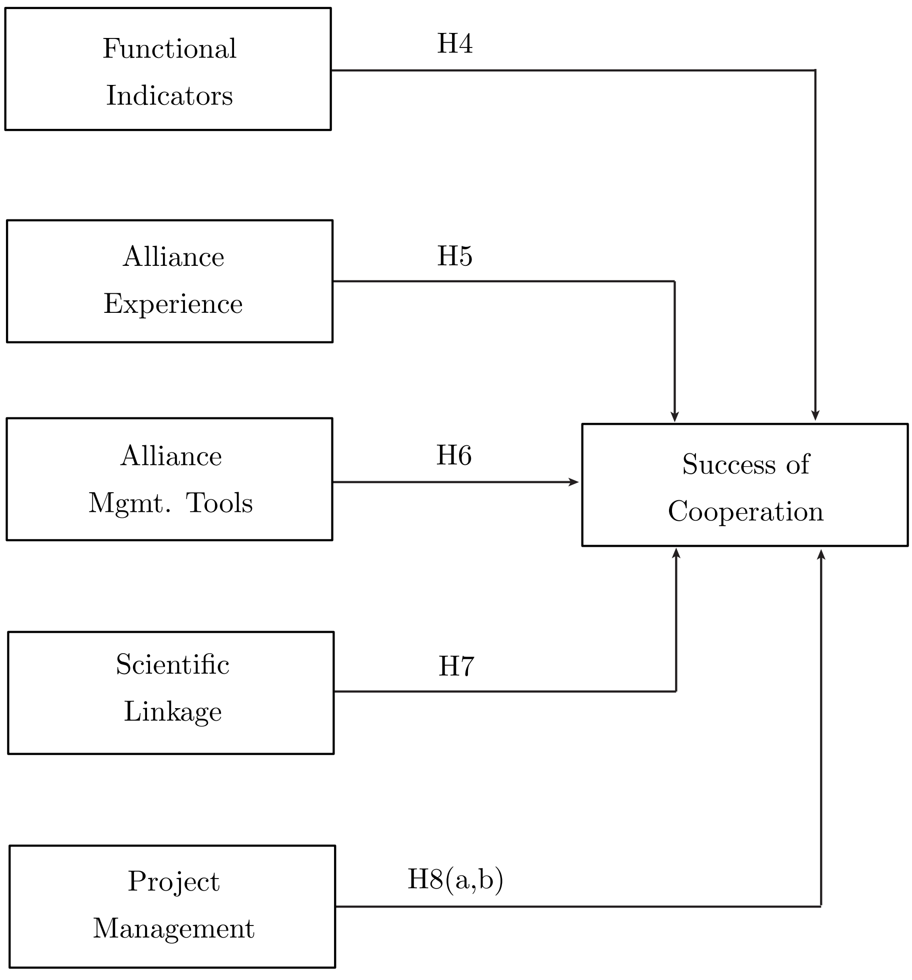

Figure 3.3: Measurement model analyzing the success of R&D cooperations

Chapter 4

Research Design

This chapter discusses the research design of the quantitative study. A definition of the population is given in Section 4.1. Section 4.2 addresses the operationalization of the study, including the description of the (a) independent, (b) dependent and (c) control variables. This chapter is concluded with a description of the sample and the data collection (Section 4.3).

4.1 Population

This study focuses on firms from the high-technology industry in Austria, Germany, and Switzerland (German speaking part) with at least ten employees. High-technology is defined by the OECD (2005a, p. 172) as firms producing: (a) chemicals and pharmaceutical products; (b) office machinery and computer equipment; (c) electrical machinery and material; (d) electronic components, radio and TV apparatus and communications; (e) medical, precision and optical instruments. In the contact phase the industry affiliation of a firm was taken from an Austrian and German marketing[23] organization according the NACE classification[24]. The high-

[23]Herold Marketing-CD-ROM Professional Edition (version 02/2008); www.werliefertwas.de; www.werliefertwas.ch

[24]NACE classification Rev.1.1:

24.4 "Manufacture of pharmaceuticals, medicinal chemicals and botanical products"

30 "Manufacture of office machinery and computers"

32 "Manufacture of radio, television and communication equipment and apparatus"

33 "Manufacture of medical, precision and optical instruments, watches and clocks"

technology industry was chosen because firms in the high-technology industry are more likely to cooperate on R&D than firms in the mid- and low-technology industries (Chesbrough and Crowther, 2006). The regional restriction on the three German speaking regions is chosen due to the geographical proximity to Graz. This proximity is expected to generate a higher commitment to a study from Graz University of Technology thus anticipating a higher response rate and higher data quality.

4.2 Operationalization

The study is designed as quantitative study. A standardized on-line questionnaire is developed which should be completed by the CEO, top-level managers or R&D managers in a firm.

Hoang and Rothaermel (2005, p. 342) state that "alliance outcomes are most appropriately studied at the level of the individual alliances." Therefore, the dependent variable is measured at project-level, whereas the independent variables (capabilities) are measured at firm-level. The operationalization of the independent variable is described in Section 4.2.1. Section 4.2.2 discusses the dependent variables of this study. The control variables are presented in Section 4.2.3.

4.2.1 Independent Variables

The independent variables measure the absorptive capacity of a firm. As already stated earlier, Cohen and Levinthal (1989; 1990) used the variable R&D expenditure divided by sales (termed R&D intensity) as a proxy for the absorptive capacity of a firm. In a comparison to other work, the work of Cohen and Levinthal (1989; 1990) represented the industrial organization literature, not especially focusing on the capabilities of firms (Zhang et al., 2007). "Lane and Lubatkin (1998) provided empirical evidence about the relatively low explanatory power of R&D spending" (Volberda et al., 2010, p. 9) concerning the representation of absorptive capacity. Zhang et al. (2007) show that R&D intensity has no effect on the likeliness to engage in cooperations. For a deeper understanding of the underlying capabilities

35.3 "Manufacture of aircraft and spacecraft"

Classification from Statistik Austria (www.statistik.at); last visited 02/11/2010 non-metric measures are suggested to determine absorptive capability more suitably (Lane and Lubatkin, 1998; Heimeriks and Duysters, 2007). Furthermore, Lane et al. (2006, p. 844) identified "the need to more directly operationalize absorptive capacity as a capability." Additionally, Volberda et al. (2010, p. 10) stress the "[m]ultidimensional characterizations of AC [(absorptive capacity)] [...] [as] important because they can explain more variance." Therefore, absorptive capacity is operationalized with the following independent variables: (a) function specific measures, (b) alliance experience, (c) alliance management tools, (d) scientific linkage and (e) project management capability.

Function Specific Measures

The functional measures consist of the following three items: (a) existing R&D department, (b) the existence of an alliance function and (c) the existence of a technological gatekeeper. "Absorption capabilities depend on specific investment, including in particular the existence of an R&D department and enough qualified personnel" (Miotti and Sachwald, 2003, p. 1483). Hypotheses 1 and 4 state that the above existing functional measures enhance the propensity to cooperate and also the likeliness of success of such a cooperation. A dichotomous variable evaluated by the manager is used to indicate (a) an existing R&D department (Miotti and Sachwald, 2003), (b) an alliance function (see Table 4.1) and (c) a technological gatekeeper (Fritsch and Lukas, 2001; Miotti and Sachwald, 2003; Zhang et al., 2007).

Alliance Experience

According to Hypothesis 5, it is expected that the alliance experience has an influence on the success of R&D cooperations. Table 4.1 shows how alliance experience is operationalized in other studies. The studies listed in this table do not specifically focus on R&D cooperations thus showing a broad range of determinants for successful cooperations. Six categories to measure alliance experience were identified: (a) overall number of alliances, (b) years of experience, (c) cumulative alliance years, (d) individual experience, (e) mutual experience, (f) multiple-partner experience. Some authors (e.g. Zollo and Winter, 2002; Sampson, 2005) show that alliance experience can be measured with the number of conducted alliances in a certain period (e.g. in the past ten years). Another way to operationalize alliance experience is to ask

	Anand and Khanna (2000)	Callahan and MacKenzie (1999)	Das and Kumar (2007)	Deeds and Hill (1996)	De-Man (2005)	Douma et al. (2000)	Draulans et al. (2003)	Dyer et al. (2001)	Emden et al. (2003)	Heimeriks and Duysters (2007)	Hoang and Rothaermel (2005)	Inkpen (1998)	Ireland, Hitt and Vaidyanath (2002)	Kale et al. (2001)	Kale et al. (2002)	Medcof (1997)	Reuer et al. (2002)	Rothaermel and Deeds (2006)	Sampson (2005)	Simonin (1997)	Zollo and Winter (2002)
alliance functions					x			x		x				x	x						
alliance department					x					x				x	x						
alliance specialist					x		x	x							x						
external consultants				x					x												
dedicated personnel										x			x								
experience	x		x	x	x		x	x	x	x	x		x	x	x			x	x	x	x
overall number of alliances				x	x		x											x	x		x
years of experience					x		x														
cumulative no. of alliances														x	x			x			
individual experience								x		x		x								x	
mutual experience	x					x	x				x	x		x	x	x	x	x		x	x
multiple-partner experience																x	x	x			
alliance management tools					x					x	x										
databases, manuals		x			x			x		x	x				x			x			
standardized procedures			x		x					x					x			x	x		
organizational routines										x	x						x			x	
partner selection processes					x			x						x		x		x		x	
evaluation mechanisms		x					x		x												

Table 4.1: Operationalization of alliance capability

when the first cooperation was formed (e.g. Draulans et al., 2003; De-Man, 2005). A refined measure of the just mentioned determinants is to calculate the cumulative alliance years of a firm. This measure is calculated in the following way: if a firm has formed two alliances with two and five years respectively, then the cumulative sum would be seven years of experience (e.g. Kale et al., 2002; Rothaermel and Deeds, 2006). Furthermore, some authors (e.g. Anand and Khanna, 2000; Reuer et al., 2002) distinguish the alliance experience by the type of experience a firm has made (individual, mutual, partner). The individual experience focuses on the knowledge of an expert in the firm, e.g. vice-president or manager of alliances. Meaning that alliance experience is a sticky capability staying with the expert and, therefore, being transferable[25]. The mutual experience targets dyadic alliances where the number of dyadic alliances is measured. It is shown that alliance performance improves if alliances are entered with the same partner more than once. This dyadic relationship allows a better understanding of the partners since the skills and capabilities of the partner are already known. Additionally, the multiple-partner experience is operationalized by Rothaermel and Deeds (2006), who identified three partner categories in a study about biotechnology firms: upstream alliances (with research organization), horizontal alliances (with other biotechnology firms) and downstream alliances (with pharmaceutical firms). The findings show that upstream alliances demand more effort than downstream alliances thus leading to more experience.

To conclude, in this study alliance experience is measured as a metric variable with the number of conducted cooperations in the past ten years[26] (Kale et al., 2002; Mora-Valentin et al., 2004; Rothaermel and Deeds, 2006; Heimeriks and Duysters, 2007). This measure can be evaluated in the questionnaire quickly and was therefore chosen.

[25]The issue that 'alliance experience is transferred with the manager' was also mentioned in the pilot study by Alexander Rinderhofer (CEO, Zeta GmbH, Grambach bei Graz; 06/02/2009) in the interview conducted within the context of this study.

[26]Scholars are discussing if ten years are the correct time span to measure alliance experience. Heimeriks and Duysters (2007, p. 35) states: "In the literature, there is growing consensus that five years is the correct period to examine." However, this is an individual view; Rothaermel and Deeds (2006) for example suggest ten years.

Alliance Management Tools

As already stated in Section 3.4.3 and Section 3.5.3 the alliance experience needs to be transferred into tools allowing to manage cooperations more efficiently. Alliance management tools allow to codify alliance management experience (De-Man, 2005; Hoang and Rothaermel, 2005; Heimeriks and Duysters, 2007). Table 4.1 shows the operationalization of alliance management tools used in previous studies. Manuals or databases can be used to store alliance experience (e.g. Callahan and MacKenzie, 1999; Kale et al., 2002) thus enabling access to lessons-learned from previous cooperations. Kale et al. (2002, p. 750) report that alliance management manuals allow firms "to guide action or decision making in specific alliance situations." This rather process oriented approach is also mentioned by other scholars. The formalization of standardized procedures or organizational routines also contributes to alliance management capability (e.g. Reuer et al., 2002; Das and Kumar, 2007). The organizational routines include, for example, the partner selection process (e.g. Dyer et al., 2001; De-Man, 2005) or the evaluation mechanism after a completed cooperation (Callahan and MacKenzie, 1999; Emden et al., 2003).

In this study two measures are used to describe the degree of alliance management tool usage: level of detail of the (a) manuals and (b) standardized procedures. A 6-point Likert scale is used to evaluate these two measures. Following the argumentation from above, these two measures evaluate the respective level of detail, therefore, they also cover the aspect of the partner selection process and the evaluation mechanisms.

Scientific Linkage

As already motivated in Section 3.4.4 and 3.5.4 scientific linkage consists in this study of two dimensions: (a) screening the environment for external knowledge and (b) network to scientific partners. Table 4.2 shows previous studies using these dimensions.

Search strategies are seen as a basic element of absorptive capacity. Spithoven et al. (2010) even state that "search processes are generally known as absorptive capacity". However, as argued earlier the scope of absorptive capacity is broader than just the focus on search strategies or R&D intensity (e.g. Fontana et al., 2006;

	Baker et al. (2003)	Bizan (2003)	Borgatti and Cross (2003)	Cohen and Levinthal (1990)	Fabrizio (2009)	Fontana et al. (2006)	Lane et al. (2006)	Lane and Lubatkin (1998)	Laursen and Salter (2006)	Owen-Smith and Powell (2004)	Rothwell and Dogson (1991)	Rothwell (1992)	Shenkar and Li (1999)	Spithoven et al. (2010)	Van den Bosch et al. (1999)	Vanhaverbeke et al. (2007)	Veugelers (1997)	Volberda et al. (2010)	Zahra and George (2002)	Zucker et al. (2002)
linkage to																				
science and technology								x			x	x					x			
outside scientists					x				x											x
potential knowledge sources	x		x	x			x			x				x	x	x				
search for knowledge			x			x	x		x					x		x			x	
similarity	x			x				x								x		x		
complementarity		x						x					x			x				

Table 4.2: Operationalization of scientific linkage

Rothaermel and Boeker, 2008). The search strategies of a firm are just one aspect of scientific linkage. To, furthermore, overcome the problem that "more distant knowledge falls outside the [search] scope" (Vanhaverbeke et al., 2007, p. 12) of a firm, a close link to scientific partners could help to identify relevant and helpful knowledge outside the scope of the firm itself (Shenkar and Li, 1999; Owen-Smith and Powell, 2004; Vanhaverbeke et al., 2007). The construct of scientific linkage is operationalized with three measures: (a) search strategies; network to scientific partners (b) nationally and (c) internationally. For the evaluation of these three items a 6-point Likert scale is used.

Project Management Capability

Hypotheses 8a and 8b focus on the project management capability. The hypotheses state that project management capability has a positive influence on the success of R&D cooperations. In this study project management capability is determined by two factors: (a) project management efficiency and (b) the degree of knowledge transfer involved in project management. Standardized questionnaires from previous studies on project management capability were evaluated. The following five measures were identified fitting the perspective of project management efficiency (Ibbs and Kwak, 2004; Munns and Bjeirmi, 1996; Andersen and Jessen, 2003; Atkinson, 1999; Grant and Pennypacker, 2006; Jugdev and Mathur, 2006; Jugdev et al., 2007): (i) best of our branch of business, (ii) methods and tools, (iii) project management system, (iv) project closure in line with budget, (v) project closure in line with time. According to Jugdev and Mathur (2006) and Jugdev et al. (2007) the knowledge transfer is regarded as tacit knowledge of the firm and in this study consists of seven items, including the following items (Jugdev and Mathur, 2006; Jugdev et al., 2007; Eisenhardt and Martin, 2000): (i) teach knowledge, (ii) experience transfer, (iii) experience discussion, (iv) learning-by-doing, (v) informal knowledge exchange, (vi) mentorship and (vii) use of pictorial language. All project management items are measured by means of a 6-point Likert scale.

4.2.2 Dependent Variables

This study focuses on two aspects of R&D cooperation management. First, the propensity to participate in an R&D cooperation (Hypotheses 1–3) is modeled. A dichotomous variable is used to identify if a firm has already participated in an R&D cooperation. In the questionnaire R&D is defined according to Section 2.2. Furthermore, it is stated that the cooperation needs to be entered with a legal independent partner, according to the definition of a cooperation in Section 3.1.2.

Second, this study looks at the success of R&D cooperations (Hypotheses 4–8). The measure of success is more difficult to define than the participation in a cooperation. Freeman and Beale (1992) state that "success means different things to different people." Studies based on the Community Innovation Survey measure the success according to the sales of innovative products and, furthermore, according to the cost reduction due to innovative processes improvements (Belderbos et al., 2004; Aschhoff and Schmidt, 2008). Cloodt (2009) measures the innovation performance based on the number of patents, whereas Hagedoorn and Cloodt (2003) combine R&D input, patent count, patent citations and new product announcements. Hagedoorn and Cloodt's (2003) study shows that these four variables have a strong correlation, which is why they suggest using any of these indicators to measure innovation success.

"Traditionally, companies patent more than they publish, and university researchers publish usually more than they patent"(Meyer, 2000, p. 410). Publications are considered as indicators for scientific success and patents as indicators for technological success (Meyer, 2000; Hagedoorn and Cloodt, 2003; Van Looy, Callaert and Debackere, 2006). However, this study focuses on R&D projects, therefore, including both science and technology indicators. Technology indicators include for example prototypes (Veryzer, 1998; OECD, 2005b) or the transfer to product/service development (Hagedoorn and Cloodt, 2003; OECD, 2005b; Okamuro, 2007; Aschhoff and Schmidt, 2008). Additionally, the compliance with the project schedule (Dvir et al., 2006; Curran et al., 2009; Kerssens-van Drongelen and Bilderbeek, 1999; Dvir, Lipovetsky, Shenhar and Tishler, 1998) and budget (Dvir et al., 2006; Curran et al., 2009; Dvir et al., 1998) are also considered as essential for a successful project. The six identified success dimensions are listed below:

- patent or utility model application
- accepted publication
- existence of a prototype
- transfer to new process or product development
- stayed within budget
- finished within scheduled time frame

The above stated variables are measured dichotomously. The influence of the stated capabilities on these success variables is tested individually by means of a binary regression analysis. Furthermore, a formative index[27] is created which combines the six above stated success categories. As an example, Nokia uses a multidimensional construct to measure the outcome of their innovation process consisting of (a) publication, (b) patent, (c) prototype and (d) product[28]. Additionally, "as most project managers' attention is focussing [sic!] on compliance with timelines and budgets" (Curran et al., 2009, p. 460) these two variables complete the proposed formative index. Projects having more than three positive answers are considered to be more successful projects than the others, leading to the categorization into more successful and less successful projects. The advantage of the created formative index is that the included variables overcome the problem of the different output-foci from basic research, applied research and experimental development. In the case of basic research it is difficult to define an output dimension since basic research is "directed towards some broad fields of general interest, with the explicit goal of a broad range of applications in the future" (OECD, 2002, p. 78). However, researchers conducting basic and applied research aim for publications and patents. Experimental development projects focus on prototypes and new product developments (OECD, 2002,

[27] A formative index is given "when a latent variable is defined as a linear sum of a set of measurements or when a set of measures of a dependent variable is determined by a linear combination of measures of independent variables, the measures are termed formative indicators: the measures produce the constructs so to speak" (Diamantopoulos and Winklhofer, 2001, p. 270).

[28] Known at Nokia as the 4Ps of innovation. Luminary Talk of Claudio Marinelli (Director; Open Innovation and Academic Relations; Nokia Research Center) at the International Conference of ISPIM - The International Society for Professional Innovation Management (ISPIM) in Bilbao (06/08/2010)

pp. 78-79). The individual success variables measure different stages in the innovation process and, therefore, can be uncorrelated but still combined in a formative index. The possible problem that the individual variables might not be correlated is desired "because two variables that might even be negatively related can both serve as meaningful indicators of a construct" (Diamantopoulos and Winklhofer, 2001, p. 271). The validation of the measures will follow in Section 5.2.

4.2.3 Control Variables

Previous studies showed an influence of the industry affiliation on the success of a cooperation (e.g. Zahra and Nielsen, 2002; Aschhoff and Schmidt, 2008; Tsai, 2009). Therefore, this study is controlled for industry dummies within the high-technology industry: (a) pharmaceutical industry, (b) computer and office equipment (IT), (c) electronic-communication and aerospace, and (d) medical, precision and optical instruments. Furthermore, previous studies show a positive relationship between the success of an R&D cooperation and the size of the firm (Bayona et al., 2001; Fritsch and Lukas, 2001; Miotti and Sachwald, 2003). This study controls for the firm size. The firm size is measured dichotomously with the affiliation to a group of companies (e.g. Miotti and Sachwald, 2003). This dichotomous measure is also used in the CIS surveys as classification if a firm is a small or medium-sized enterprise (SME) or not (Aschhoff and Schmidt, 2008).

4.3 Sample and Data Collection

In the selected countries a total of 2,515 firms from the high-technology industry were identified. A selection of every fourth firm gave a sample of 629 firms. For this survey R&D managers, CTOs or CEOs were targeted as respondents. Therefore, contact persons for these 629 firms were identified by (a) using marketing information[29], (b) searching social media platforms[30] and (c) by calling the firm. The identified managers were contacted via telephone and asked to participate in this study (see also Figure 4.1 for an illustration of the response process). 322 firms

[29]Herold Marketing-CD-ROM Professional Edition

[30]www.xing.com, last visited 09/06/2010; www.linkedin.com, last visited 09/06/2010

rejected the participation on the phone, leaving 307 firms which agreed to participate. The managers who agreed to participate received an e-mail with a link to a standardized online questionnaire[31]. 122 managers filled out the questionnaire, however, 41 questionnaires had to be excluded due to random answers, wrong industry categorization or firms having less than ten employees. This gives a final sample of 81 questionnaires and leading to a response rate of 13%. The data was collected in a nine-month period (from June 2009 – January 2010).

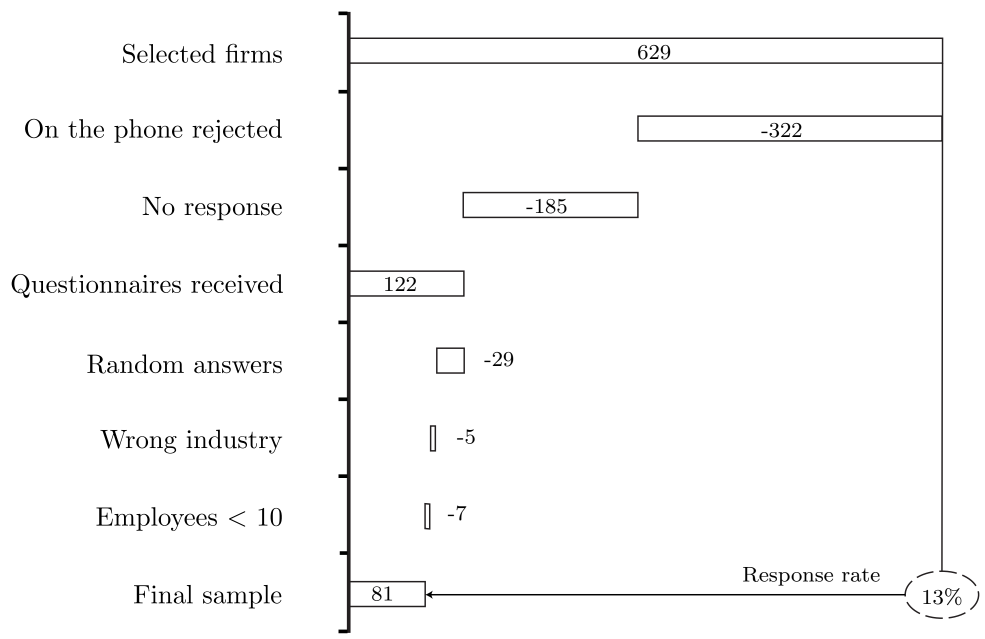

Figure 4.1: Response process

As mentioned above, the data was collected through a standardized online questionnaire. To enhance validity, the questionnaire was tested in a pilot study with 14 people including academics, CEO/CFOs, R&D managers, entrepreneurs and psychologists[32]. The feedback of this pilot study contributed to the structure and the

[31] The software LimeSurvey was used to create and conduct the online questionnaire (www.limesurvey.org last visited 09/06/2010).

[32] Academics: Bernd Zunk (Graz University of Technology; 05/26/2009); Caroline Riemer (Graz University of Technology; 05/28/2009); Paul Pfleger (Graz University of Technology; 05/30/2009); Prof. Ulrich Bauer (Graz University of Technology; 06/02/2009)

clarity of the questionnaire, resulting in minor changes to the questionnaire. The results of this study will be presented in the next chapter.

CEO/CFO: Alexander Rinderhofer (Zeta GmbH, Grambach bei Graz; 06/02/2009); Gerhard Zrim (Virtual Vehicle, Graz; 06/05/2009)

Entrepreneur: Andreas Flanschger (Bionic Surface Technologies, Graz; 05/28/2009); Mario Fallast (SmaXtec, Graz; 06/04/2009)

R&D Manager: Johannes Wolkerstofer (Graz University of Technology; 06/04/2009); Christoph Adametz (Graz University of Technology; 06/09/2009); Prof. Franz Stelzer (Graz University of Technology; 06/15/2009); Thomas Bereuter (Graz University of Technology; 06/30/2009)

Psychologists: Verena Schieretz (Graz; 05/29/2009); Barbara Lindinger (Kirchdorf/Krems; 06/05/2009)

Chapter 5

Results

This chapter presents the results of this study. Section 5.1 addresses the descriptive statistics. Section 5.2 discusses the validation of the used variables. In Section 5.3 the assessed regressions models are presented and interpreted regarding (a) the propensity to cooperate and (b) the likeliness of success of an R&D cooperation. Finally, Section 5.4 summarizes the hypotheses tests of this study.

5.1 Descriptive Statistics

This section provides the descriptive statistics of the variables used to answer the stated research questions. The characteristics of the firm are reported in Section 5.1.1. The responses concerning the independent variables are presented in Section 5.1.2–5.1.5. Section 5.1.6 and 5.1.7 discusses the responses regarding the dependent variables.

5.1.1 Firm Characteristics

Figure 5.1 gives an overview of the responses concerning the firm's industry categorization. Most of the responses belong to the industry category medical, precision and optical instruments accounting for 59.3% responses in the investigated sample.

12.4% of the responses belong to the pharmaceutical industry; 16.0% to the IT industry. 8.6% of the responses fall into the electronics-communication category. The smallest group is the aerospace industry accounting for 3.7% of the responses.

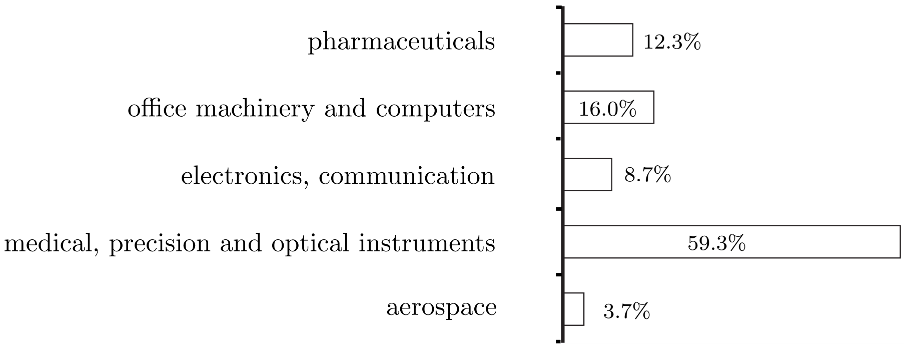

Figure 5.1: Industry affiliation of the responding firms (n=81)

Slightly more than half of the firms (56.8%) belong to a group of companies[33]. This indicates that the other firms (43.2%) can be considered being SMEs (see also Figure 5.2).

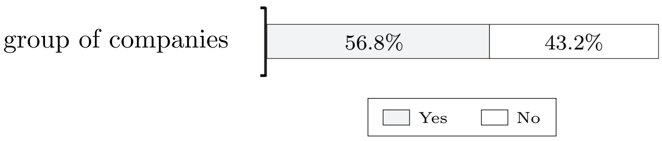

Figure 5.2: Affiliation to a group of companies (n=81)

Figure 5.3 shows the occupation of the responders of this study. The occupation of the responders allows to estimate the level of expertise from the responder affecting the data quality of this study. The data quality is considered high since almost three quarters of the responders (72.3%) are employeed in an R&D department. Two thirds of the responders (68.4%) have a management responsibility in the R&D department. Almost another quarter (22.4%) is engaged in management activities concerning the overall firm. Not fitting the described categories (Others) account for 5.3% of the responders and include: business development managers, head of university collaboration activities, IT and marketing managers.

[33]The affilitation to a group of companies is used in the CIS survey study design as indicator if a firm is an SME or not. Firms which do not belong to a group of companies are considered as SMEs (Arranz and de Arroyabe, 2008).

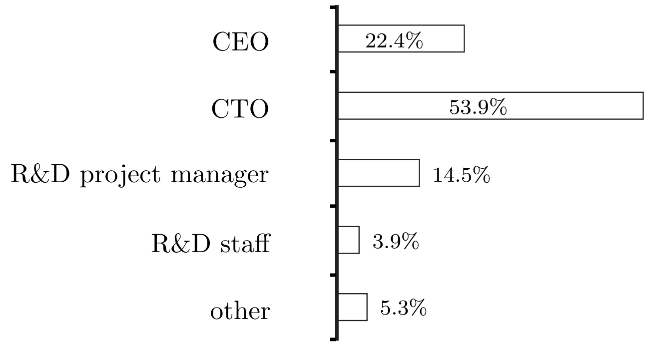

Figure 5.3: Function of the responder in the firm (n=76)

5.1.2 Function Specific Indicators

Figure 5.4 illustrates the responses regarding the function specific indicators. In the sample 91.4% of the responders have declared that their firm has an R&D department. 43.6% of the responders indicated that their firm has at least one person looking for potential cooperation partners (alliance function). Almost two thirds of the firms (63.0%) have at least one person systematically looking for new technological developments (gatekeeper).

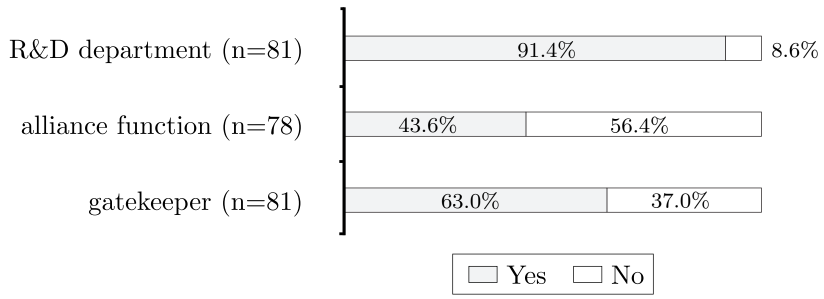

Figure 5.4: Existence of function specific indicators in firms

5.1.3 Alliance Management Capability

Alliance management capability is measured twofold: (1) the descriptive statistics of previous alliance experience are presented; (2) the adoption of alliance management tools are discussed.

Alliance Experience

Alliance management experience is measured with the number of formed cooperations in the past ten years. This measure also includes non-R&D cooperations. The findings are presented in Figure 5.5. Five firms did not enter any cooperation in the past ten years. Almost three quarters of the firms (70.4%) undertook between one and ten cooperations. 14.5% have formed between eleven and twenty cooperations. Another 14.5% were engaged in more than 20 cooperations, including three firms (3.9%) with over 100 conducted cooperations.

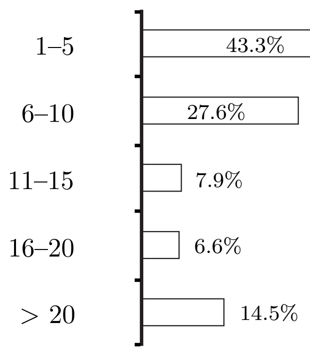

Figure 5.5: Formed cooperations in the past ten years (n=76)

Alliance Tools

The first two items in Figure 5.6 show the responses of the managers regarding their estimations of the availability and usage of alliance management tools. The managers assessed the following items on a 6-point Likert scale. The left side in the figure represents a full agreement (1: '+ + +') and the right side a full disagreement (6: '− − −'). The dashed line builds the boarder from each individual item in respect of the standard deviation. The findings indicate that more firms use standardized procedures than having a detailed alliance manual[34]. However, the means indicate that the responders disagreed more often than agreed on these two items.

[34]The abbreviations of the variables and items can be found in Appendix C on Page 126.

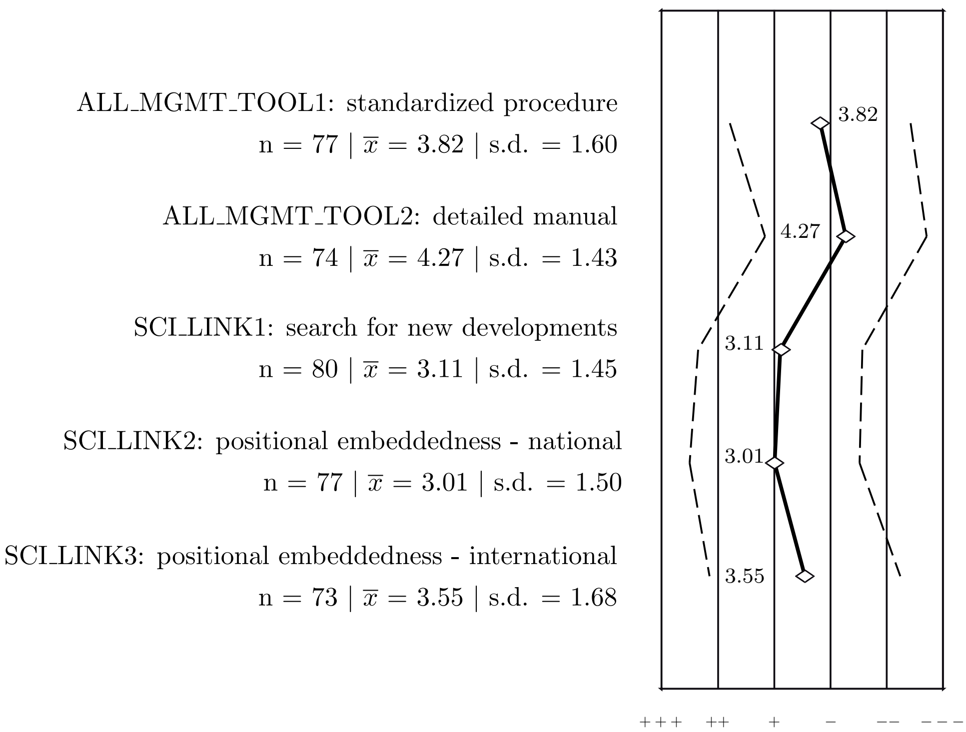

Figure 5.6: Likert estimation: Alliance management tools and scientific linkage (n ... sample, $\overline{x}$ ... mean, s.d. ... standard deviation)

5.1.4 Scientific Linkage

The last three items in Figure 5.6 show the estimates concerning the scientific linkage of a firm. All three items have a higher agreement than disagreement rate. The findings show that firms are nationally better embedded in their respective scientific field than internationally. Furthermore, the systematic search for new technological developments is estimated to lie in between the two previously mentioned items.

5.1.5 Project Management Capability

This section discusses the two concepts of project management capability: (1) project management efficiency and (2) project management knowledge transfer. First, the estimations of the project management efficiency are illustrated in Figure 5.7. The figure shows that the investigated firms have a higher agreement rate than disagreement rate. The highest agreement rate regarding the project management efficiency is found for the adoption of a project management system. This item is followed by the estimation that the project closes in line with (a) budget and (b) schedule. In between the last two mentioned items there is the agreement that the firms use good project management methods and tools. The item with the least agreement in this set of items is the estimation that the firm has the best project management in their individual branch of business.

Second, Figure 5.8 shows the estimations regarding the project management knowledge transfer. Two items received more disagreements than agreements: (a) reflection of own project management experience and (b) the adoption of a project management mentoring program. The highest agreement received the aspect that face-to-face communication is used as an effective method to exchange project management know-how in the focal firm. Another way to transfer project management knowledge is with an active participation in a project (learning-by-doing). This aspect of knowledge transfer received also a rather high agreement rate. Furthermore, most responders agreed that firms motivate their project managers to transfer their project management knowledge to other team members. Additionally, the transfer of project management knowledge is supported by a special type of communication style. Slightly more than half of the responders agreed that the usage of pictorial language is a good method to transfer project management knowledge.

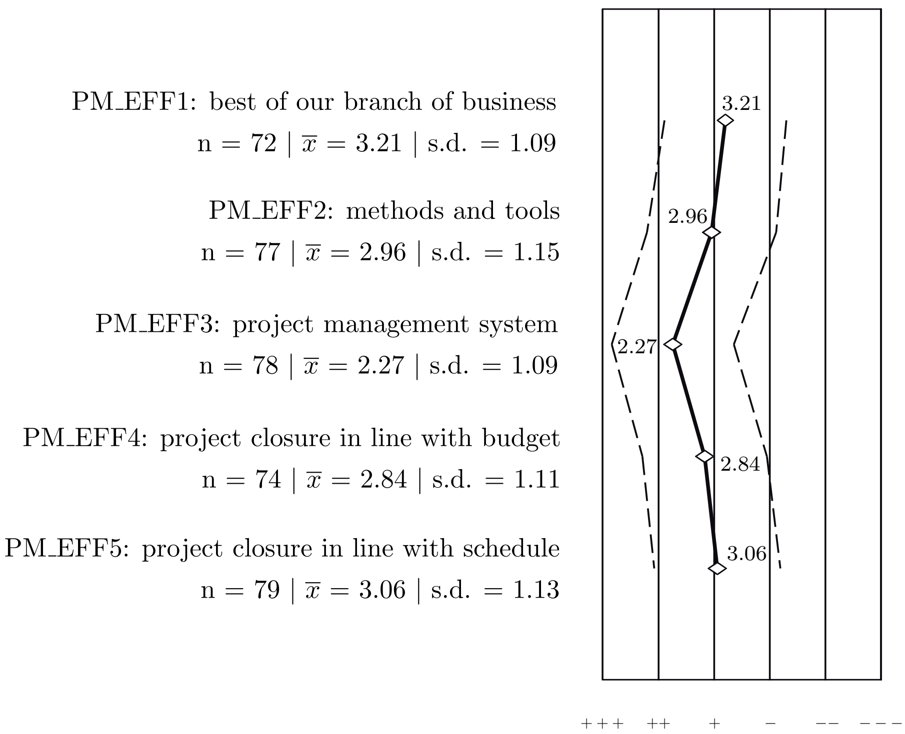

Figure 5.7: Likert estimation: Project management efficiency
(n ... sample, $\overline{x}$ ... mean, s.d. ... standard deviation)

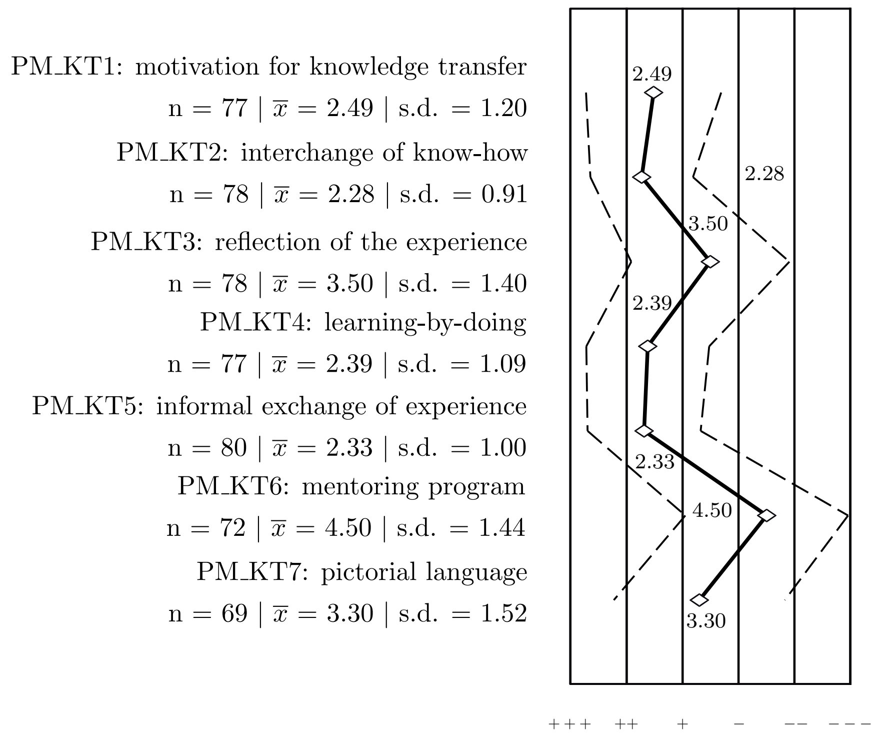

Figure 5.8: Likert estimation: Project management knowledge transfer
(n ... sample, $\overline{x}$ ... mean, s.d. ... standard deviation)

5.1.6 Engagement in R&D Cooperations

The sample shows that almost two thirds of the investigated firms have conducted R&D in a cooperation with at least one other legally independent partner. The two following illustration show the engagement in cooperations depending on a firm's (1) industry category and (2) affiliation to a group of companies.

First, firms from the subcategories computer, office equipment (also including the semiconductor industry) and firms from the pharmaceutical industry have a higher share of cooperation activities than the other subcategories within the high-technology sector (see Figure 5.9 for an illustration). Others include the subcategories: electronic communication and aerospace

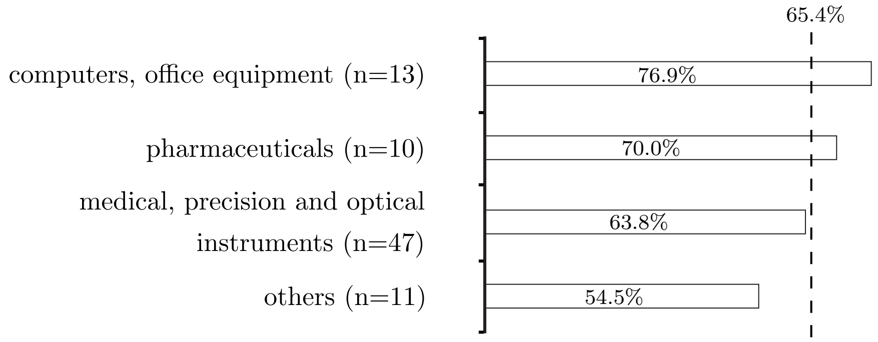

Figure 5.9: Firms entering R&D cooperations in the high-technology sector

Second, as stated in Section 4.2.3 the affiliation to a group of companies is used as proxy for the firm size. Firms which belong to a group of companies are categorized as large firms and firms which have no affiliation to a group of companies are categorized as SMEs. The descriptive findings show that large firms have a higher rate to be engaged in R&D cooperations than SMEs. See Figure 5.10 for an illustration.

5.1.7 Success of R&D Cooperations

The success of an R&D cooperation is measured with the following six dichotomous variables:

- patent or utility model application
- accepted publication

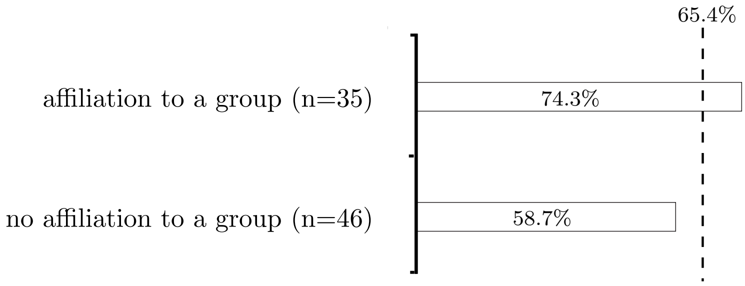

Figure 5.10: Engagement in R&D cooperations in respect to group affiliation

- existence of a prototype
- transfer to new process or product development
- stayed within budget
- finished within scheduled time frame

Figure 5.11 illustrates the outcomes of the individual R&D cooperations investigated in this study. The responses state that 36% of the projects resulted in a patent or utility model application. A little bit less than half of the projects (48%) generated a scientific publication as output. A prototype was developed in most of the cases (92%). A transfer to a product or service was achieved in 84% of the projects. Three quarters of the projects finished within time and half of the projects (52.8%) finished within schedule.

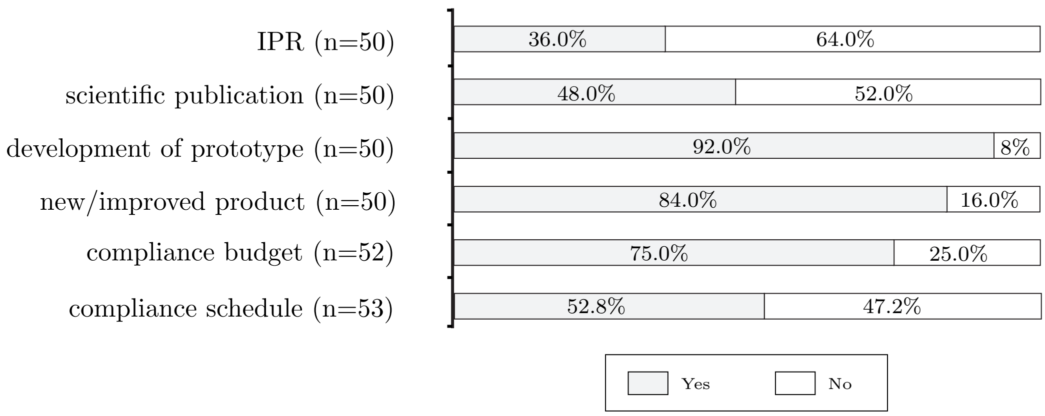

Figure 5.11: Success of investigated R&D cooperations

5.2 Validation of Measures

In this section the independent and dependent variables are checked for validity. First, the data is preprocessed by analyzing the missing values and by imputing missing data. Second, a factor analysis is done to verify unidimensionality of the items representing the individual variables. Third, a single measure is calculated for the independent variables. This is done after checking the variables for the internal consistency with a Cronbach-α analysis. Fourth, the formative construct of the *Success Index* is validated representing the dependent variable used in the success hypotheses tests.

5.2.1 Data Preprocessing

Before calculating a single measure for the independent and the dependent variables the following steps need to be done: (a) the missing values of the individual items are analyzed and (b) are imputed if the missing value rate is below 10%. Furthermore, (c) the scales of the items belonging to the independent variables are reversed to fit the success dimension.

Missing Value Analysis

Table 5.1 lists how many cases are missing for each item. The value analysis shows that all but three items have less than 10% missing values. The three items above the 10% level are: PM_EFF1, PM_KT6, PM_KT7.

Value Imputation

The imputation of variables below 10% is unproblematic (Hair, Black, Babin and Anderson, 2009, p. 56). Therefore, the items with a higher missing value rate are excluded from the value imputation and, furthermore, are also excluded from any further analysis. Mean substitution was used to impute the missing values. The value imputation was only applied for the independent variables but not for the dependent variables.

	N	Missing	
	Count	Count	Percent
RD_DEP	81	0	0.0%
ALL_FUNC	78	3	3.7%
GATEKEEPER	81	0	0.0%
ALL_MGMT_TOOL1	77	4	4.9%
ALL_MGMT_TOOL2	74	7	8.6%
SCI_LINK1	80	1	1.2%
SCI_LINK2	77	4	4.9%
SCI_LINK3	73	8	9.9%
PM_EFF1	72	9	11.1%
PM_EFF2	77	4	4.9%
PM_EFF3	78	3	3.7%
PM_EFF4	74	7	8.6%
PM_EFF5	79	2	2.5%
PM_KT1	77	4	4.9%
PM_KT2	78	3	3.7%
PM_KT3	78	3	3.7%
PM_KT4	77	4	4.9%
PM_KT5	80	1	1.2%
PM_KT6	72	9	11.1%
PM_KT7	69	12	14.8%

Table 5.1: Missing value analysis for the independent variables

Recoding of Variables

The dependent variables measure (a) if a firm has already cooperated on R&D and (b) the success of a cooperation. Ad (a), the dependent variable COOP is coded '1' if a firm has cooperated on R&D and '0' if not. Ad (b), a higher score indicates more successful cooperation projects. However, a higher score represents a non-presence of the individual construct in case of the independent variable. Therefore, the scores of the independent variables are reversed.

5.2.2 Factor Analysis

Exploratory factor analysis is used to investigate if the individual items belong to a certain set of variables. For this analysis the following parameters are used[35]:

- Principal component analysis
- Eigenvalues over 1.0 as criterion to extract the number of factors
- VARIMAX rotation

Principal component analysis is used to generate a reduced set of m variables (components) from a set of p items. Multicollinearity is assumed among the individual items since a set of items is designed to measure an underlying construct. The issue of multicollinearity among the items should be assessed with a Kaiser-Meyer-Olkin's measure of sampling adequacy (MSA) according to Hair et al. (2009, p. 105). The overall MSA value is 0.715 and is well above the recommended value of 0.5. The individual MSA values are listed in Table 5.2. In the table a minimum value of 0.561 is reported being also above the recommended value of 0.5.

The factor matrix is shown in Table 5.3. Only the factor loadings above 0.65 are shown in this table. All other factor loadings are suppressed. The cut-off value of 0.65 is selected according to Hair et al. (2009, p. 117), stating that this is the lower level of a factor loading providing significant results for a sample between 70 and 84 (the investigated sample includes 81 responses). The factor analysis extracted four factors which explain 70.03% of the total variance of the data. The identified variables can be attributed to the following latent variables:

[35] This set up represents a quasi standard when applying a factor analysis.

Item	MSA
ALL_MGMT_TOOL1	0.644
ALL_MGMT_TOOL2	0.660
SCI_LINK1	0.806
SCI_LINK2	0.690
SCI_LINK3	0.561
PM_EFF2	0.706
PM_EFF3	0.803
PM_EFF4	0.704
PM_EFF5	0.746
PM_KT1	0.711
PM_KT2	0.830
PM_KT3	0.716
PM_KT4	0.699
PM_KT5	0.722

Table 5.2: MSA values for the individual items

	Component				Comm-
Item	1	2	3	4	unality
ALL_MGMT_TOOL1		0.849			0.851
ALL_MGMT_TOOL2		0.923			0.785
SCI_LINK1			0.680		0.540
SCI_LINK2			0.810		0.617
SCI_LINK3			0.867		0.768
PM_EFF2					0.807
PM_EFF3					0.641
PM_EFF4				0.864	0.677
PM_EFF5				0.837	0.567
PM_KT1	0.828				0.478
PM_KT2	0.806				0.678
PM_KT3					0.810
PM_KT4	0.790				0.780
PM_KT5	0.744				0.804

Table 5.3: Rotated component matrix of factor analysis solution

1. Project Management Knowledge Transfer
2. Alliance Management Tools
3. Scientific Linkage
4. Project Management Efficiency

The communalities reported in the table are all but one (PM_KT1) above the guideline value of 0.5 as stated in Hair et al. (2009, p. 119). However, the item PM_KT1 is included in the analysis since this item loads highest on the first factor.

The findings of the factor analysis are used for a dimension reduction by combining the items into a single measures. Three possibilities are reported for data reduction (Hair et al., 2009, pp. 123-128):

- pick one variable with the highest factor loading to represent the factor
- replace the items with the summated scales
- replace the items with the factor scores

For this study, the second option is chosen. Therefore, the next section describes how the summated scales are calculated.

5.2.3 Calculating the Variables

Reliability tests are conducted to verify if a summated scale is a good representative for the combined items. Therefore, the Cronbach-α values are calculated for the four identified variables. A Cronabach-α value above 0.70 represents a good fit of unidimensionality for the individual variable (Hair et al., 2009, p. 127). The reliability tests are done twice: (1) for the variables used to determine the propensity to cooperate including the full sample (see Table 5.4); (2) for the variables used to predict the success of a cooperation using the sample with the cooperating firms (see Table 5.5). In the first case the lowest Cronbach-α is 0.803 and in the second case the lowest Cronbach-α is 0.732. In both cases all Cronbach-α's are above 0.70 hence showing sufficient internal consistency to be combined into a single measure.

The next step is to calculate the summated scales. Summated scales is a "[m]ethod of combining several variables that measure the same concept into a single variable

Variable	Cronbach's α
ALL_MGMT_TOOL	0.859
SCI_LINK	0.803

N=81

Table 5.4: Reliability measurement (Propensity to cooperate)

Variable	Cronbach's α
ALL_MGMT_TOOL	0.866
SCI_LINK	0.732
PM_EFF	0.780
PM_KT	0.784

N=53

Table 5.5: Reliability measurement (Success)

in an attempt to increase the reliability of the measurement through multivariate measurement. In most instances, the separate variables are summed and then their total or average score is used in the analysis" (Hair et al., 2009, p. 3). In this analysis the average score of the variables is calculated. Equation 5.1–5.4 report the equation to calculate the individual variables.

$$ALL\_MGMT\_TOOL = \frac{ALL\_MGMT\_TOOL1 + ALL\_MGMT\_TOOL2}{2} \tag{5.1}$$

$$SCI\_LINK = \frac{SCI\_LINK1 + SCI\_LINK2 + SCI\_LINK3}{3} \tag{5.2}$$

$$PM\_EFF = \frac{PM\_EFF1 + PM\_EFF2}{2} \tag{5.3}$$

$$PM\_KT = \frac{PM\_KT1 + PM\_KT2 + PM\_KT4 + PM\_KT5}{4} \tag{5.4}$$

Additionally, a dichotomous variable is calculated representing the compliance with the project schedule. In the questionnaire the project duration of the R&D cooperation project was asked twofold: (1) planned project duration and (2) actual project duration. In the case that the project duration does not exceed the planned project duration the variable *Schedule* is set to '1' otherwise set to '0' (see also Equation 5.5).

$$SCHEDULE = \begin{cases} 1 \text{ if } SCHED\_PLAN \leq SCHED\_ACT \\ 0 \text{ else} \end{cases} \tag{5.5}$$

5.2.4 Validation of the Summative Index

In Section 4.2.2 a *Success Index* is proposed to measure the success of an R&D cooperation. The proposed *Success Index* is a formative construct and consists of the following elements:

- patent or utility model application
- accepted publication
- existence of a prototype
- transfer to new process or product development
- stayed within budget
- finished within scheduled time frame

A formative construct requires different validation mechanisms compared to reflective constructs. The use of validation mechanisms used for "reflective indicators (e.g., factor analysis and assessment of internal consistency) are not appropriate for composite variables (i.e., indexes) with formative indicators" (Diamantopoulos and Winklhofer, 2001, p. 271). The "internal consistency is of minimal importance because two variables that might even be negatively related can both serve as meaningful indicators of a construct" (Diamantopoulos and Winklhofer, 2001, p. 271). Therefore, the means, standard deviations and the correlations of the individual success variables (dummy coding: 0 = if not present; 1 = if present) are inspected and presented in Table 5.6. For a discussion of the means see Section 5.1.6.

The correlation coefficients were calculated as point-biserial correlation with a 2-tailed significance test (Fields, 2009). A significant positive correlation can be shown regarding the *Project Schedule* and *Budget*. However, projects which stayed within

	Mean	S.D.	(1)	(2)	(3)	(4)	(5)	(6)
(1) IPR	0.360	0.485	1					
(2) Publication	0.480	0.505	-0.053	1				
(3) Prototype	0.920	0.274	0.068	-0.159	1			
(4) Product/Service	0.840	0.370	-0.127	0.310*	-0.129	1		
(5) Budget	0.740	0.443	-0.220	0.204	-0.175	-0.010	1	
(6) Schedule	0.500	0.505	-0.167	0.240+	-0.295*	0.109	0.410**	1

N=50

Abbreviations: (S.D.) Standard Deviation; (1) Patents or utility pattern; (2) Publication; (3) Prototype; (4) Product or Service; (5) Budget; (6) Time;

$^{+}$p-value < 0.10; *p-value < 0.05; **p-value < 0.01

Table 5.6: Descriptive statistics and correlation matrix (Success items)

schedule show a positive correlation with the variable *Publication* and a negative correlation with the variable of a built *Prototype*. These issues could be interpreted with the higher uncertainty planning for building a prototype than for writing a publication. Furthermore, a positive significant correlation is found between the variable *Publication* and the variable transfer to a *Product or Service*.

To conclude, the individual success items contribute to an additional understanding of the success dimensions. Lane et al. (2006) also propose that the success of a firm has the dimensions (a) knowledge output and (b) commercial output. Equation 5.6 shows how the *Success Index* is calculated. The *Success Index* is a dichotomous variable where it is expected that an R&D cooperation project is more successful if more than half of the individual success dimensions are present.

$$SUCC\_INDEX = \begin{cases} 1 \text{ if } IPR + PUBL + PROTO + PRO + \\ \quad BUDGET + SCHEDULE > 3 \\ \\ 0 \text{ else} \end{cases} \tag{5.6}$$

As stated already above the validation of this measure is not possible with methods used for reflective indicators. However, as argued in Section 4.2.2 and shown with the correlation analysis the *Success Index* is a well-balanced construct including these six different success items. Furthermore, in the regression analysis the six individual success items will also act as dependent variables next to the proposed *Success Index* thus checking the validity of this index also at the level of the regression analysis.

5.3 Estimations and Analysis of Regression Model

This section describes the hypotheses tests for (a) the propensity to cooperate on R&D (see Section 5.3.3) and (b) the success of an R&D cooperation (see Section 5.3.4). The tests are carried out with a logistic regression analysis. “The advantages of logistic regression compared to discriminant analysis and even multiple regression stem in large degree to the general lack of assumptions required in a logistic regression analysis” (Hair et al., 2009, p. 323). However, to be comparable to a multiple regression analysis the univariate normality is assessed in Section 5.3.1. Furthermore, the issue of multicollinearity is assessed in Section 5.3.2.

5.3.1 Assessing Univariate Normality

The independent variables are inspected for univariate normality according to Hair et al. (2009, pp. 181–186). The variables are (a) visually inspected and (b) by testing the variables for normality with a Kolmogorov-Smirnov test. The variables ALL_EXP and SCI_LINK show a strong deviance from normality and are, therefore, accordingly transformed. Table 5.7 shows the performed transformations.

Variable	Transformation
ALL_EXP	$ln(X)$ transformation
ALL_MGMT_TOOL	no
SCI_LINK	$\sqrt{X}$ transformation
PM_EFF	no
PM_KT	no

Table 5.7: Variable transformations

Table 5.8 shows the results of the Kolmogorov-Smirnov test after the variable transformation. The results in this table show the data of the complete sample (81 responses). The variable SCI_LINK reaches the lower bound of the true significance hence indicating a normal distribution in the data.

The hypotheses testing the success of an R&D cooperation use a reduced data set where only the responses reporting an engagement in an R&D cooperation are included. The Kolmogorov-Smirnov test of this reduced data set is reported in Table 5.9. The variables SCI_LINK and PM_KT show a normal distribution in

	Kolmogorov-Smirnov		
	Statistic	df	Sig.
ALL_MGMT_TOOL	0.105	81	0.028
SCI_LINK	0.074	81	0.200*

N=81; Lillifors Significance Correction

*This is a lower bound of the true significance.

Table 5.8: Univariate Normality Test (Data Set: Propensity)

the data. For the other variables the normality cannot be proven at a significant level. However, as the logistic regression analysis has not as strong assumptions as the multiple regression analysis the variables which do not fully comply with the normality assumption can also be included in the logistic regression analysis (Hair et al., 2009, p. 323).

	Kolmogorov-Smirnov		
	Statistic	df	Sig.
ALL_EXP	0.140	50	0.016
ALL_MGMT_TOOL	0.125	50	0.051
SCI_LINK	0.080	50	0.200*
PM_EFF	0.118	50	0.081
PM_KT	0.109	50	0.188

N=50; Lillifors Significance Correction

*This is a lower bound of the true significance.

Table 5.9: Univariate Normality Test (Data Set: Success)

5.3.2 Assessing Multicollinearity

Multicollinearity represents a correlation among the independent variables. In the ideal case there is no correlation between the independent variables. In this ideal case there is only a correlation between the independent variables and the dependent variable. However, this is unlikely to happen for a given set of data. If a variable is fully explained by another variable (total correlation), then mathematically no regression coefficients can be estimated. To avoid this problem, multicollinearity is assessed before conducting a regression analysis by using a variance inflation factor (VIF) test. A VIF value above 10 indicates a strong correlation in the data (Hair et al., 2009, pp. 200–201). The maximum VIF value in the full data set (measuring the propensity) is 2.071. In case of the reduced data set (measuring the success) the maximum VIF value is 2.544. These results show that no multicollinearity was found in the data since the maximum values are well below the threshold of 10.

5.3.3 Propensity to Cooperate on R&D

This section discusses the hypotheses test regarding the first research question (Hypotheses 1–3) :

> *To what extent does absorptive capacity influence the propensity to engage in R&D cooperations?*

Table 5.10 shows the descriptive statistics and the correlation matrix of the used variables. The industry is coded with dummy variables where the industry category medical, precision and optical instruments is the default case, accounting for 59.3% of the responses. 12.4% of the responses belong to the pharmaceutical industry, 16.0% to the IT industry. The other responses (12.3%) belong to the electronic communication and the aerospace industry. More than half of the firms (56.8%) belong to a group of companies, indicating dichotomously the firm size. In the sample 91.4% of the respondents have declared that they have an existing *R&D department* in their firm. 42.0% of the responders indicated that they have a dedicated *Alliance Function* in their firm. A slightly higher share of 63.0% have at least one person who is looking systematically for new technological developments (*gatekeeper*). The variables *Alliance Management Tools* and *Scientific Linkage* both have their mean below the middle of the scale. *Alliance Management Tools* has its mean at 2.955; *Scientific Linkage* at 2.856[36].

The correlation analysis for the independent variables shows a positive correlation between the existence of an *R&D department* and the existence of a *gatekeeper*. The existence of an *Alliance Function* is correlated with the existence of a *gatekeeper*,

[36]This variable was transferred with the square root; therefore, for the interpretation a retransformation is performed ($1.690^2 = 2.856$).

	Mean	S.D.	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
(1) Pharma	0.123	0.331	1									
(2) IT	0.160	0.369	-0.164	1								
(3) Others	0.123	0.331	-0.141	-0.164	1							
(4) Group	0.568	0.498	-0.127	-0.230*	-0.051	1						
(5) R&D department	0.914	0.497	0.115	0.015	-0.018	-0.268*	1					
(6) Alliance Function	0.420	0.486	-0.015	0.310**	-0.015	0.035	0.084	1				
(7) Gatekeeper	0.630	0.283	0.132	0.196	-0.178	-0.101	0.219*	0.393**	1			
(8) Alliance Mgmt. Tools	2.955	1.369	0.109	0.113	-0.117	-0.117	0.041	0.293**	0.387**	1		
(9) Scientific Linkage	1.690	0.360	0.138	0.225*	-0.143	-0.202	0.149	0.371**	0.633**	0.523**	1	
(10) Cooperate	0.654	0.479	0.036	0.106	-0.122	-0.162	0.146	0.092	0.303**	0.306**	0.390**	1

N=81

Abbreviations: (S.D.) Standard Deviation

$^{+}$p-value $<$ 0.10; *p-value $<$ 0.05; **p-value $<$ 0.01

Table 5.10: Descriptive statistics and correlation matrix (Propensity)

the *Alliance Management Tools* and the *Scientific Linkage*. Furthermore, the presence of a *gatekeeper* shows a positive correlation with the variable *Scientific Linkage*. This finding indicates a similarity in the underlying concept which is intended in the study design. However, no multicollinearity was found. Therefore, both variables are included in the regression analysis. Furthermore, the variable *Alliance Management Tools* correlates positively with the variable *Scientific Linkage*. In this case a multicollinearity was not found either hence both variables are included in the analysis. The dependent variable correlates with the variables *Alliance Function*, *gatekeeper* and *Scientific Linkage*.

The following regression analysis will show which of the independent variables will be the best predictor determining the propensity to cooperate. The hypotheses are tested with nested models to see the impact of the individual independent variables (see Table 5.11). Model I shows the base model which only includes the control variables. Model I shows no significant results indicating that firms from different industries do not differ in the propensity to cooperate on R&D. Additionally, the firm size[37] shows no change in the propensity to cooperate on R&D contradicting previous research results (e.g. Bayona et al., 2001; Fritsch and Lukas, 2001). All consecutive models are tested against this base model by analyzing the value and the significance of the model improvement ($\Delta\chi^2$). Equation 5.7 shows the equation for the overall model (Model IV).

$$\begin{aligned} LOGIT(COOP) = & b_0 + b_1 * PHARMA\_IND + b_2 * IT\_IND + \\ & b_3 * OTH\_IND + b_4 * GROUP + \\ & b_5 * ALL\_FUNC + b_6 * GATEKEEPER + \\ & b_7 * RD\_DEP + b_8 * ALL\_MGMT\_TOOL + \\ & b_9 * SCI\_LINK \end{aligned} \tag{5.7}$$

Model II tests Hypothesis 1 which includes the function specific indicators. An existing *gatekeeper* function has a significant influence on the propensity to cooperate. Adding the variable *Alliance Management Tools* (Model III) shows that this variable can better predict the propensity to cooperate than the function specific indicators alone. The model is significant at a 10% level. The improvement over

[37]The group variable is used as proxy for the firm size.

base is significant at a 5% significance level. By further adding the variable *Scientific Linkage* the model becomes significant at a 5% level. To sum up, *Scientific Linkage* is the best predictor determining the propensity to cooperate in this model.

	Model I	Model II	Model III	Model IV
Pharma	0.053 (0.776)	-0.241 (0.815)	-0.328 (0.842)	-0.444 (0.886)
IT	0.351 (0.754)	0.082 (0.824)	0.107 (0.843)	-0.014 (0.859)
Others	-0.747 (0.721)	-0.549 (0.761)	-0.492 (0.771)	-0.473 (0.771)
Group	-0.693 (0.518)	-0.609 (0.564)	-0.501 (0.587)	-0.346 (0.608)
R&D Department		0.398 (0.889)	0.572 (0.952)	0.612 (0.947)
Alliance Function		-0.127 (0.589)	-0.287 (0.604)	-0.433 (0.625)
Gatekeeper		1.234* (0.576)	0.913 (0.598)	0.310 (0.684)
Alliance Mgmt. Tools			0.416^{+} (0.218)	0.293 (0.234)
Scientific Linkage				1.956^{+} (1.079)
Constant	1.094* (0.489)	0.057 (1.015)	-1.083 (1.225)	-3.626^{+} (1.891)
-2 Log likelihood	100.681	94.658	90.812	87.323
Cox & Snell R^2	0.045	0.114	0.155	0.191
Nagelkerke R^2	0.063	0.157	0.214	0.263
χ^2	3.765	9.788	13.635^{+}	17.123*
Improvement over base ($\Delta\chi^2$)		6.023	9.87*	13.358*

N=81; Dependent Variable: Engaged in an R&D Cooperation (yes/no)

$^{+}$p-value < 0.10; *p-value < 0.05; **p-value < 0.01; standard errors in parentheses

Table 5.11: Regression results (Propensity to cooperate)

Interpretation of the Results

The results of previously conducted studies showed that a firm's size has a positive influence on the propensity to engage in R&D cooperations. However, this result cannot be confirmed in this study. A reason why no difference has been identified[38] is the industry focus of this study. This study focuses on the high-technology industry.

[38]The descriptive statistics showed that there is an overhead of larger firms which cooperate on R&D than smaller firms (see also Figure 5.10 on 84). However, the difference between these two categories did not show any significant difference in the regression analysis thus being not considered any further.

In the high-technology industry it is essential to stay at the technological frontier which also requires to access external knowledge sources (e.g. in form of an R&D cooperation). The results of this study show that the motivation conducting R&D in cooperations is independent form the firm size in the investigated firms belonging to the high-technology industry.

Firms which belong to the IT and to the pharmaceutical industry showed on average a higher rate to be engaged in an R&D cooperation than firms from other industry segments. However, the industry classification did not show any significant influence on the propensity to cooperate. This means that other factors than the firm size and the industry classification are more important determining the propensity to cooperate.

The function specific indicators showed that most of the investigated firms have an existing R&D department. No significant influence was found between the existence of an R&D department and the propensity to cooperate. However, the existence of an R&D department showed a correlation with the gatekeeper function in the firm. This result suggests that a firm with an existing R&D department has a higher chance to nominate a person (gatekeeper) looking for new technical developments. Furthermore, the results indicate that a gatekeeper shows a significant influence on the propensity to cooperate. In addition to a person looking for new technological developments also the firms were asked whether there is a person in the firm who initiates and coordinates R&D cooperations (alliance function). However, this alliance function did not show any significant influence on the propensity to cooperate.

Conceptually similar to the last two mentioned functional indicators are the two variables (1) *Alliance Management Tools* and (2) *Scientific Linkage*. The variable *Alliance Management Tools* is derived from the functional description of an alliance function. The variable *Scientific Linkage* is derived from the functional description of the gatekeeper function. These two variables focus on capabilities, representing the mechanisms and routines of these functional indicators. These variables measure the adoption of the individual concepts. First, the adoption of alliance management tools shows a significant influence on the propensity to cooperate on R&D . Second, the linkage to scientists external to the firm and the search for external development shows a significant influence on the propensity to cooperate. This last mechanism shows the biggest influence determining the propensity to cooperate.

According to the findings, a manager wishing to engage in R&D cooperation needs to build teams which cover the following three aspects: (a) members of the team should investigate scientific publication for new technological developments; (b) actively build up a network to scientists outside the firm; this network can, for example, be built by participating in scientific conferences; (c) building up alliance management mechanisms and tools allowing an effective initiation of new R&D cooperations.

5.3.4 Success of R&D Cooperations

This section discusses the hypotheses test concerning the second research question (Hypotheses 4–8):

> *To what extent does absorptive capacity influence the success of R&D cooperation projects?*

Table 5.12 shows the correlation analysis. The sample consists of 50 responses including (a) firms which cooperate on R&D and (b) fully filled out all six success dimensions. Therefore, the new set of data is discussed in Table 5.12 regarding the mean, standard deviation and the correlation among the different variables.

The industry is coded with dummy variables as already discussed in Section 5.3.3. The default industry is the medical, precision and optical instruments industry accounting for 58.0% of the responses. 14.0% of the responses belong to the pharmaceutical industry, 18.0% to the IT industry. The other responses (10.0%) belong to the electronic communication and the aerospace industry. Slightly more than half of the firms (52.0%) are part of a group of companies.

The independent variables show that almost every firm in the sample has an *R&D department* (94.0%). Less than half of the firms (42.0%) has a dedicated *Alliance Function*. 72% of the respondents indicated that they have a *gatekeeper* who is systematically scanning the environment for new technological developments. The firms did on average 9.08 cooperation projects[39] in the past ten years (*Alliance*

[39]This variable was transfered with the natural logarithm; therefore, for the interpretation a retransformation is applied ($e^{2.206} = 9.08$).

	Mean	S.D.	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)
(1) Pharma	0.140	0.351	1												
(2) IT	0.180	0.388	-0.189	1											
(3) Other	0.100	0.303	-0.134	-0.156	1										
(4) Group	0.520	0.505	-0.189	-0.175	-0.080	1									
(5) R&D department	0.940	0.240	0.102	0.118	0.084	-0.243^{+}	1								
(6) Alliance Function	0.420	0.499	0.124	0.340*	-0.014	0.006	0.215	1							
(7) Gatekeeper	0.720	0.454	0.123	0.176	-0.089	0.025	0.405**	0.440**	1						
(8) All. Experience	2.206	0.703	0.192	0.244^{+}	0.385**	-0.159	0.081	0.262^{+}	0.258	1					
(9) All. Capability	3.183	1.299	0.234	0.055	-0.233	-0.091	0.331*	0.288*	0.392**	0.055	1				
(10) Scientific Linkage	1.780	0.331	0.095	0.217	-0.033	-0.021	0.316*	0.476**	0.572**	0.267^{+}	0.542**	1			
(11) PM Efficiency	4.188	0.902	-0.076	0.047	0.060	0.010	-0.183	-0.077	-0.032	-0.031	0.086	0.185	1		
(12) PM Knowl. Tr.	4.827	0.620	0.067	0.168	-0.166	-0.033	-0.071	0.313*	-0.080	0.126	0.103	0.353*	0.343*	1	
(13) Success Index	0.640	0.485	-0.058	0.026	0.250^{+}	0.030	-0.189	-0.206	0.089	0.282*	-0.260^{+}	0.003	0.321*	0.099	1

N=50

Abbreviations: (S.D.) Standard Deviation; (11) Project Management Efficiency; (12) Project Management Knowledge Transfer

$^{+}$p-value < 0.10; *p-value < 0.05; **p-value < 0.01; standard errors in parentheses

Table 5.12: Descriptive statistics and correlation matrix (Success)

Experience). The variable *Scientific Linkage* has its mean slightly above the middle of the scale with a value of 3.18[40]. In comparison the project management scales show on average a higher adoption rate compared to the variable *Scientific Linkage*. The variable *Project Management Efficiency* has its mean at 4.19. The responders of the study rated the adoption of *Project Management Knowledge Transfer* slightly higher (4.83) than the variable *Project Management Efficiency*. For the dependent variable (*Success Index*) more than half of the firms (64.0%) fulfill the criteria of a successfully conducted R&D cooperation project.

The correlation table shows some correlation among the independent variables. Correlations above 0.5 (representing a medium correlation[41]) are only found for the variable *Scientific Linkage*. The variable *Scientific Linkage* correlates positively with the variables *gatekeeper* and *Alliance Management Tools*. The dependent variable (*Success Index*) is positively correlated with the variables *Alliance Experience* and *Project Management Efficiency*. However, the dependent variable is negatively correlated with the variable *Alliance Management Tools*. The following regression analysis shows which of the independent variables is the better predictor determining the success of an R&D cooperation. Equation 5.7 shows the equation for the overall model.

$$\begin{aligned} LOGIT(SUCC) =& b_0 + b_1 * PHARMA\_IND + b_2 * IT\_IND + \\ & b_3 * OTH\_IND + b_4 * GROUP + \\ & b_5 * ALL\_FUNC + b_6 * GATEKEEPER + \\ & b_7 * RD\_DEP + b_8 * ALL\_EXP + \\ & b_9 * ALL\_MGMT\_TOOL + b_{10} * SCI\_LINK + \\ & b_{11} * PM\_EFF + b_{12} * PM\_KT \end{aligned} \tag{5.8}$$

Hypotheses Test (Success Index)

The hypotheses were tested with a logistic regression using the *Success Index* as dependent variable. However, as already stated above, the six success dimensions

[40] This variable was transferred with the square root; therefore, for the interpretation a retransformation is done ($1.780^2 = 3.168$).

[41] The respective correlation levels ([very] low – medium – [very] high) are shown in Table D.1 on Page 128.

are also tested individually and reported later on in this section. Table 5.13 provides the results of the logistic regression analysis investigating the success index.

Model I shows the base case with only control variables as predictors for the dependent variable. The results show no significant influence of the control variables. Model II adds the function specific indicators. When looking at the standard deviation of the regression coefficients a high standard deviation is found for the variables *Others*, *R&D department* and the constant. The reason is that the variable *R&D department* and the constant seem to explain the same concept indicated by the same standard deviation of both variables. This results from the high share of firms having an existing R&D department which is interpreted in the regression analysis almost as a constant and causes, therefore, problems with multicollinearity. Accordingly, this variable is excluded from further analysis; hence Hypothesis 4 cannot be tested.

A detailed analysis of the variable *Other* showed that all firms belonging to the other industry categorization (electronic communication and aerospace industry) fulfill the requirements of successful projects thus having an 100% success-rate. This 100% succes-rate originates from the few cases belonging to the other industry categorization. Therefore, these cases are excluded from the analysis thus having a total of 45 responses in the sample.

Equation 5.9 shows the new formulated equation for the reduced model excluding the functional indicators and the samples belonging to the electronic communication and aerospace industry. Table 5.14 shows the results of the regression analysis avoiding the problems of multicollinearity.

$$\begin{aligned} LOGIT(SUCC) =& b_0 + b_1 * PHARMA\_IND + \\ & b_2 * IT\_IND + b_3 * GROUP + \\ & b_4 * ALL\_EXP + b_5 * ALL\_MGMT\_TOOL + \\ & b_6 * SCI\_LINK + b_7 * PM\_EFF + b_8 * PM\_KT \end{aligned} \tag{5.9}$$

The hypotheses are tested with nested models allowing to see the effects of the individual independent variables. Model I includes only the control variables. The findings show that no significant influence is found between the control variables and the success of an R&D cooperation. Model II adds the variable *Alliance Experience*

	Model I	Model II	Model III	Model IV	Model V	Model VI
Pharma	0.051 (0.887)	0.339 (1.070)	-0.213 (1.183)	-0.185 (1.194)	-0.081 (1.218)	0.332 (1.326)
IT	0.444 (0.832)	1.081 (0.952)	0.564 (1.045)	0.462 (1.115)	0.434 (1.127)	0.088 (1.291)
Others	20.937 (17936.498)	21.543 (17251.703)	20.810 (16169.060)	20.616 (15330.994)	20.511 (15490.059)	21.366 (13933.128)
Group	0.302 (0.650)	0.001 (0.741)	0.102 (0.777)	0.034 (0.804)	0.056 (0.807)	0.544 (0.943)
R&D Department		-21.912 (23205.434)	-21.609 (23029.370)	-20.890 (23155.557)	-20.882 (23173.824)	-19.401 (21271.473)
Alliance Function		-1.810* (0.858)	-2.003* (0.918)	-1.926* (0.932)	-2.027* (0.959)	-2.711$^+$ (1.387)
Gatekeeper		2.023* (0.975)	1.892$^+$ (1.002)	2.263* (1.056)	2.053$^+$ (1.134)	4.130* (1.864)
Alliance Experience			1.061 (0.717)	1.271 (0.774)	1.203 (0.792)	1.554$^+$ (0.929)
Alliance Mgmt. Tools				-0.534 (0.356)	-0.604 (0.383)	-0.994$^+$ (0.562)
Scientific Linkage					0.777 (1.525)	-1.424 (2.357)
PM Efficiency						1.643$^+$ (0.943)
PM Knowledge Transfer						1.038 (0.943)
Constant	0.152 (0.564)	21.202 (23205.434)	19.036 (23029.370)	19.459 (23155.557)	18.603 (23173.824)	8.638 (21271.473)
-2 Log likelihood	60.137	49.355	46.991	44.529	44.265	35.207
Cox & Snell R^2	0.099	0.274	0.307	0.340	0.344	0.453
Nagelkerke R^2	0.136	0.375	0.421	0.467	0.472	0.621
χ^2	5.205	15.986*	18.351*	20.813*	21.077*	30.134**
Improvement over base ($\Delta\chi^2$)		10.781**	13.146*	15.608**	15.872*	24.929**

N=50; Dependent Variable: Success Index

$^+$p-value < 0.10; *p-value < 0.05; **p-value < 0.01; standard errors in parentheses

Table 5.13: Intermediate regression results (Success Index) – Problem with multicollinearity

	Model I	Model II	Model III	Model IV	Model V
Pharma	0.051 (0.887)	-0.622 (1.002)	-0.385 (1.031)	-0.397 (1.029)	-0.140 (1.158)
IT	0.444 (0.832)	-0.234 (0.960)	-0.224 (1.016)	-0.395 (1.066)	-0.510 (1.092)
Group	0.302 (0.650)	0.338 (0.673)	0.366 (0.685)	0.348 (0.687)	0.578 (0.775)
Alliance Experience		1.038 (0.639)	1.231^{+} (0.673)	1.182^{+} (0.688)	1.500* (0.748)
Alliance Mgmt. Tools			-0.493^{+} (0.288)	-0.623^{+} (0.350)	-0.819* (0.412)
Scientific Linkage				0.851 (1.229)	0.443 (1.502)
PM Efficiency					1.272* (0.532)
PM Knowledge Transfer					-0.254 (0.694)
Constant	0.152 (0.564)	-1.795 (1.328)	-0.599 (1.497)	-1.537 (2.043)	-4.960 (3.222)
-2 Log likelihood	60.137	57.272	53.998	53.510	45.673
Cox & Snell R^2	0.010	0.071	0.136	0.145	0.282
Nagelkerke R^2	0.013	0.096	0.184	0.196	0.381
χ^2	0.434	3.299	6.573	7.061	14.898^{+}
Improvement over base ($\Delta\chi^2$)		2.865^{+}	6.139*	6.627^{+}	14.464*

N=45; Dependent Variable: Success Index; (PM)...Project Management

$^{+}$p-value $<$ 0.10; *p-value $<$ 0.05; **p-value $<$ 0.01; standard errors in parentheses

Table 5.14: Regression results (Success Index)

as predictor variable. By adding this variable the model improves significantly at a 10% level; however, the variable *Alliance Experience* is not significant. Model III adds the variable *Alliance Management Tools* showing a model improvement against Model I at a 5% significant level. In this model the variables *Alliance Experience* and *Alliance Management Tools* are both significant at a 10% level. *Alliance Experience* shows a positive influence on the success of an R&D cooperation; however, the variable *Alliance Management Tools* shows a negative influence on the success of an R&D cooperation, thus contradicting Hypothesis 6. Adding the independent variable *Scientific Linkage* does not improve the model any further. Nevertheless, by adding the two project management variables the model becomes significant at a 10% level. The improvement over the base case is significant at a 5% level. Adding these two variables also contributes to the significance of the independent variables. The variables *Alliance Experience* and *Project Managment Efficiency* show a positive impact on the success dimension at a 5% level. In the overall model the variable *Alliance Management Tools* is also significant at a 5% level influencing the success of an R&D cooperation negatively. The interpretation of the results will be discussed after the regression results of the individual success items are presented.

Hypotheses Test (Success Items)

As already stated above, the hypotheses are also tested for the individual success items:

- patent or utility model application
- accepted publication
- existence of a prototype
- transfer to new process or product development
- stayed within budget
- finished within scheduled time frame

An overview of the results is shown in Table 5.15. The full regression tables are listed in Appendix E.2 (starting on Page 139). As already stated above, Hypothesis 4 cannot be tested due to multicollinearity problems. The results of these regression analyses are reported in Appendix E.1 (starting on Page 131) to provide completeness of contents.

		Success Index	IPR	Publications	Prototype	Product/Process	Budget	Schedule
	Pharma			(+)				
	IT							
	Others							
	Group			+				
H5	Alliance Experience	+					+	(+)
H6	Alliance Mgmt. Tools	−						(−)
H7	Scientific Linkage							
H8 (a)	PM Efficiency	+		(+)				(+)
H8 (b)	PM Knowledge Transfer							

N=45; (PM)...Project Management

+/− ... p-value < 0.05; (+/−) ... p-value < 0.10

Table 5.15: Overview of the regression results (Success)

The table also summarizes the results of the regression analysis with the *Success Index* as dependent. The findings in the previous subsection showed that the variables *Alliance Experience* and *Project Management Efficiency* have a positive effect on the success, whereas the variable *Alliance Management Tools* has a negative effect. These effects are found at a significance level of 5%. The same results were also found for the compliance with the schedule as dependent; however, in this case only for a significance level of 10%. It is found that the firm size has a positive influence on the propensity to generate a publication in an R&D cooperation (p-value < 0.05). Besides the influence of the firm size there is also a positive effect found regarding the industry affiliation. Belonging to the pharmaceutical industry improves the propensity to get a paper published (p-value < 0.05). Furthermore, the relative *Project Management Efficiency* has a positive effect on the propensity to publish (p-value < 0.10). Additionally, it can be shown that *Alliance Experi-*

ence has a positive influence on the compliance with the budget. Nevertheless, no effect from the independent variables on the output dimensions were found for the following dependent variables: (a) patent or utility pattern application, (b) existing prototype, (c) transfer to become a product or service.

Interpretation of the Results

The results show that the industry affiliation and the size of a firm do not have a significant impact on the propensity for a successful R&D cooperation. This observation is valid for the influence on most of the success items. In case of defining the success in terms of accepted scientific publications firms in the pharmaceutical industry show a higher propensity to publish. This finding indicates that the perception to publish is higher in the pharmaceutical industry than in the other investigated industries. Furthermore, the propensity to publish also increases with the firm size. Bigger firms seem to have also a higher perception to discuss their output of research projects in the scientific community than smaller firms do.

The findings show that firms from the IT industry are more likely to have a person nominated looking strategically for alliance partners than firms from other industries. Interestingly, with the affiliation to a group of companies the propensity to have an own R&D department decreases. Since the investigated sample includes only firms which cooperate on R&D, the conclusion can be drawn that these firms might have a central R&D facility in their group of companies.

The functional specific indicators could not be tested with the same statistical quality as the other results due to problems with multicollinearity in the dataset. However, a statement about the tendency of the individual aspects is given and interpreted. It has already been stated in Section 5.3.3 that the variables *Alliance Management Tools* and *Scientific Linkage* conceptually originate from the function specific indicators *Alliance Function* and *gatekeeper*. This intended conceptual similarity is also found in the correlation among each other. These correlations results are similar for the dataset investigating the propensity and the dataset investigating the success of an R&D cooperation (consult Section 5.3.3 for a discussion).

The capability to manage a cooperation is measured twofold: (a) number of formed cooperations in the past ten years (*Alliance Experience*) and (b) the adoption of tools to manage such alliances (*Alliance Management Tools*). A correlation between these two variables was identified, which suggests that firms which cooperate on R&D also develop routines and manuals systematizing the alliance experience. The regression analysis showed that previously formed cooperations have a positive effect on the success of an R&D cooperation but the use of alliance management tools has a negative one. This last finding contradicts the proposed hypothesis, i.e. the use of alliance management tools has a positive effect on the success of R&D cooperations. Sampson (2005) provides an interpretation for this effect stating that the over formalization of manuals and routines leads to an increased bureaucratic effort because of too strict rules. For managers this means that researchers working in an R&D cooperation need to be discharged from too much bureaucracy involved in managing an R&D cooperation. This goes in line with the research of Curran et al. (2009), who found out that project leaders of R&D cooperations that are above average performers have a higher administrative activity than the low performer project leaders. This higher administrative activity of the project leaders allows the project team members to focus on the research problem in the project.

A firm's commitment to stay within the project's budget and on schedule shows a positive influence on the success of R&D cooperations. The project management training and scientific linkage, however, shows no significant influence on the success of R&D cooperations.

The findings show that managers can improve the success of R&D cooperations by (a) allowing an engagement in cooperations to generate alliance experience. However, (b) this alliance experiences should not be transferred too strictly into manuals and procedures since this enhances the bureaucratic effort leading to lower cooperation performance. Furthermore, (c) the project management skills should be developed allowing a higher commitment to comply with the budget and the schedule.

5.4 Summary of the Hypotheses Tests

5.4.1 Hypotheses Tests 1–3

Table 5.16 gives on overview of the hypotheses tests regarding Research Question 1. Hypothesis 3 can be confirmed. Hypothesis 1b and Hypothesis 2 can also be confirmed but only moderately since the variable *Scientific Linkage* (Hypothesis 3) is the better determinant to predict the propensity to cooperate on R&D.

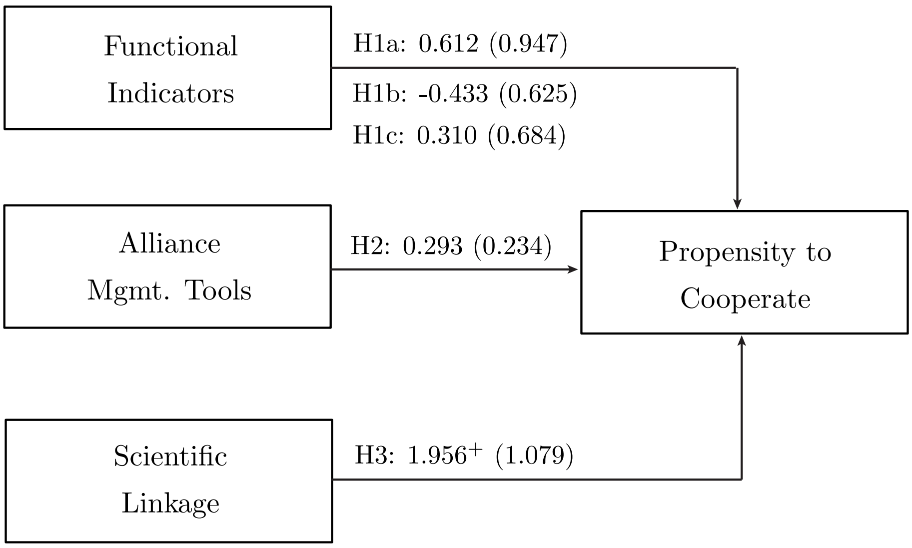

Figure 5.12: Measurement model analyzing the propensity to cooperate on R&D

Hypotheses	Interpretation
Hypothesis 1a	rejected (non-significant)
Hypothesis 1b	moderately confirmed
Hypothesis 1c	rejected (non-significant)
Hypothesis 2	moderately confirmed
Hypothesis 3	confirmed

Table 5.16: Hypotheses Test 1–3

5.4.2 Hypotheses Tests 4–8

Table 5.17 shows a summary of the hypotheses tests regarding Research Question 2. Hypotheses 4 could not be tested due to multicollinearity problems in the data set. Hypotheses 5 and 8a are confirmed, whereas the Hypotheses 6 and 8a could not be confirmed because the tests did not deliver significant results. Hypothesis 7 needs to be rejected. The results showed a negative effect on the dependent variable.

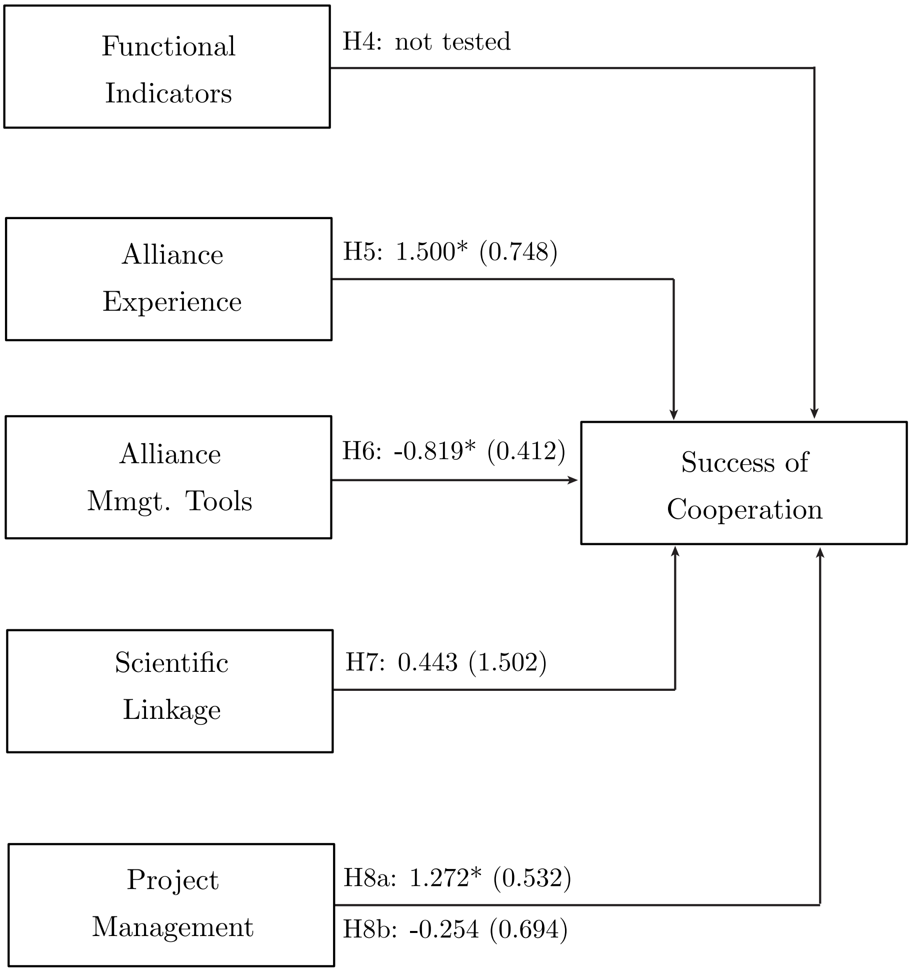

Figure 5.13: Measurement model analyzing the success of R&D cooperations

Hypotheses	Interpretation
Hypothesis 4a	not tested*
Hypothesis 4b	not tested*
Hypothesis 4c	not tested*
Hypothesis 5	confirmed
Hypothesis 6	rejected (negative-significant)
Hypothesis 7	rejected (non-significant)
Hypothesis 8a	confirmed
Hypothesis 8a	rejected (non-significant)

*due to problems with multicollinearity

Table 5.17: Hypotheses Test 4–8

Chapter 6

Conclusion

This last chapter concludes the paper with a summary, including managerial and research implications (Section 6.1). The limitations of this study are presented in Section 6.2. Avenues for further research are discussed in Section 6.3.

6.1 Summary

Bundling the R&D effort through partnerships with other companies has become a major trend in the past two decades. The issue of R&D cooperations has been researched mainly at firm-level thus providing implications for policy makers. However, little attention has been paid to studies at project-level to learn the mechanism required to manage these cooperations efficiently. This research project covers two aspects of R&D cooperation management: (1) propensity to cooperate and (2) determinants predicting the success of R&D cooperations.

The study is embedded in the research field of absorptive capacity. Absorptive capacity can be seen as funnel (see Figure 6.1 for an illustration).

The funnel shows the three process steps of absorptive capacity: (a) exploration, (b) transformation and (c) exploitation (Lane et al., 2006). The solid lines of the funnel represent the boundaries of the firm. This view on absorptive capacity is similar to the concept of closed innovation where a firm's innovation process is also represented as funnel. New ideas are put into the innovation process on the wider opening of the funnel and are quantitatively condensed during the innovation process to derive a designated innovation output. The closed innovation paradigm lacks

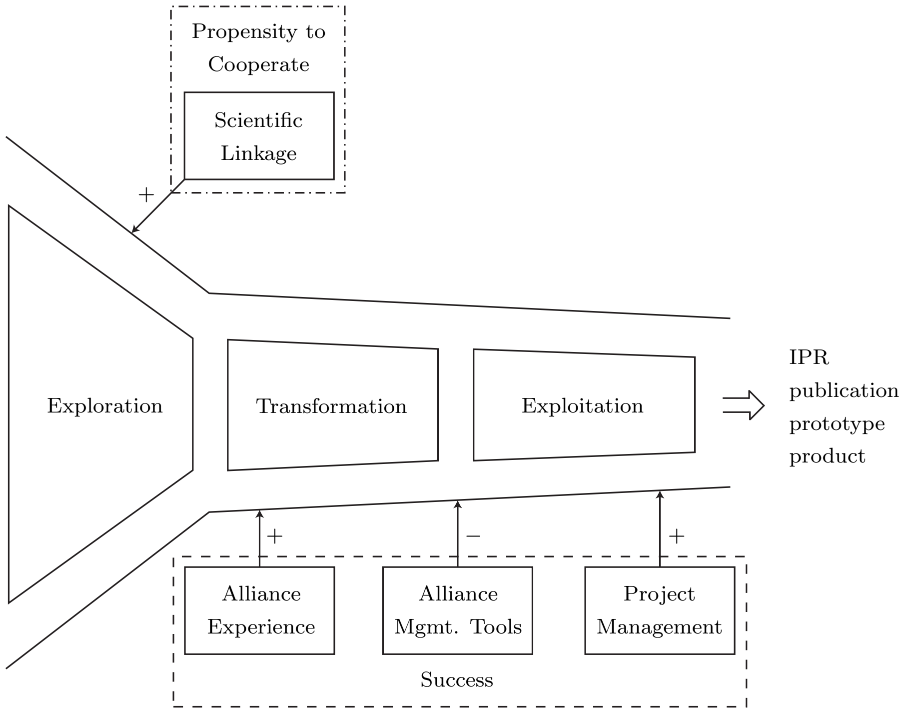

Figure 6.1: Findings of the study

external inspiration in the innovation process. This lack of external inspiration is explicitly overcome with the concept of open innovation. The concept of open innovation sees the boundaries of the firm permeable where knowledge from outside the firm is included into a firm's innovation process (Chesbrough, 2003). This knowledge can, for example, be integrated into the innovation process by forming R&D cooperations with potential knowledge sources.

This study found out that, first, the propensity to engage in an R&D cooperation increases with the scientific linkage of a firm. This scientific linkage includes a firm's systematic search for new technological developments. Furthermore, firms with a higher propensity to cooperate on R&D also have access to a network of scientific partners which can be accessed in case of technological questions.

Second, the propensity of a successful R&D cooperation increases with the experience gained in previous cooperations. However, this experience should not be coded too strictly into alliance management tools (routines and manuals) because these alliance management tools enhance the bureaucratic effort leading to lower cooperation performance. Additionally, the success increases with a firm's general commitment to project management efficiency.

The identified results contribute to the management and the research community. First, the managerial implications are discussed in Section 6.1.1. Second, the research implications are discussed in Section 6.1.2.

6.1.1 Managerial Implications

This study identified a couple of implications for managers. First, firms with existing R&D departments have a higher chance to nominate a person who systemically searches for new technological developments (gatekeeper). The results show that an existing gatekeeper increases the propensity to cooperate. Therefore, managers wishing to engage in R&D cooperations need to motivate at least one person to scan systematically for new technological developments. Second, the propensity increases with the quality of the network a firm has to external scientific partners. For that reason it is necessary that managers motivate people in the firm to actively build up a network to scientists outside the firm. Such a network can be built by participating in scientific conferences, for example. Third, a small positive effect was shown regarding an alliance function and the adoption of alliance management tools on the propensity to engage in R&D cooperations. Managers need to build up alliance capabilities which support the formation phase of R&D cooperations.

Fourth, the success of R&D cooperations increases with previous engagements in cooperations. Managers need to allow researchers to conduct R&D in cooperations where they can build up alliance experience thus leading to better alliance performance in the future. Fifth, this gained alliance experience, however, should not be transferred too strictly into manuals and procedures since these rules enhance the bureaucratic effort leading to lower cooperation performance. This managerial implication shows a discrepancy between the formation phase of a cooperation and the post-formation phase. In the formation phase the adoption of alliance management tools has a positive effect on the propensity to cooperate but while working in the cooperation the adoption of alliance management tools shows a negative one. Sixth, the likeliness of success increases if managers in the firm have developed a commitment to comply with the project budget and schedule. The last two implications show that the formation phase benefits from the use of alliance management tools. However, while working in the project, standard project management tools should be used instead of alliance management tools.

The above mentioned implications focus on the internal environment of a firm. The seventh managerial implication, however, focuses on the external environment. Managers wishing to enhance the likeliness of success in an R&D cooperation should specifically pay attention to the identified capabilities which a potential partner brings into the cooperation[42].

6.1.2 Research Implications

The results derived from this study contribute to the academic literature in the following ways. First, this study is a comprehensive study including the investigation of the propensity to cooperate and the likeliness of success determined by a firm's absorptive capacity. Second, a firm's absorptive capacity is operationalized as capability, as suggested by researchers in the field of absorptive capacity. Third, this study combines insights from (a) the alliance management research and (b) the project management research into the research on R&D cooperations. Fourth, the output dimension of an R&D cooperation is measured with the knowledge and the commercial output allowing a comprehensive look at the success dimension of a cooperation.

6.2 Limitations of the Study

As every study this research also has its limitations. These limitations include: First, only one response is used per case hence having a possible responder bias in the data set. Second, the study includes (a) only firms in the German speaking countries in Europe and (b) only firms in the high-technology industry. Therefore, this study lacks generalizability above the investigated countries and the investigated industries. Third, the quality of the conducted study also suffers from the low response rate of 13%, allowing only a set of statistical tests. Fourth, the proposed formative success index is derived from the scientific literature and firm's practical adoption but lacks validation in the empirical study, e.g. in form of a structural equation model.

[42]Thanks to Claudia Kaefer who contributed to this insight at the XXI ISPIM conference in Bilbao.

6.3 Suggestions for Further Research

This study identified some points of departure for further research. First, this study focuses on the high-technology industry. A suggestion for further research would be to expand the focus to other industries, thus allowing a cross industry study. Second, such a cross industry study could result in a bigger sample size allowing a broader range of statistical tests (e.g. structural equation model). Third, a structural equation model would also allow a verification of the formative success index, which needs further statistical validation.

Fourth, it would be interesting to focus more specifically on the operationalization of absorptive capacity on the triplet exploration-transformation-exploitation to explain the effects of R&D cooperations. Sixth, the exploration phase of absorptive capacity could be further investigated to show if firms rather search for similar or for complementary knowledge when engaging in R&D cooperations.

Seventh, this study did not ask for the ownership of the generated IPR. This critical issue in a cooperation could also serve as starting point for further research. Eighth, the output in this study was only measured quantitatively and no quality aspect of the output was considered. Consequently, the quality of patents could be assessed by investigating the citations of the granted patent (bibliometric analysis). Ninth, the output dimension does not focus on financial measures, which could be another avenue for further research. Tenth, financial measures could also cover the question whether the investment in R&D cooperations also benefits the financial performance of firms in the long-term.

Appendix A

Abbreviations

CEO	chief executive officer
CFO	chief financial officer
CTO	chief technical officer
CIS	community innovation survey
EBIT	earnings before Interest and taxes
EU	European Union
IPR	intellectual property rights
mgmt	management
n	sample size
pharma	pharmaceutical
PM	project management
R&D	research and experimental development
s.d.	standard deviation
SME	small and medium-sized enterprise
U.S.	United States of America
vs.	versus
$\overline{x}$	mean

Appendix B

Questionnaire

F&E-Kooperationsumfrage

Studie des Instituts für Betriebswirtschaftslehre und Betriebssoziologie
Technische Universität Graz
o.Univ.-Prof. Dipl.-Ing. Dr.techn. Ulrich Bauer

Kopernikusgasse 24/II
A-8010 Graz
http://www.bwl.tugraz.at
DVR 008 1833

Sehr geehrte Studienteilnehmerin, sehr geehrter Studienteilnehmer,

vielen Dank, dass Sie sich Zeit nehmen, diesen Fragebogen auszufüllen. Für die Beantwortung des Fragebogens benötigen Sie etwa 10 Minuten.

Im Mittelpunkt dieser Studie steht die Auswirkung der Projektmanagementerfahrung und der Kooperationserfahrung auf den **F&E - Kooperationserfolg**. Im Rahmen dieser Studie werden Hoch-Technologie Unternehmen im deutschen Sprachraum befragt.

Bitte nehmen Sie bei der Fragenbeantwortung Bezug auf jenen Unternehmensbereich in dem Sie beschäftigt sind. Sollte es vorkomme n, dass Sie einzelne Fragen für sich bzw. Ihren Unternehmensbereich nicht sinnvoll beantworten können, geben Sie bitte – soweit möglich – Ihre Einschätzung bekannt.

Wichtig für die Qualität der Studienergebnisse ist, dass Sie den Fragebogen in jedem Fall **möglichst vollständig** beantworten. Der ausgefüllte Fragebogen wird **anonymisiert**. So kann auch technisch nicht auf den Ausfüller des Fragebogens geschlossen werden.

Dieser Fragebogen gliedert sich in folgende Themenbereiche:

1. Allgemeine Daten zu Ihrem Unternehmen
2. Fragen zum Kooperationserfahrung und zum Projektmanagement im Unternehmen
3. F&E-Projekt bezogene Daten
4. Umsetzung der F&E-Projekt-Ergebnisse

Bitte füllen Sie den Fragebogen bis zum 31. Jänner aus. Es besteht die Möglichkeit den Fragebogen in Etappen auszufüllen und au f der Plattform zwischenzuspeichern. Kontakt: markus.ringhofer@tugraz.at bzw. +43 316 873 7286

Vielen Dank für Ihre wertvolle Unterstützung!

o.Univ.-Prof. Dipl.-Ing. Dr.techn. Ulrich Bauer Dipl.-Ing. Markus Ringhofer

Diese Umfrage enthält 36 Fragen.

Allgemeine Fragen

Bitte beantworten Sie die folgenden Fragen bezogen auf Ihr **Unternehmen**

1 Ist Ihr Unternehmen Teil einer Unternehmensgruppe? *

Bitte wählen Sie nur eine der folgenden Antworten aus:

- Ja
- Nein

2 Wo ist der Sitz Ihres Unternehmens? *

Bitte wählen Sie nur eine der folgenden Antworten aus:

- Deutschland
- Österreich
- Schweiz

3 In welcher Branche ist Ihr Unternehmen primär tätig? *

Bitte wählen Sie nur eine der folgenden Antworten aus:

- Herstellung von pharmazeutischen Erzeugnissen (NACE 24.4)
- Herstellung von Büromaschinen, Datenverarbeitungsgeräten und –einrichtungen (NACE 30)
- Rundfunk- und Nachrichtentechnik (NACE 32)
- Mess-, Steuer-, Medizin- und Regelungstechnik, Optik, Herstellung von Uhren (NACE 33)
- Luft- und Raumfahrzeugbau (NACE 35.3)
- Sonstiges

4 Haben Sie eine F&E Abteilung? *

Bitte wählen Sie nur eine der folgenden Antworten aus:

- Ja
- Nein

Kooperationsvergangenheit

Die folgenden Fragen beziehen sich auf Ihre **Kooperationsvergangenheit** und beziehen sich auf die **Kooperationserfahrung** Ihres Unternehmens.

Wie **schätzen Sie** die folgenden Aussagen/Fragen **für Ihren Unternehmensbereich** bzw. Ihr Unternehmen **ein**?

5

Bitte wählen Sie die zutreffende Antwort für jeden Punkt aus:

	Sehr +++	++	+	-	--	Gar nicht ---
Wie stark ist in Ihrem Unternehmen der **Ablauf für das Eingehen einer Kooperation formalisiert?**	○	○	○	○	○	○
Wie stark ist der **Vorstand/oberste Führungsebene in die Anbahnung von Kooperationen eingebunden?**	○	○	○	○	○	○
Wie schätzen Sie die **Detailliertheit** Ihres **Handbuchs/Prozesses** zur Durchführung von Kooperationen ein?	○	○	○	○	○	○

6

Bitte wählen Sie die zutreffende Antwort für jeden Punkt aus:

	Stimme voll zu +++	++	+	-	--	Stimme gar nicht zu ---
Eingehen von **Kooperationen** ist ein wesentlicher **Bestandteil** unserer **Strategie**.	○	○	○	○	○	○
Kooperationen werden **hauptsächlich von Unternehmensexternen** an uns **herangetragen**.	○	○	○	○	○	○

7

Bitte wählen Sie die zutreffende Antwort für jeden Punkt aus:

	Ja	Nein
In unserem Unternehmen gibt es zumindest eine **Person** die systematisch nach **Kooperationspartnern sucht.**	○	○
Nach **Kooperationsabschluss** gibt es eine **Evaluierung**.	○	○
Es gibt dazu einen **standardisierten Prozess**.	○	○

8

Wie viele Kooperationensprojekte hat Ihre Abteilung in den letzten 10 Jahren durchgeführt?
*****

Bitte schreiben Sie Ihre Antwort hier

9 Mit welchen Partner hat Ihre Abteilung diese Kooperationen durchgeführt (in den letzten 10 Jahren)?

Bitte geben Sie auch die Erfahrung in Projekt-Jahren* an!

[Bitte beantworten Sie diese Frage nur, wenn Sie nicht geantwortet haben war bei der Frage '8']

	Anzahl der Kooperationen	Projekt-Jahre*
Universitäten/Forschungsinstituten		
Kunden		
Lieferanten		

	Anzahl der Kooperationen	Projekt-Jahre*
Mitbewerbern		

*Bitte summieren Sie dazu die Monate/Jahre der einzelnen Projekte auf (z.B.: 1. Kooperationsprojekt dauerte 5 Jahre und das 2. Kooperationsprojekt dauerte 3 Jahre => d.h. Kooperationserfahrung von 8 Jahren)

Technologische Aufnahmefähigkeit

Der nachfolgende Fragenteil bezieht sich auf die **Aufnahmefähigkeit von Forschungsergebnissen** .

Wie **schätzen Sie** die folgenden Aussagen **für Ihren Unternehmensbereich** bzw. Ihr Unternehmen **ein**?

10 Wie systematisch wird in Ihrem Unternehmen nach neuesten Entwicklungen/Forschungsergebnissen gesucht? (z.B. durchsuchen von Patentdatenbanken, wissenschaftlichen Journalen)

Bitte wählen Sie die zutreffende Antwort für jeden Punkt aus:

	+++	++	+	-	--	---	
Sehr	○	○	○	○	○	○	Gar nicht

11 In unserem Unternehmen gibt es zumindest eine Person die diese systematische Suche nach neuen Entwicklungen vornimmt. (z.B. durchsuchen von Patentdatenbanken, wissenschaftlichen Journalen) *

Bitte wählen Sie nur eine der folgenden Antworten aus:

- ○ Ja
- ○ Nein

12 Wie stark ausgeprägt schätzen Sie das Netzwerk zu externen wissenschaftlichen Partnern ein?

Bitte wählen Sie die zutreffende Antwort für jeden Punkt aus:

	Sehr +++	++	+	-	--	Gar nicht ---
National	○	○	○	○	○	○
International	○	○	○	○	○	○

Projekt Management

Dieser Fragebogenblock bezieht sich auf **das im Unternehmen verwendete Projekt Management** .

Wie **schätzen Sie** die folgenden Aussagen **für Ihren Unternehmensbereich** bzw. Ihr Unternehmen **ein**?

13

Bitte wählen Sie die zutreffende Antwort für jeden Punkt aus:

	Stimme voll zu +++	++	+	-	--	Stimme gar nicht zu ---
Im Projektmanagement sind wir die Besten unserer Branche.	○	○	○	○	○	○
Wir haben sehr gute Projektmanagement Methoden und Werkzeuge.	○	○	○	○	○	○
Unser Projektmanagementsystem reicht für unsere Zwecke.	○	○	○	○	○	○
Projekte werden budgetgerecht abgeschlossen.	○	○	○	○	○	○
Projekte werden termingerecht abgeschlossen.	○	○	○	○	○	○
Die Mitarbeiter eines Projektes kennen Ihre Aufgabe.	○	○	○	○	○	○
Die Projektmanagementkompetenz ist einem ständigem Verbesserungsprozess unterworfen.	○	○	○	○	○	○
Es gibt eine positive Einstellung zur Planung notwendiger Eventualitäten eines Projektes.	○	○	○	○	○	○
Interdisziplinäre Teams verbessern den Projektoutput.	○	○	○	○	○	○
Ressourcenbedarf und Risiken in Projekten werden richtig eingeschätzt.	○	○	○	○	○	○
Es gibt ein ausgeprägtes Verständnis wie Projekte effektiv organisiert und durchgeführt werden.	○	○	○	○	○	○
Es werden die Komplexität und der Schwierigkeitsgrad eines Projekts richtig eingeschätzt.	○	○	○	○	○	○
Die Projekte werden sehr gut organisiert und durchgeführt.	○	○	○	○	○	○
Im Unternehmen gibt es einen dokumentierten Projektmanagement-Prozess und ein Projektmanagement-Handbuch.	○	○	○	○	○	○
Es gibt ein gutes Zusammenspiel zwischen den Projektleitern und den Abteilungsleitern der Projektmitarbeiter.	○	○	○	○	○	○
Alle Projekte haben einen guten Zugang zu IT-support.	○	○	○	○	○	○
In unserer Organisation wird jeder ermutigt sein Projektmanagementwissen weiterzugeben.	○	○	○	○	○	○
Die eigene Projekterfahrung wird durch persönliche Gespräche weitergegeben.	○	○	○	○	○	○
Projektmanagementerfahrung wird systematisch diskutiert und reflektiert.	○	○	○	○	○	○
Projektmanagementerfahrung wird durch praktische Mitarbeit in Projekten an Projektmitarbeiter vermittelt.	○	○	○	○	○	○
Erfahrungen aus Projekten werden bei uns auch informell ausgetauscht.	○	○	○	○	○	○
Es gibt ein sehr effizientes Projektmanagement Mentorenprogramm.	○	○	○	○	○	○
Die Beschreibung von Sachverhalten mit Hilfe bildhafter Sprache führt oft zu „Aha-Erlebnissen“.	○	○	○	○	○	○

F&E Projekt

14 Haben Sie bisher an einem nach den folgenden Regeln* definierten F&E-Projekt mit einem externen Partner zusammengearbeitet? *

Bitte wählen Sie nur eine der folgenden Antworten aus:

- Ja
- Nein

* Für diese Umfrage gilt der von der OECD 2002 definierte F&E Begriff:

Das Kriterium, welches es gestattet, die **F&E** von anderen verwandten Tätigkeiten abzugrenzen, ist das Vorhandensein eines Elements, das neuartig ist, sowie die **Auflösung** einer **wissenschaftlichen oder technologischen Unsicherheit** . Anders gesagt geht es darum, dass die vorgelegte Lösung eines Problems nicht als evident erscheint für jemanden, der sich mit der Fragestellung, dem aktuellen Wissensstand und den im betrachteten Bereich geläufigen Verfahren auskennt.

- Prototypenentwicklung ist der F&E zuzurechnen solange das Hauptziel weitere Verbesserungen sind.
- Eine Versuchsanlage ist dann F&E wenn diese auch hauptsächlich der F&E dient.

Externer Partner: rechtlich eigenständiges Unternehmung (kann jedoch auch in der eigenen Unternehmensgruppe angesiedelt sein)

15 Beantworten Sie die folgenden Fragen bezogen auf das letzte abgeschlossene F&E-Kooperationsprojekt mit einem externen Partner.

Was war der Hauptgrund für dieses F&E-Kooperationsprojekt? *

[Bitte beantworten Sie diese Frage nur, falls ihre Antwort 'Ja' war bei der Frage '14']

Bitte wählen Sie nur eine der folgenden Antworten aus:

- Partner hat know-how
- Verkürzung des time-to-market
- Kostenreduktion

16 Welche F&E Kategorie beschreibt dieses Kooperationsprojekt am Besten? * *

[Bitte beantworten Sie diese Frage nur, falls ihre Antwort 'Ja' war bei der Frage '14']

Bitte wählen Sie nur eine der folgenden Antworten aus:

- Grundlagenforschung
- Angewandte Forschung
- Experimentelle Entwicklung

*Für diese Umfrage gilt der von der OECD 2002 definierte F&E Begriff.

Forschung und experimentelle Entwicklung (F&E) umfasst alle schöpferischen Arbeiten, welche in einer systematischen Art und Weise unternommen werden, um das Wissen zu vertiefen oder neue Erkenntnisse zu erlangen. Dies umfasst auch die Kenntnisse über den Menschen, über die Kultur und die Gesellschaft sowie die Umsetzung des Wissens für neue Anwendungen.

Die **Grundlagenforschung** besteht aus experimentellen oder theoretischen Arbeiten, welche in erster Linie zur Gewinnung neuer Erkenntnisse über die Grundlagen von Phänomenen und beobachtbaren Tatbeständen führen, ohne dass damit eine bestimmte Anwendung oder Umsetzung angestrebt wird. Die Grundlagenforschung analysiert Eigenschaften, Strukturen und Beziehungen mit dem Ziel, Hypothesen zu testen oder Theorien zu formulieren und Gesetze zu entdecken. Die Ergebnisse der Grundlagenforschung werden in der Regel nicht kommerzialisiert, sondern in Form wissenschaftlicher Publikationen veröffentlicht . Sie können auch direkt zwischen interessierten Organisationen oder Personen ausgetauscht werden. Unter gewissen Umständen kann die Veröffentlichung der Ergebnisse der Grundlagenforschung aus Sicherheitsgründen „eingeschränkt" werden.

Die **angewandte Forschung** besteht ebenfalls aus originären Arbeiten, die dem Erwerb neuer Erkenntnisse dienen. Allerdings sind die Aktivitäten auf ein bestimmtes Ziel oder einen Zweck im Bereich der praktischen Anwendung oder Umsetzung ausgerichtet. Die Ergebnisse der angewandten Forschung zielen in erster Linie auf die Herstellung eines einzigartigen Produkts oder einer limitierten Serie von Produkten sowie auf die Erarbeitung von Prozessen, Methoden oder Systemen. Diese Forschungsaktivitäten gestatten die operationelle Ausgestaltung von Ideen. Erkenntnisse oder Informationen, die mittels angewandter Forschung gewonnen werden, werden vielfach patentiert; sie können aber auch geheim gehalten werden.

Die **experimentelle Entwicklung** besteht aus systematischen Arbeiten, welche die Erkenntnisse aus Forschung und Praxis im Hinblick auf die Herstellung neuer Materialien, Produkte oder Verfahren nutzen. Das Ziel ist in der Regel die Entwicklung neuer Herstellungsprozesse, Produktionsverfahren oder Dienstleistungssysteme bzw. die erhebliche Verbesserung bestehender Verfahren.

17

Mit wie vielen Partnern hat dieses Projekt stattgefunden?
*****

[Bitte beantworten Sie diese Frage nur, falls ihre Antwort 'Ja' war bei der Frage '14']

Bitte schreiben Sie Ihre Antwort hier

18 Wurde das Projektbudget eingehalten? *

[Bitte beantworten Sie diese Frage nur, falls ihre Antwort 'Ja' war bei der Frage '14']

Bitte wählen Sie nur eine der folgenden Antworten aus:

LimeSurvey - F&E-Kooperationsumfrage http://lamp3.tugraz.at/~bwlumfrage/admin/admin.php?action=showprint...

- Überschritten
- Eingehalten
- Unterschritten

19 Bitte geben Sie die Projektdauer in Monaten an: *

[Bitte beantworten Sie diese Frage nur, falls ihre Antwort 'Ja' war bei der Frage '14']

Bitte Ihre Antwort(en) hierher schreiben

Wie lange war für die Projektdauer geplant?

Wie lange hat das Projekt gedauert?

20 Sie haben angegeben, dass Sie in diesem Projekt mit mehreren Partner kooperiert haben.
Bitte legen Sie in Ihrem Projekt einen Hauptpartner fest, aufgrund folgender Einschätzung: *

[Bitte beantworten Sie diese Frage nur, wenn Sie nicht geantwortet haben war bei der Frage '17']

Bitte wählen Sie nur eine der folgenden Antworten aus:

- **Intensivste Zusammenarbeit**
- **Größtes Projektbudget**
- **Koordinator des Projekts**

21 Welchem Typ entspricht Ihr Projektpartner? *

[Bitte beantworten Sie diese Frage nur, falls ihre Antwort war bei der Frage '17']

Bitte wählen Sie nur eine der folgenden Antworten aus:

- **Forschungseinrichtung**
- **Kunde**
- **Lieferant**
- **Mitbewerber**
- **Universität**
- **Sonstiges**

22 Haben Sie mit dem Hauptprojektpartner schon vorher kooperiert? *

[Bitte beantworten Sie diese Frage nur, wenn Sie nicht geantwortet haben war bei der Frage '17']

Bitte wählen Sie die zutreffende Antwort für jeden Punkt aus:

	Ja	Nein
Generell	◯	◯
Auf F&E Ebene	◯	◯

23 Welchem Typ entspricht Ihr Hauptprojektpartner? *

[Bitte beantworten Sie diese Frage nur, wenn Sie nicht geantwortet haben war bei der Frage '17']

Bitte wählen Sie nur eine der folgenden Antworten aus:

- **Lieferant**
- **Kunde**
- **Mitbewerber**
- **Universität**
- **Forschungseinrichtung**
- **Sonstiges**

24 Haben Sie mit Ihrem Projektpartner schon vorher kooperiert? *

[Bitte beantworten Sie diese Frage nur, falls ihre Antwort war bei der Frage '17']

Bitte wählen Sie die zutreffende Antwort für jeden Punkt aus:

	Ja	Nein
Generell	◯	◯
Auf F&E Ebene	◯	◯

F&E Kooperationsprojekterfolg

25 Ist aus der Kooperation eine Patentanmeldung entstanden? *

[Bitte beantworten Sie diese Frage nur, falls ihre Antwort 'Ja' war bei der Frage '14']

Bitte wählen Sie nur eine der folgenden Antworten aus:

- Ja
- Nein

26 Wurde ein Gebrauchsmuster (industrial design) angemeldet? *

[Bitte beantworten Sie diese Frage nur, falls ihre Antwort 'Ja' war bei der Frage '14']

Bitte wählen Sie nur eine der folgenden Antworten aus:

- Ja
- Nein

27 Ist eine wissenschaftliche Publikation entstanden? *

[Bitte beantworten Sie diese Frage nur, falls ihre Antwort 'Ja' war bei der Frage '14']

Bitte wählen Sie nur eine der folgenden Antworten aus:

- Ja
- Nein

28 Wurde ein Prototyp entwickelt? *

[Bitte beantworten Sie diese Frage nur, falls ihre Antwort 'Ja' war bei der Frage '14']

Bitte wählen Sie nur eine der folgenden Antworten aus:

- Ja
- Nein

29 Würden Sie mit dem Hauptprojektpartner wieder kooperieren? *

[Bitte beantworten Sie diese Frage nur, wenn Sie nicht geantwortet haben war bei der Frage '17']

Bitte wählen Sie nur eine der folgenden Antworten aus:

- Ja
- Nein

30 Würden Sie mit Ihrem Projektpartner wieder kooperieren? *

[Bitte beantworten Sie diese Frage nur, falls ihre Antwort war bei der Frage '17']

Bitte wählen Sie nur eine der folgenden Antworten aus:

- Ja
- Nein

31 Bitte wählen Sie die zutreffende Antwort für jeden Punkt aus: *

[Bitte beantworten Sie diese Frage nur, falls ihre Antwort 'Ja' war bei der Frage '14']

Bitte wählen Sie die zutreffende Antwort für jeden Punkt aus:

	Stimme voll zu					Stimme gar nicht zu
	+++	++	+	-	--	---
Der **Projektverlauf** wurde durch die Kooperation **positiv beeinflusst.**	○	○	○	○	○	○
Es wurden **alle Meilensteine eingehalten.**	○	○	○	○	○	○

32 Kann/konnte das neu gewonnene Wissen für ein neues/verbessertes Produkt oder eine neue/verbesserte

Dienstleistung verwendet werden? *

[Bitte beantworten Sie diese Frage nur, falls ihre Antwort 'Ja' war bei der Frage '14']

Bitte wählen Sie nur eine der folgenden Antworten aus:

- Ja
- Nein

Statistische Angaben

Sie sind am Ende des Fragebogens angekommen. Bitte geben Sie noch folgende statistische Angaben für Ihr Unternehmen an:

33 Bitte geben Sie das Alter Ihres Unternehmens in Jahren an.

Bitte schreiben Sie Ihre Antwort hier

34 Bitte geben Sie die Unternehmensdaten für das abgeschlossene Geschäftsjahr an:

[Bitte beantworten Sie diese Frage nur, falls ihre Antwort 'Nein' war bei der Frage '1']

Bitte Ihre Antwort(en) hierher schreiben

Umsatz (in Tausend EUR)

Beschäftigte Personen

35 Bitte geben Sie die Unternehmensdaten für Ihre Unternehmensgruppeund das abgeschlossene Geschäftsjahr an:

[Bitte beantworten Sie diese Frage nur, falls ihre Antwort 'Ja' war bei der Frage '1']

Bitte Ihre Antwort(en) hierher schreiben

Umsatz (in Tausend EUR)

Beschäftigte Personen

36 Wie kann man Ihre Tätigkeit am besten beschreiben? *

Bitte wählen Sie nur eine der folgenden Antworten aus:

- Geschäftsführer
- F&E-Leiter
- F&E-Projektmanager
- F&E-Mitarbeiter
- Sonstiges

2009-05-18
Bitte faxen Sie den ausgefüllten Fragebogen an +43/316/873-107286 Übermittlung Ihres ausgefüllten Fragebogens:
Vielen Dank für die Beantwortung des Fragebogens.

Appendix C

Description of the Variables

Item	Question	Level of Measurement
	Firm Characteristics	
INDUSTRY	primary branch of business	nominal
GROUP	part of a group of companies	nominal
OCCUPATION	occupation of the responder	nominal
	Function Specific Indicators	
R&D_DEP	existing R&D department	nominal
ALL_FUNC	search for cooperation partners from in-house staff	nominal
GATEKEEPER	gatekeeper	nominal
	Alliance Capability	
ALL_EXP	cumulative sum of alliance duration (past 10 years)	metric
ALL_MGMT_TOOL1	standardized procedure	metric*
ALL_MGMT_TOOL2	detailed manual	metric*
	Scientific Linkage	
SCI_LINK1	search for new developments	metric*
SCI_LINK2	positional embeddedness (national)	metric*
SCI_LINK3	positional embeddedness (international)	metric*

Continued on next page

*6-point Likert scale

Item	Question	Level of Measurement
	Project Management	
PM_EFF1	best of our branch of business	metric*
PM_EFF2	methods and tools	metric*
PM_EFF3	project management system	metric*
PM_EFF4	project closure in line with budget	metric*
PM_EFF5	project closure in line with schedule	metric*
PM_KT1	motivation for knowledge transfer	metric*
PM_KT2	interchange of know-how	metric*
PM_KT3	reflection of the experience	metric*
PM_KT4	learning-by-doing	metric*
PM_KT5	informal exchange of experience	metric*
PM_KT6	mentoring program	metric*
PM_KT7	pictorial language	metric*
	Success Variables	
COOP	engaged in an R&D cooperation	nominal
IPR	patent or industrial design application	nominal
PUBL	scientific publication	nominal
PROTO	development of a prototype	nominal
PROD	new/improved product/service	nominal
PROC	new/improved processes/procedures	nominal
BUDGET	budget	nominal
SCHED_PLAN	project duration in months (planned)	metric
SCHED_ACT	project duration in months (actual)	metric
	Generated Variables	
ALL_MGMT_TOOL	Summated Scale: Alliance Management Tools	metric
SCI_LINK	Summated Scale: Scientific Linkage	metric
PM_EFF	Summated Scale: PM Efficiency	metric
PM_KT	Summated Scale: PM Knowledge Transfer	metric
SCHEDULE	project in line with schedule (see Equation 5.5)	nominal
SUCC_INDEX	Success Index (see Equation 5.6)	nominal

*6-point Likert scale

Appendix D

Correlation Table – Success

Value of the Correlation Coefficient r	Interpretation
$0 < r \leq 0,2$	Very low correlation
$0,2 < r \leq 0,5$	Low correlation
$0,5 < r \leq 0,7$	Medium correlation
$0,7 < r \leq 0,9$	High correlation
$0,9 < r \leq 1$	Very high correlation

Table D.1: Interpretation of correlation coefficients (Bühl, 2008, p. 269)

	Mean	S.D.	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
(1) Pharma	0.140	0.351	1									
(2) IT	0.180	0.388	-0.189	1								
(3) Others	0.100	0.303	-0.134	-0.156	1							
(4) Group	0.520	0.505	-0.189	-0.175	-0.080	1						
(5) R&D department	0.940	0.240	0.102	0.118	0.084	-0.243^{+}	1					
(6) Alliance Function	0.420	0.499	0.124	0.340*	-0.014	0.006	0.215	1				
(7) Gatekeeper	0.720	0.454	0.123	0.176	-0.089	0.025	0.405**	0.440**	1			
(8) Alliance Experience	2.206	0.703	0.192	0.244^{+}	0.385**	-0.159	0.081	0.262^{+}	0.258	1		
(9) Alliance Capability	3.183	1.299	0.234	0.055	-0.233	-0.091	0.331*	0.288*	0.392**	0.055	1	
(10) Scientific Linkage	1.780	0.331	0.095	0.217	-0.033	-0.021	0.316*	0.476**	0.572**	0.267^{+}	0.542**	1
(11) PM Efficiency	4.188	0.902	-0.076	0.047	0.060	0.010	-0.183	-0.077	-0.032	-0.031	0.086	0.185
(12) PM Knowledge Transfer	4.827	0.620	0.067	0.168	-0.166	-0.033	-0.071	0.313*	-0.080	0.126	0.103	0.353*
(13) Success Index	0.640	0.485	-0.058	0.026	0.250^{+}	0.030	-0.189	-0.206	0.089	0.282*	-0.260^{+}	0.003
(14) IPR	0.360	0.485	-0.183	-0.026	0.028	0.053	0.189	-0.132	0.004	-0.157	0.101	-0.090
(15) Publication	0.480	0.505	0.074	0.071	0.347*	0.202	-0.094	0.075	0.064	0.259^{+}	-0.017	0.125
(16) Prototype	0.920	0.274	-0.306*	-0.054	0.098	0.012	-0.075	-0.048	-0.184	-0.148	-0.445**	-0.415**
(17) Product/Process	0.840	0.370	0.019	0.062	0.145	0.017	-0.110	0.040	0.092	0.216	-0.147	0.048
(18) Budget	0.740	0.443	0.108	0.040	0.046	0.161	-0.150	-0.050	0.138	0.351*	-0.243^{+}	0.096
(19) Schedule	0.500	0.505	0.058	0.260^{+}	0.067	-0.080	-0.084	-0.122	0.089	0.174	-0.147	0.157

Continued on next page

N=50

$^{+}$p-value $<$ 0.10; *p-value $<$ 0.05; **p-value $<$ 0.01

	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)	(19)
(1) Pharma									
(2) IT									
(3) Others									
(4) Group									
(5) R&D department									
(6) Alliance Function									
(7) Gatekeeper									
(8) Alliance Experience									
(9) Alliance Capability									
(10) Scientific Linkage									
(11) PM Efficiency	1								
(12) PM Knowledge Transfer	0.343*	1							
(13) Success Index	0.321*	0.099	1						
(14) IPR	-0.058	-0.240^{+}	0.042	1					
(15) Publication	0.241^{+}	0.005	0.554**	-0.053	1				
(16) Prototype	-0.227	-0.383**	-0.221	0.068	-0.159	1			
(17) Product/Process	0.092	0.099	0.355*	-0.127	0.310*	-0.129	1		
(18) Budget	0.169	0.104	0.505**	-0.220	0.204	-0.175	-0.010	1	
(19) Schedule	0.295*	0.216	0.667**	-0.167	0.240^{+}	-0.295*	0.109	0.410**	1

N=50

$^{+}$p-value < 0.10; *p-value < 0.05; **p-value < 0.01

Table D.2: Descriptive statistics and correlation matrix (Success)

Appendix E

Regression Models – Success Items

This chapter presents the regression tables for the individual success items and provides an overview of the regression results for the success consideration. As discussed in Section 5.3.4, part of the sample and some variables cause problems with multicollinearity. Therefore, the results reported in Appendix E.1 are intermediate results and listed to provide completeness of contents. Appendix E.2 gives an overview of the regression results without the problems regarding multicollinearity.

E.1 Hypotheses 4 – 8

The following tables list the regression results for Hypotheses 4-8 on the individual success items[43]:

- patent or utility model application
- accepted publication
- existence of a prototype
- transfer to new process or product development
- stayed within budget
- finished within scheduled time frame

[43]Hypothesis 4 causes problems with multicollinearity. Therefore, this results are only seen as intermediate results.

		Success Index	IPR	Publications	Prototype	Product/Process	Budget	Schedule
	Pharma							
	IT							(+)
	Others							
	Group			+				
H4 (a)	R&D Department							
H4 (b)	Alliance Function	(–)						(–)
H4 (c)	Gatekeeper	+						
H5	Alliance Experience	(+)					+	
H6	Alliance Mgmt. Tools	(–)					(–)	
H7	Scientific Linkage							
H8 (a)	PM Efficiency	(+)						
H8 (b)	PM Knowledge Transfer							

N=50; (PM)...Project Management

+/– ... p-value < 0.05; (+/–) ... p-value < 0.10

Table E.1: Overview of the intermediate regression results (Success) – Problem with multicollinearity

	Model I	Model II	Model III	Model IV	Model V	Model VI
Pharma	-1.436 (1.167)	-1.381 (1.189)	-1.157 (1.234)	-1.400 (1.291)	-1.403 (1.283)	-1.340 (1.262)
IT	-0.338 (0.827)	-0.111 (0.911)	0.118 (0.976)	0.251 (0.999)	0.277 (1.005)	0.233 (1.035)
Others	-0.052 (1.001)	-0.121 (1.029)	0.312 (1.227)	0.667 (1.297)	0.715 (1.292)	0.416 (1.419)
Group	0.021 (0.633)	0.356 (0.665)	0.334 (0.670)	0.434 (0.679)	0.454 (0.686)	0.400 (0.697)
R&D Department		21.413 (23205.423)	21.246 (23169.702)	20.853 (23173.381)	20.929 (23150.745)	20.822 (23142.760)
Alliance Function		-0.702 (0.760)	-0.685 (0.768)	-0.930 (0.838)	-0.708 (0.863)	-0.515 (0.959)
Gatekeeper		-0.023 (0.816)	0.128 (0.853)	0.025 (0.879)	0.276 (0.932)	-0.084 (1.056)
Alliance Experience			-0.379 (0.568)	-0.373 (0.564)	-0.308 (0.573)	-0.256 (0.591)
Alliance Mgmt. Tools				0.321 (0.311)	0.426 (0.331)	0.388 (0.345)
Scientific Linkage					-1.283 (1.366)	-0.735 (1.521)
PM Efficiency						-0.016 (0.422)
PM Knowledge Transfer						-0.556 (0.732)
Constant	-0.362 (0.561)	-21.559 (23205.423)	-20.790 (23169.702)	-21.384 (23173.381)	-19.934 (23150.745)	-17.822 (23142.760)
-2 Log likelihood	63.264	58.649	58.201	57.084	56.163	55.456
Cox & Snell R^2	0.041	0.125	0.133	0.152	0.168	0.179
Nagelkerke R^2	0.056	0.172	0.182	0.209	0.230	0.246
χ^2	2.078	6.693	7.141	8.258	9.179	9.886
Improvement over base ($\Delta\chi^2$)		4.615	5.063	6.18	7.101	7.808

N=50; Dependent Variable: IPR; (PM)...Project Management

$^{+}$p-value < 0.10; *p-value < 0.05; **p-value < 0.01; standard errors in parentheses

Table E.2: Intermediate regression results (IPR) – Problem with multicollinearity

	Model I	Model II	Model III	Model IV	Model V	Model VI
Pharma	1.861^{+} (1.068)	1.910^{+} (1.114)	1.817 (1.174)	1.783 (1.186)	1.876 (1.210)	2.047 (1.261)
IT	1.697^{+} (0.976)	1.774^{+} (1.051)	1.676 (1.123)	1.707 (1.127)	1.725 (1.137)	1.580 (1.190)
Others	22.696 (16999.628)	22.849 (17194.388)	22.704 (17085.424)	22.748 (17298.720)	22.776 (17289.382)	22.529 (16156.481)
Group	1.876* (0.846)	1.722* (0.876)	1.736* (0.880)	1.731* (0.882)	1.745* (0.880)	2.043* (0.954)
R&D Department		-1.383 (1.533)	-1.318 (1.556)	-1.415 (1.580)	-1.453 (1.582)	-0.673 (1.672)
Alliance Function		-0.238 (0.779)	-0.247 (0.782)	-0.301 (0.804)	-0.421 (0.829)	0.005 (0.919)
Gatekeeper		0.606 (0.974)	0.558 (0.992)	0.469 (1.022)	0.298 (1.072)	0.317 (1.247)
Alliance Experience			0.160 (0.641)	0.154 (0.641)	0.067 (0.663)	0.390 (0.716)
Alliance Mgmt. Tools				0.105 (0.301)	0.018 (0.335)	-0.184 (0.372)
Scientific Linkage					0.861 (1.385)	0.712 (1.582)
PM Efficiency						0.887 (0.540)
PM Knowledge Transfer						-0.483 (0.788)
Constant	-2.018* (0.810)	-1.029 (1.506)	-1.360 (2.010)	-1.498 (2.056)	-2.390 (2.523)	-4.660 (3.682)
-2 Log likelihood	53.021	52.019	51.957	51.835	51.450	48.275
Cox & Snell R^2	0.277	0.291	0.292	0.294	0.299	0.342
Nagelkerke R^2	0.369	0.389	0.390	0.392	0.399	0.457
χ^2	16.213**	17.215*	17.278*	17.400*	17.785^{+}	20.960^{+}
Improvement over base ($\Delta\chi^2$)		1.002	1.065	1.187	1.572	4.747

N=50; Dependent Variable: Publications; (PM)...Project Management

$^{+}$p-value < 0.10; *p-value < 0.05; **p-value < 0.01; standard errors in parentheses

Table E.3: Intermediate regression results (Publications) – Problem with multicollinearity

	Model I	Model II	Model III	Model IV	Model V	Model VI
Pharma	-2.667^{+} (1.423)	-2.416^{+} (1.449)	-2.051 (1.588)	-0.301 (2.759)	-71.383 (6588.229)	10.486 (7403.885)
IT	-1.456 (1.526)	-1.331 (1.691)	-0.854 (1.886)	-1.749 (3.506)	-69.259 (11124.126)	-2.605 (25589.284)
Others	17.710 (17866.897)	17.351 (16632.534)	18.239 (16498.892)	6.826 (14005.936)	-46.505 (20411.048)	-36.087 (36084.219)
Group	-0.621 (1.196)	-0.445 (1.214)	-0.415 (1.222)	2.254 (3.078)	-52.996 (11418.700)	-4.771 (16644.574)
R&D Department		0.003 (25883.253)	-0.141 (25808.907)	14.287 (20957.536)	89.084 (22902.154)	21.833 (25567.805)
Alliance Function		0.503 (1.258)	0.399 (1.255)	2.829 (3.071)	53.190 (5980.766)	25.098 (24700.068)
Gatekeeper		-18.628 (11465.214)	-18.457 (11388.631)	-17.385 (8359.634)	235.671 (19521.315)	-3.150 (22054.613)
Alliance Experience			-0.564 (1.102)	1.183 (1.605)	12.552 (9810.357)	-15.404 (9070.437)
Alliance Mgmt. Tools				-6.714^{+} (3.606)	-54.668 (9295.434)	-17.315 (7164.605)
Scientific Linkage					-286.997 (40343.538)	0.925 (20342.909)
PM Efficiency						-8.202 (9051.278)
PM Knowledge Transfer						-42.019 (11562.235)
Constant	3.777** (1.375)	21.648 (23205.423)	22.751 (23160.284)	31.421 (19218.085)	595.298 (76268.869)	346.401 (58906.435)
-2 Log likelihood	23.082	21.234	20.959	8.150	0.000	0.000
Cox & Snell R^2	0.091	0.124	0.129	0.326	0.427	0.427
Nagelkerke R^2	0.214	0.291	0.302	0.763	1.000	1.000
χ^2	4.795	6.643	6.918	19.727*	27.877**	27.877**
Improvement over base ($\Delta\chi^2$)		1.848	2.123	14.932*	23.082***	23.082**

N=50; Dependent Variable: Prototype; (PM)...Project Management

$^{+}$p-value $<$ 0.10; *p-value $<$ 0.05; **p-value $<$ 0.01; standard errors in parentheses

Table E.4: Intermediate regression results (Prototype) – Problem with multicollinearity

	Model I	Model II	Model III	Model IV	Model V	Model VI
Pharma	0.588 (1.215)	0.536 (1.288)	0.124 (1.381)	0.072 (1.371)	0.094 (1.382)	0.104 (1.392)
IT	0.860 (1.190)	0.804 (1.272)	0.427 (1.359)	0.284 (1.404)	0.293 (1.407)	0.336 (1.494)
Others	19.958 (17930.210)	20.171 (17727.888)	19.596 (16890.787)	19.321 (16173.346)	19.292 (16277.851)	19.614 (16253.104)
Group	0.378 (0.828)	0.017 (0.875)	0.137 (0.896)	0.076 (0.894)	0.076 (0.896)	0.181 (0.928)
R&D Department		-20.612 (23205.434)	-20.330 (23119.769)	-19.739 (23176.759)	-19.734 (23175.687)	-19.399 (22987.233)
Alliance Function		-0.204 (0.967)	-0.288 (1.001)	-0.118 (1.048)	-0.149 (1.077)	-0.442 (1.230)
Gatekeeper		0.995 (0.972)	0.856 (0.983)	1.147 (1.073)	1.082 (1.192)	1.748 (1.485)
Alliance Experience			0.757 (0.828)	0.865 (0.838)	0.842 (0.854)	0.747 (0.859)
Alliance Mgmt. Tools				-0.429 (0.416)	-0.446 (0.439)	-0.480 (0.478)
Scientific Linkage					0.208 (1.671)	-0.703 (1.963)
PM Efficiency						0.070 (0.542)
PM Knowledge Transfer						0.838 (1.017)
Constant	1.106 (0.680)	21.185 (23205.434)	19.586 (23119.769)	20.059 (23176.759)	19.843 (23175.687)	16.753 (22987.233)
-2 Log likelihood	41.382	38.992	38.142	36.989	36.973	36.027
Cox & Snell R^2	0.050	0.095	0.110	0.130	0.131	0.147
Nagelkerke R^2	0.086	0.162	0.188	0.223	0.223	0.251
χ^2	2.585	4.975	5.825	6.978	6.994	7.940
Improvement over base ($\Delta\chi^2$)		2.39	3.24	4.393	4.409	5.355

N=50; Dependent Variable: Product; (PM)...Project Management

$^+$p-value < 0.10; *p-value < 0.05; **p-value < 0.01; standard errors in parentheses

Table E.5: Intermediate regression results (Product or service) – Problem with multicollinearity

	Model I	Model II	Model III	Model IV	Model V	Model VI
Pharma	1.405 (1.208)	1.767 (1.370)	1.094 (1.425)	0.794 (1.367)	1.010 (1.424)	1.087 (1.390)
IT	0.976 (0.950)	1.246 (1.036)	0.613 (1.218)	0.456 (1.333)	0.365 (1.434)	0.372 (1.444)
Others	0.876 (1.236)	1.178 (1.251)	-0.301 (1.842)	-0.918 (2.277)	-1.227 (2.205)	-0.890 (2.271)
Group	1.122 (0.726)	0.945 (0.772)	1.224 (0.856)	1.082 (0.897)	1.250 (0.975)	1.432 (1.015)
R&D Department		-20.787 (23205.434)	-20.063 (22689.069)	-18.976 (23089.419)	-18.521 (23199.017)	-17.813 (22815.720)
Alliance Function		-1.043 (0.888)	-1.643 (1.031)	-1.358 (1.091)	-1.786 (1.207)	-1.861 (1.395)
Gatekeeper		1.445 (0.903)	1.120 (0.967)	1.540 (1.068)	0.846 (1.226)	1.446 (1.508)
Alliance Experience			1.812* (0.764)	1.922* (0.827)	1.966* (0.895)	2.020* (0.884)
Alliance Mgmt. Tools				-0.735$^+$ (0.417)	-1.019* (0.514)	-1.096$^+$ (0.568)
Scientific Linkage					2.248 (1.890)	1.108 (2.159)
PM Efficiency						0.489 (0.626)
PM Knowledge Transfer						0.594 (0.930)
Constant	0.151 (0.588)	20.258 (23205.434)	16.497 (22689.069)	17.435 (23089.419)	14.500 (23199.017)	10.664 (22815.721)
-2 Log likelihood	54.885	50.246	43.140	39.472	37.880	36.285
Cox & Snell R^2	0.067	0.146	0.256	0.306	0.327	0.347
Nagelkerke R^2	0.099	0.217	0.378	0.453	0.484	0.515
χ^2	3.598	8.237	15.343$^+$	19.011*	20.603*	22.198*
Improvement over base ($\Delta\chi^2$)		4.639	11.745*	15.413**	17.005**	18.6*

N=50; Dependent Variable: Budget; (PM)...Project Management

$^+$p-value < 0.10; *p-value < 0.05; **p-value < 0.01; standard errors in parentheses

Table E.6: Intermediate regression results (Budget) – Problem with multicollinearity

	Model I	Model II	Model III	Model IV	Model V	Model VI
Pharma	0.596 (0.873)	0.825 (0.964)	0.629 (1.007)	0.659 (1.001)	0.813 (1.053)	0.899 (1.042)
IT	1.695^{+} (0.894)	2.150* (0.980)	1.978* (1.007)	1.961^{+} (1.022)	1.972^{+} (1.047)	1.857^{+} (1.060)
Others	0.719 (0.994)	1.111 (1.047)	0.626 (1.204)	0.343 (1.277)	0.289 (1.273)	0.111 (1.330)
Group	-0.048 (0.607)	-0.217 (0.654)	-0.173 (0.663)	-0.272 (0.679)	-0.408 (0.703)	-0.393 (0.731)
R&D Department		-1.787 (1.469)	-1.587 (1.490)	-1.341 (1.524)	-1.617 (1.571)	-0.875 (1.647)
Alliance Function		-1.159 (0.738)	-1.290^{+} (0.769)	-1.230 (0.772)	-1.565^{+} (0.829)	-1.569^{+} (0.893)
Gatekeeper		1.274 (0.854)	1.111 (0.878)	1.255 (0.903)	0.796 (0.994)	1.022 (1.081)
Alliance Experience			0.463 (0.548)	0.507 (0.555)	0.379 (0.573)	0.472 (0.600)
Alliance Mgmt. Tools				-0.221 (0.294)	-0.402 (0.321)	-0.472 (0.334)
Scientific Linkage					2.443^{+} (1.454)	1.909 (1.589)
PM Efficiency						0.655 (0.463)
PM Knowledge Transfer						0.423 (0.560)
Constant	-0.294 (0.534)	0.910 (1.389)	-0.049 (1.792)	0.293 (1.847)	-2.390 (2.456)	-7.006^{+} (3.978)
-2 Log likelihood	68.458	63.876	63.159	62.581	59.385	56.125
Cox & Snell R^2	0.087	0.163	0.174	0.183	0.231	0.277
Nagelkerke R^2	0.117	0.218	0.233	0.244	0.308	0.370
χ^2	4.846	9.427	10.145	10.723	13.919	17.179
Improvement over base ($\Delta\chi^2$)		4.581	5.299	5.877	9.073	12.333

N=50; Dependent Variable: Schedule; (PM)...Project Management

$^{+}$p-value < 0.10; *p-value < 0.05; **p-value < 0.01; standard errors in parentheses

Table E.7: Intermediate regression results (Schedule) – Problem with multicollinearity

E.2 Hypotheses 5 – 8

The following tables list the regression results for Hypotheses 5–8 on the individual success items[44]:

- accepted publication
- patent or utility model application
- existence of a prototype
- transfer to new process or product development
- stayed within budget
- finished within scheduled time frame

		Success Index	IPR	Publications	Prototype	Product/Process	Budget	Schedule
	Pharma			(+)				
	IT							
	Others							
	Group			+				
H5	Alliance Experience	+					+	(+)
H6	Alliance Mgmt. Tools	–						(–)
H7	Scientific Linkage							
H8 (a)	PM Efficiency	+		(+)				(+)
H8 (b)	PM Knowledge Transfer							

N=45; (PM)...Project Management

+/- ... p-value < 0.05; (+/-) ... p-value < 0.10

Table E.8: Overview of the regression results (Success)

[44]Excluding the electronic-communication and aerospace industry industry to avoid problems with multicollinearity.

	Model I	Model II	Model III	Model IV	Model V
Pharma	-1.468 (1.172)	-1.447 (1.237)	-1.740 (1.278)	-1.777 (1.294)	-1.816 (1.288)
IT	-0.366 (0.831)	-0.344 (0.930)	-0.397 (0.941)	-0.201 (0.968)	-0.308 (1.024)
Group	-0.067 (0.673)	-0.068 (0.673)	-0.018 (0.677)	0.044 (0.689)	-0.096 (0.718)
Alliance Experience		-0.032 (0.611)	-0.114 (0.617)	0.035 (0.634)	0.172 (0.661)
Alliance Mgmt. Tools			0.373 (0.281)	0.579^{+} (0.335)	0.527 (0.350)
Scientific Linkage				-1.444 (1.214)	-0.751 (1.318)
PM Efficiency					0.001 (0.403)
PM Knowledge Transfer					-0.967 (0.675)
Constant	-0.305 (0.579)	-0.243 (1.292)	-1.299 (1.523)	0.204 (1.957)	3.602 (3.073)
-2 Log likelihood	56.525	56.522	54.626	53.136	50.703
Cox & Snell R^2	0.045	0.045	0.084	0.114	0.160
Nagelkerke R^2	0.061	0.061	0.115	0.156	0.220
χ^2	2.048	2.051	3.947	5.437	7.870
Improvement over base ($\Delta\chi^2$)		2.865^{+}	6.139*	6.627^{+}	14.464*

N=45; Dependent Variable: IPR; (PM)...Project Management

$^{+}$p-value < 0.10; *p-value < 0.05; **p-value < 0.01; standard errors in parentheses

Table E.9: Regression results (IPR)

	Model I	Model II	Model III	Model IV	Model V
Pharma	1.861^{+} (1.068)	1.698 (1.138)	1.679 (1.151)	1.706 (1.159)	2.037^{+} (1.228)
IT	1.697^{+} (0.976)	1.525 (1.066)	1.521 (1.066)	1.469 (1.079)	1.569 (1.131)
Group	1.876* (0.846)	1.881* (0.847)	1.878* (0.847)	1.859* (0.848)	2.138* (0.926)
Alliance Experience		0.253 (0.624)	0.247 (0.625)	0.176 (0.649)	0.460 (0.693)
Alliance Mgmt. Tools			0.030 (0.257)	-0.051 (0.318)	-0.199 (0.350)
Scientific Linkage				0.550 (1.258)	0.788 (1.397)
PM Efficiency					0.930^{+} (0.496)
PM Knowledge Transfer					-0.543 (0.708)
Constant	-2.018* (0.810)	-2.493^{+} (1.434)	-2.571 (1.583)	-3.128 (2.048)	-5.213 (3.207)
-2 Log likelihood	53.021	52.855	52.842	52.650a	48.458
Cox & Snell R^2	0.168	0.171	0.171	0.175	0.248
Nagelkerke R^2	0.226	0.230	0.230	0.235	0.334
χ^2	8.269*	8.435^{+}	8.448	8.639	12.832
Improvement over base ($\Delta\chi^2$)		2.865^{+}	6.139*	6.627^{+}	14.464*

N=45; Dependent Variable: Publication; (PM)...Project Management

$^{+}$p-value < 0.10; *p-value < 0.05; **p-value < 0.01; standard errors in parentheses

Table E.10: Regression results (Publication)

	Model I	Model II	Model III	Model IV	Model V
Pharma	-2.667$^+$ (1.423)	-2.150 (1.570)	-1.159 (2.525)	-133.276 (9937.289)	4.326 (16179.523)
IT	-1.456 (1.526)	-0.851 (1.741)	-0.916 (2.604)	56.219 (6916.217)	1.102 (12407.621)
Group	-0.621 (1.196)	-0.581 (1.206)	2.752 (3.141)	-134.215 (7116.494)	-22.642 (8476.925)
Alliance Experience		-0.817 (1.144)	0.924 (1.566)	-86.111 (3133.318)	-23.092 (7539.542)
Alliance Mgmt. Tools			-6.808$^+$ (4.019)	-0.089 (4101.470)	-12.453 (8536.110)
Scientific Linkage				-754.251 (27948.280)	-4.994 (32482.466)
PM Efficiency					-30.741 (9647.546)
PM Knowledge Transfer					-37.940 (8657.485)
Constant	3.777** (1.375)	5.349* (2.705)	31.376$^+$ (17.170)	1984.425 (76813.583)	485.365 (67761.692)
-2 Log likelihood	23.082	22.546	9.378	0.000	0.000
Cox & Snell R^2	0.083	0.094	0.324	0.451	0.451
Nagelkerke R^2	0.185	0.209	0.718	1.000	1.000
χ^2	3.915	4.450	17.619**	26.996**	26.996**
Improvement over base ($\Delta\chi^2$)		2.865$^+$	6.139*	6.627$^+$	14.464*

N=45; Dependent Variable: Prototype; (PM)...Project Management

$^+$p-value < 0.10; *p-value < 0.05; **p-value < 0.01; standard errors in parentheses

Table E.11: Regression results (Prototype)

	Model I	Model II	Model III	Model IV	Model V
Pharma	0.588 (1.215)	0.033 (1.323)	0.200 (1.332)	0.190 (1.328)	0.318 (1.331)
IT	0.860 (1.190)	0.344 (1.288)	0.441 (1.302)	0.361 (1.323)	0.302 (1.332)
Group	0.378 (0.828)	0.440 (0.853)	0.405 (0.843)	0.376 (0.845)	0.414 (0.859)
Alliance Experience		0.893 (0.793)	1.002 (0.801)	0.917 (0.808)	0.874 (0.822)
Alliance Mgmt. Tools			-0.398 (0.372)	-0.525 (0.438)	-0.548 (0.459)
Scientific Linkage				0.809 (1.407)	0.462 (1.557)
PM Efficiency					0.257 (0.489)
PM Knowledge Transfer					0.243 (0.789)
Constant	1.106 (0.680)	-0.554 (1.601)	0.569 (1.897)	-0.226 (2.322)	-1.691 (3.306)
-2 Log likelihood	41.382	40.070	38.821	38.485	37.960
Cox & Snell R^2	0.016	0.045	0.071	0.078	0.088
Nagelkerke R^2	0.027	0.073	0.116	0.128	0.145
χ^2	0.739	2.051	3.299	3.635	4.161
Improvement over base ($\Delta\chi^2$)		2.051	3.299	3.635	4.161

N=45; Dependent Variable: Product or Service; (PM)...Project Management

$^+$p-value < 0.10; *p-value < 0.05; **p-value < 0.01; standard errors in parentheses

Table E.12: Regression results (Product or Service)

	Model I	Model II	Model III	Model IV	Model V
Pharma	1.354 (1.207)	0.592 (1.290)	0.784 (1.307)	0.642 (1.323)	0.961 (1.351)
IT	0.928 (0.949)	0.106 (1.099)	0.175 (1.219)	-0.149 (1.336)	-0.113 (1.322)
Group	1.004 (0.747)	1.134 (0.796)	1.120 (0.821)	1.097 (0.841)	1.209 (0.891)
Alliance Experience		1.375^{+} (0.731)	1.682* (0.813)	1.615^{+} (0.861)	1.724* (0.870)
Alliance Mgmt. Tools			-0.744^{+} (0.390)	-1.050* (0.488)	-1.143* (0.538)
Scientific Linkage				1.748 (1.385)	1.392 (1.575)
PM Efficiency					0.741 (0.552)
PM Knowledge Transfer					-0.135 (0.780)
Constant	0.219 (0.600)	-2.390 (1.511)	-0.458 (1.835)	-2.263 (2.384)	-4.014 (3.371)
-2 Log likelihood	50.528	46.485	41.929	40.268	38.108
Cox & Snell R^2	0.059	0.137	0.217	0.244	0.278
Nagelkerke R^2	0.0873	0.202	0.319	0.359	0.409
χ^2	2.873	6.917	11.473*	13.134*	15.294^{+}
Improvement over base ($\Delta\chi^2$)		2.865^{+}	6.139*	6.627^{+}	14.464*

N=45; Dependent Variable: Budget; (PM)...Project Management

$^{+}$p-value < 0.10; *p-value < 0.05; **p-value < 0.01; standard errors in parentheses

Table E.13: Regression results (Budget)

	Model I	Model II	Model III	Model IV	Model V
Pharma	0.624 (0.878)	0.125 (0.948)	0.222 (0.961)	0.227 (0.965)	0.418 (1.035)
IT	1.722^{+} (0.899)	1.221 (0.963)	1.251 (0.978)	1.089 (1.017)	1.111 (1.028)
Group	0.029 (0.644)	0.067 (0.664)	-0.017 (0.672)	-0.151 (0.687)	-0.110 (0.721)
Alliance Experience		0.922 (0.583)	1.046^{+} (0.599)	0.917 (0.627)	1.146^{+} (0.669)
Alliance Mgmt. Tools			-0.275 (0.263)	-0.491 (0.308)	-0.535^{+} (0.315)
Scientific Linkage				1.701 (1.205)	1.311 (1.286)
PM Efficiency					0.805^{+} (0.440)
PM Knowledge Transfer					0.270 (0.558)
Constant	-0.344 (0.553)	-2.180^{+} (1.298)	-1.496 (1.436)	-3.447^{+} (2.068)	-7.849* (3.639)
-2 Log likelihood	61.732	59.092	57.947	55.855	51.342
Cox & Snell R^2	0.094	0.142	0.162	0.198	0.270
Nagelkerke R^2	0.125	0.190	0.217	0.264	0.360
χ^2	4.727	7.367	8.512	10.604	15.117^{+}
Improvement over base ($\Delta\chi^2$)		2.64	3.785	5.877	10.39^{+}

N=45; Dependent Variable: Schedule

$^{+}$p-value < 0.10; *p-value < 0.05; **p-value < 0.01; ***p-value < 0.001; standard errors in parentheses

Table E.14: Regression results (Schedule)

Appendix F

Additional Findings

This chapter presents non-hypotheses related findings of this study. Section F.1 discusses the characteristics of the R&D department. Section F.2 shows the motivation and organization of the R&D cooperation agreement.

F.1 Characteristics of the R&D Department

Figure F.1 illustrates the size of the R&D department in respect to the employed people. The findings indicate that almost half of the firms (47.7%) have an R&D department with less than ten employees.

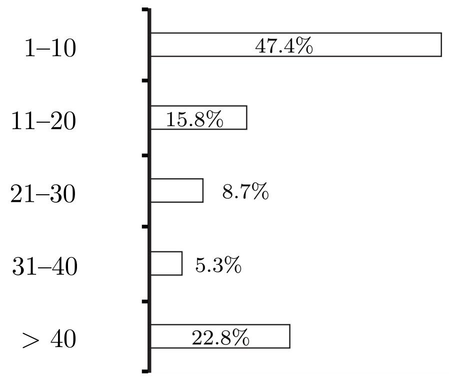

Figure F.1: Question: How many people are employed in your R&D department? (n=57)

Almost one third of the firms (29.5%) has between eleven and fourty employees. A quarter (22.8%) of the responders state that their R&D department has more than

40 employees. 7% of the responders specified that they have an R&D department with more than 100 employees.

The findings, further show that all firms in the sample conduct experimental development. 80% of the firms conduct applied research. Less than half of the firms (41.7%) are engaged in basic research activities. See Figure F.2 for an illustration.

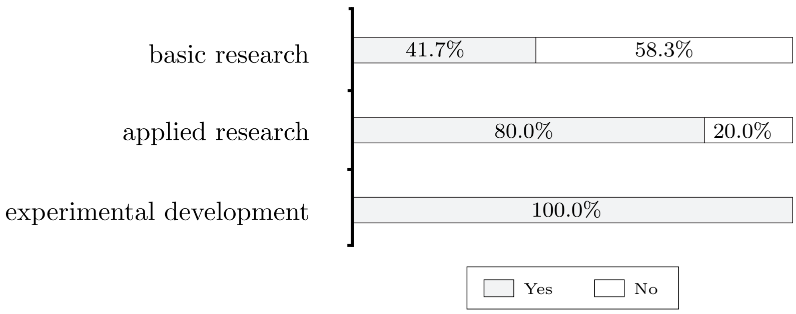

Figure F.2: Question: Which kind of R&D is conducted in your firm? (n=60)

F.2 Characteristics of the R&D Cooperation Project

The illustration in Figure 5.9 (Page 83) shows that almost two thirds of the investigated firms are engaged in an R&D cooperation. Almost all of these investigated R&D cooperations are regulated with a legal contract (see Figure F.3 for an illustration).

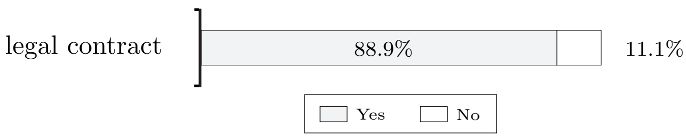

Figure F.3: Question: Was the R&D cooperation regulated with a legal contract? (n=36)

The main motivation to conduct R&D in a cooperation is that the partner brings know-how into the cooperation (see also Figure F.4). Basic research was conducted in 5.7% of the investigated cooperations. 64.1% of the investigated cooperations focused on applied research activities and 30.2% conduct experimental development (see also Figure F.5).

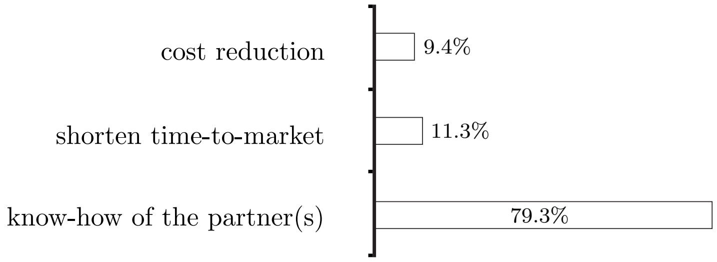

Figure F.4: Question: What was the main motivation for the R&D cooperation? (n=53)

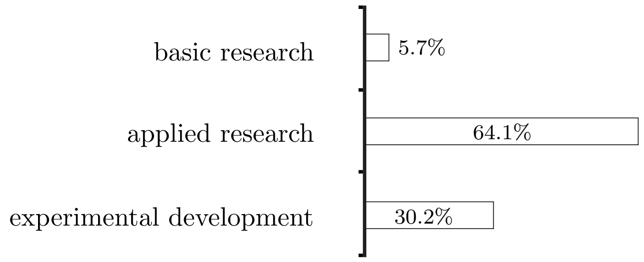

Figure F.5: Question: Which kind of R&D was conducted in the cooperation? (n=53)

The funding of the cooperations is illustrated in Figure F.6. Most of the cooperations were founded nationally (64.9%); however, only 25% were founded from the EU.

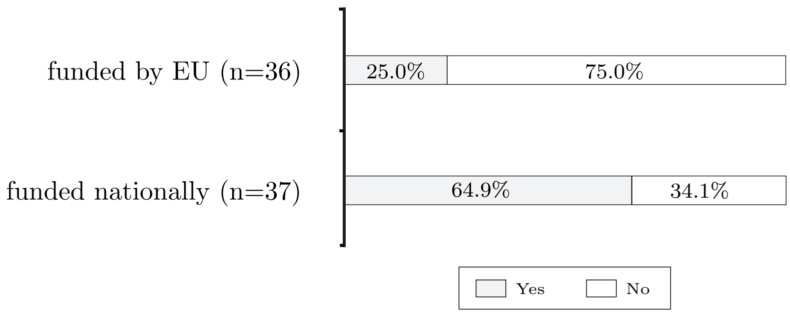

Figure F.6: Question: Was the R&D cooperation funded?

The following two diagrams present the findings regarding the partner structure of the cooperation: (1) number of partners and (2) the origin of the partners. First, most of the cooperations were done with one partner (42.3%). 23.1% of the investigated cooperations have worked together with more than four partners. See also

Figure F.7 for the distribution according to the number of partners.

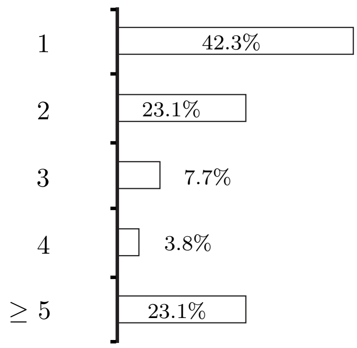

Figure F.7: Question: How many partners were involved in the cooperation? (n=52)

Second, half of the cooperations were conducted with one or more partners from the same country as the firm's country orign. 38.9% of the cooperation had partners within the EU and the rest of the cooperations (11.1%) had partners from all over the world (see Figure F.8 for an illustration).

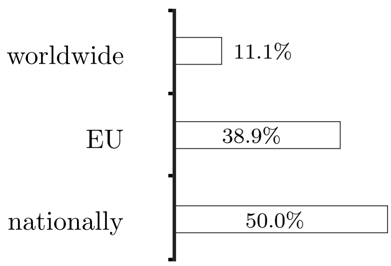

Figure F.8: Question: Origin of partner(s)? (n=36)

In case of a cooperation with multiple partners a main partner was selected according to the intensity of the collaboration. Figure F.9 and Figure F.10 show the characteristics of the main partner in the cooperation. The main partner was either a research organization or a university in most of the cooperations (63.3%). 18.4% of the cooperations were conducted with a supplier and 16.3% with a customer[45] (see also Figure F.9).

[45]Cooperations with customers are seen as an important source in open innovation activities. Kale and Singh (2009) see the investigation of partnerships with customers as an open field for further research. Schwarz, Faullant, Krajger and Breitenecker (2009), for example, investigate the impact of the creativity of a lead customer on a firm's innovation process.

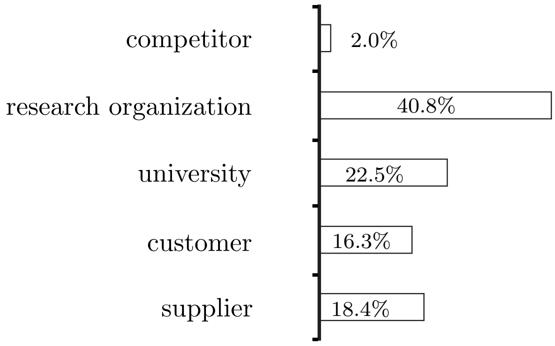

Figure F.9: Question: Classification of main partner in the R&D cooperation? (n=49)

In most of the cases (61.8%) the main cooperation partner was smaller than the own firm. 29.4% of the firms were bigger and 8.8% had equal size compared to their main cooperation partner (illustrated in Figure F.10).

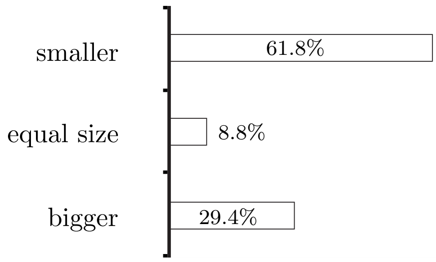

Figure F.10: Question: Size (number of employees) of your main partner? (n=34)

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